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Technical entreprenenurship in high technology small firms: some observations on the implications for management

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Abstract

There is much current interest, both in the encouragement of entrepreneurship, and in the formation and growth difficulties encountered by high technology small firms. This paper seeks to inform these concerns by offering a number of conceptual insights on the role of the technical entrepreneur in the high technology firm formation and growth process. Since many new high technology firms are founded by technical entrepreneurs (often from university backgrounds), an understanding of the factors that influence the behaviour of such individuals is highly pertinent to future policies aimed at encouraging this key type of high technology enterprise. By exploring aspects of the strategic approaches adopted by these individuals, this paper seeks to provide guiding principles for such policies.

Keywords: Entrepreneurship; Innovation; Motivation; Introspection; Strategies

1. Introduction

The technical entrepreneur is an acknowledged key catalyst in the process of industrial formation and growth (Cooper, 1970; Rothwell and Zegveld, 1982; Cardullo, 1999). Commencing in the eighteenth century, the Industrial Revolution was dependant upon technical entrepreneurs who, although originally trained as professional engineers, instinctively taught themselves to become expert business managers (e.g. James Watt; Isombard Kingdom Brunel; Robert Stevenson). Such industrial history confirms that the birth of new industries have usually depended upon the revolutionary skills of one or more of these key technical innovators, who make the critical pioneering scientific discoveries (and/or innovations in management) that trigger the birth of new industrial sectors (Schumpeter, 1934; Schmookler, 1966; Freeman, 1982).

However, these powerful historical examples of past success should not obscure the fact that technical entrepreneurship remains important today, and that there is a common heritage shared between the above early entrepreneurs and their modern counterparts. For example, the relatively recent development of the computer industry is an instance of how technical entrepreneurs continue to create new industries. From the initial exploits of Hewlett and Packard, through the contributions of Jobs and Wasniak at Apple Computers, to the Software-empire of Bill Gates at Microsoft, it is clear that technical entrepreneurs have played key roles in the birth, growth and consolidation of this new family of software and hardware computer-related activities. Moreover, the computer industry has subsequently delivered "knock on" efficiency gains across a wide range of other industrial and service sector activities (Freeman, 1982). Clearly, technical entrepreneurs continue to be a major force within industry and commerce.

None the less, although technical ability has often provided the scientific knowledge *necessary* for an individual to become a successful technical entrepreneur, it is important to stress that *sufficiency* to ensure success lies in an ability to develop additional business management skills with which to exploit such expertise. Indeed, there are recent examples of technical entrepreneurs who, although of critical importance in scientific terms to the birth of a new sector, *were not* ultimately successful because they were unable to develop effective management skills. Perhaps the best example of this phenomenon (of key relevance to this paper on high technology technical entrepreneurship) is that of William Shockley,

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the man generally credited with invention of the point contact transistor, the technical basis for the modern semiconductor industry (Saxenian, 1985). Although forming Shockley Transistor in Palo Alto in the early 1950's, and giving the Silicon Valley industrial complex its core product, he did not instinctively have (nor was he able to develop) the business management skills necessary to allow his company to grow. This led, despite strong technical success, to a break up of his company from which eight engineers, led by Gordon Moore, "spun off" in 1957 to form the Fairchild Corporation, and later Intel (Cardullo, 1999). Most significantly, while it might be argued that such a failure is evidence that the management skill components of technical entrepreneurship is instinctive and cannot be taught, this paper will take the counterview that technical entrepreneurs *can* gainfully acquire management skills, principally through management education.

Problems resulting from unbalanced technical and business skills notwithstanding, effective technical entrepreneurship, when *balance* is achieved, continues to account for many successful "leading edge" high technology firms (Cooper, 1970; Oakey, 1995). Indeed, such balance is critical because, as noted above, although technical ability alone will rarely deliver commercial success, it is also true that high technology businesses based on entrepreneurs *without* technical skills (i.e. that he or she "buys in") rarely succeed (Rothwell and Zegveld, 1982; Oakey and Mukhtar, 1999). This is because, in order for entrepreneurs to be fully committed to new technical ideas, ideally they should have *intimate* technical knowledge of the product development concerned, and an almost "evangelical" belief in its market potential (Oakey, 1995). Significantly, this key quality often convinces external investors to invest since, when venture capitalists claim that financial projections are secondary to "the people" involved in a business proposal, it is frequently this entrepreneurial belief in the core technology driving the business idea that they find most compelling.

Major candidates for high technology technical entrepreneurship are scientifically qualified staff that have "spun off", either from public sector research establishments (including universities) or existing (usually large) industrial firms (Mason, 1979; Freeman, 1982; Harvey, 1994). Thus, given the above observations on the importance to success of balancing business skills, a continuing challenge for policy makers is to develop training that adds balancing business skills to existing technical knowledge. However, the United Kingdom government has only recently accepted that the key to a higher *quantity and quality* of technical entrepreneurial "spin outs" from universities is improved business training for new and prospective faculty and student technical academic entrepreneurs (Cm. 2250; Cm. 4176: Mukhtar et al., 1999; Oakey et al., 2002). Previously poor provision for the management needs of technical entrepreneurs is illustrated by the fact that those charged with the development of university science parks in the United Kingdom over the past twenty years have strongly promoted the *technical link advantages* that new high technology firms might enjoy when located adjacent to university science departments on a university science park (Cambridge Science Park Directory, 1985) (which have often not materialised (Oakey, 1985; Westhead and Cowling, 1995)). However, given the obvious initial technical skills bias evident in most technical entrepreneurs, the potentially far more useful management skills locally available in university business schools have rarely been "sold" as a key reason for a university-based Science Park location, with which to *balance* previously acquired technical skills (Oakey and Mukhtar, 1999).

Part of the blame for this rather illogical uncoordinated approach to the promotion of technical entrepreneurship derives from the attitude of senior physical scientists towards social science in general, and management science in particular. For these individuals, management science is often considered a contradiction in terms. This attitude derives from the somewhat irrational view that "social science" is either not real science, or that it is a rather intellectually sub-standard "poor relative" of physical science (Popper, 1966; Harvey, 1973). A sense of this rift between intelligence as represented by "literary intellect" on the one hand, and mathematics-based physical sciences on the other, was observed by C. P. Snow in the 1950s, when he tellingly noted a widening gulf emerging between physical scientists and "other literary intellectual forms of reasoning" (Snow, 1959).

A belief in the superior value of the physical sciences can be more practically observed in the way that many heads of university physical science departments continue to be reluctant to surrender space in their curricula for management teaching, an activity to which they often accord an almost *extracurricular* status, similar to language teaching or sport. Indeed, in the past, management education frequently has been seen as almost irrelevant. The tendency to believe that management training is of marginal importance also stems from an assumption that management skills are "instinctive" or can be "picked up as you go along". Although this paper will accept that successful management is *partly* instinctive, there is a growing body of management research to confirm the importance of management education in *improving* entrepreneurial performance, particularly for those academics and industrial researchers previously with only physical science expertise (Reitan, 1997; McMullan and Gillin, 1998; Cosh et al., 1998). In most cases, effective entrepreneurship by scientists and engineers is not possible without use of management skills involving personnel management, financial accounting, marketing knowl-

edge, and strategic awareness; management skills that clearly assist entrepreneurial success (Chell and Allman, 2002).

2. Growth options and the technical entrepreneur

While management training can assist the technical entrepreneur to *both* set and achieve strategic goals for the firm, it would be simplistic to assume that such stated aspirations always reflect traditional economic profit maximisation motives. Work by behavioural scientists has conclusively indicated that entrepreneurs often sacrifice economic rationality for other non-financial rewards (Simon, 1955; Cyert and March, 1963; Pred, 1965). For example, empirical studies of high technology small firm founders, most of which are established by technical entrepreneurs, have produced consistent evidence that a substantial number of these individualists cite *independence* (Oakey, 1984a, 1995; Deakins and Philpott, 1994) and/or a physically attractive location (Greenhut and Colberg, 1962) as of equal (or greater) importance to that of pure profit maximisation as a key goal for their businesses. Moreover, they are perfectly willing to substitute these objectives for financial gains, short of becoming insolvent (Oakey and Cooper, 1989).

Indeed, with regard to independence, the technical entrepreneur also may be prepared for his enterprise to either remain static, or grow slowly on the basis of retained profits rather than access external funds (Deakins and Philpott, 1994). While surrendering equity for capital, or taking bank loans, might allow the firm to grow faster, the danger that the involvement of external actors might cause a dilution of the founder's control over the firm often renders this option unattractive. This has been an observed strong imperative for many entrepreneurs, in both the United Kingdom *and* the United States (Oakey, 1984b). Since many new firm founders "spin out" from large public or private sector bureaucracies, a major attraction of founding a new small firm is the organisational freedom that such independence engenders. Indeed, if freedom was attributed the financial value it clearly holds for many entrepreneurs, its maximisation might not be considered economically sub-optimal when judged in terms of "rational" economic behaviour (Marris, 1964). However, in all the above circumstances, the "rational economic" definition of "profit" would need to be broadened to include such psychic factors as "peace of mind", "job satisfaction", "a pleasant work environment" and "independence", rather than simple financial gain.

3. The mix of technical entrepreneurial attributes, and the key role of control

3.1. The case of the lone entrepreneur

While a "multiple founders" variant to the classical archetype of the lone entrepreneur will be considered below, single entrepreneurship is initially discussed here, both since he or she remains a common occurrence, and because the subsequently considered values of joint-entrepreneurship may be profitably contrasted to this initial consideration of the single form. Much folklore surrounds the individual entrepreneur and, from Henry Ford to Richard Branson, media interest has been intense. This is partly because such individuals appear to personify in the public mind expressions of tenacity, risk, confidence in the face of doubt, and ultimately success; attributes to which individuals naturally aspire. However, public perceptions of entrepreneurship are ambiguous and often contradictory, fluctuating wildly between a (politically right-wing) positive view elaborated above, to an equally broadly held converse view of entrepreneurs which is strongly negative, and partly stems from the (politically left wing) socialist stance that has, from the time of Karl Marx, viewed entrepreneurs as unethical exploiters of the economic system (to achieve selfish goals) in general, and the workers they employ, in particular (Popper, 1966; Magee, 1973).

Distaste for entrepreneurship also partly stems from a belief that the pursuit of personal financial gain is, at worst, simply unethical and, at best, at odds with "the common good". This is currently well illustrated by the long running (but latterly intensifying) controversy over attempts to patent discoveries in the field of medicine in general, and the biotechnology area in particular. Here, the motives of capital gain, through attempts to appropriate Intellectual Property Rights (IPR) for new medical discoveries (and *existing* knowledge over which ownership is under dispute), rather than following the traditional course of sharing medical discoveries for the common good, can be cited as a victory of financial gain over ethics (Macdonald and Lefang, 1998). Moreover, entrepreneurship is more fundamentally feared because of a paradox inherent in the nature of entrepreneurial behaviour. Because, in order to be successful, entrepreneurs need to insist that they prevail, there is a tendency for them to become tyrannical and consequently *addicted* to the winning of arguments, even in cases where they prove to be wrong. As will be discussed below, entrepreneurs who seek independence, mainly in order to exercise *control* over their newly independent firm per se, can present major management problems for their enterprise as it grows (Oakey et al., 1988).

Fig. 1 represents the interaction of three key factors

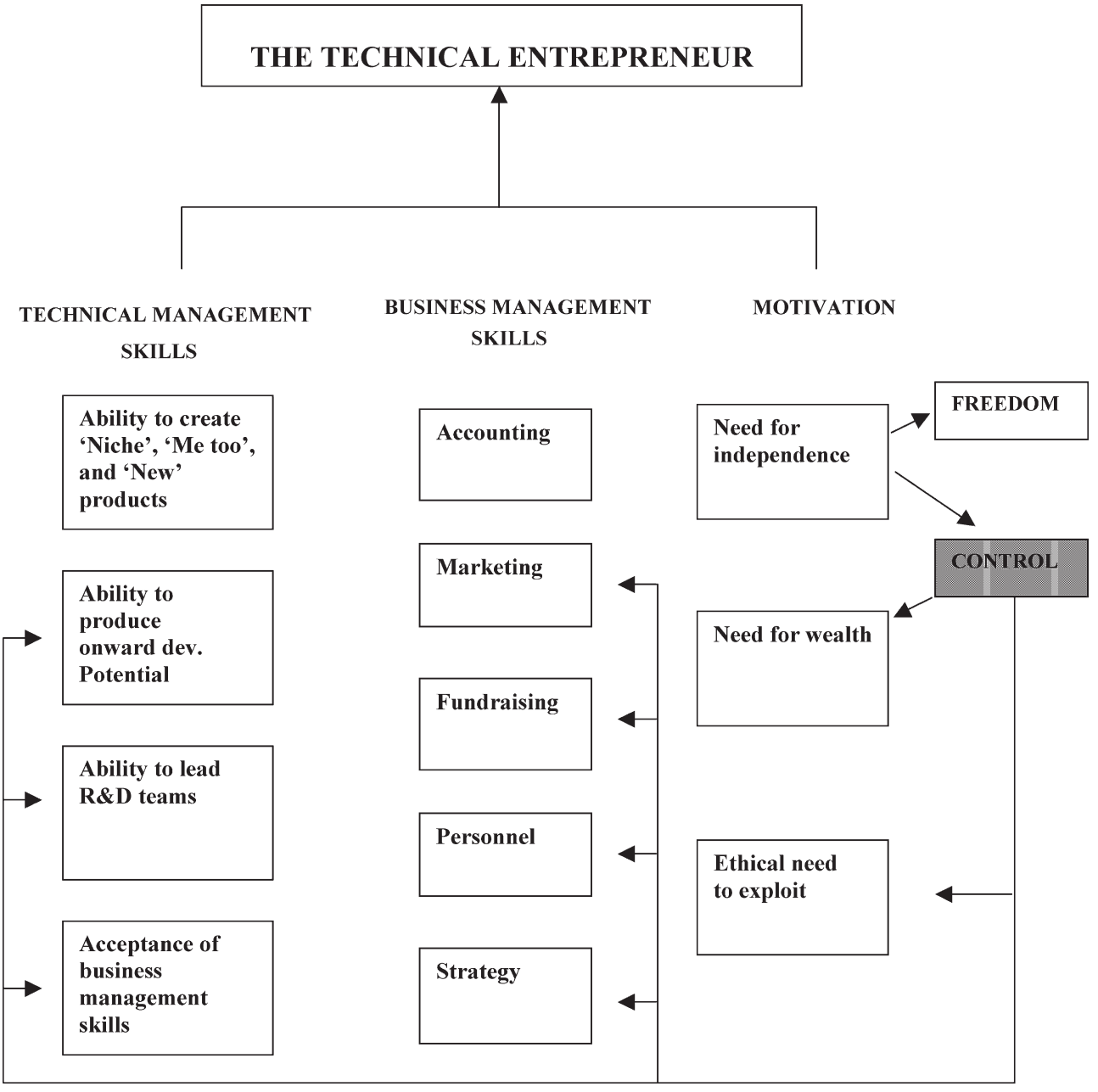

Fig. 1. The technical entrepreneur at formation.

(namely Motivation, Technical Management Skills, and Business Management Skills) that characterise the performance of technical entrepreneurs, both singularly, and through their interaction. This is particularly the case where motivational factors shape business management and technical management skills through the "control mechanism" (see Fig. 1). Significantly, the following discussion of technical entrepreneurship extends what would exist under conditions of "normal entrepreneurship" by adding the technical management skills of the founder, that can *either* enhance or constrict overall entrepreneurial performance. These three areas will be discussed in turn below, beginning with the critical strategic driver of Motivation.

3.2. Motivation

Motivation is the *key* strategic driver of the model depicted in Fig. 1 in that it shapes the *attitude* of the technical entrepreneurial founder towards his chosen mix of technical management and business management skills, the manner in which they are deployed within the firm, the amount of external resources accessed (e.g. capital; management expertise), and the level of personal

control that he or she exercises on the "day to day" running of the business. Three major motives for beginning a new business are acknowledged in Fig. 1, comprising "independence", "wealth" and "exploitation". Most importantly, the desire for independence is divided into two, sharply different, driving sub-motives; namely "freedom" and "control". While the desire for freedom frequently derives from a need to escape the stifling bureaucracy of previous employment in large public or private sector bodies and pursue a personal (often research) agenda, the control motive is a more complex psychological driver. This complexity derives from the paradox that some technical entrepreneurs did not wish to escape control per se when they "spun off" from a large bureaucratic organisation. Instead, their problem was that *they* did not exercise this key function! For such entrepreneurs, the main attractiveness of beginning their own new firm lies in *their* ability to exercise autocratic and independent control over all aspects of the new enterprise. As Fig. 1 graphically illustrates, when technical entrepreneurs have a desire for complete control of the firm, this fundamental motivation strongly influences most of the other functions. Such pervasive control influences *both* technical and business management aspects of the enterprise, and critically, shapes the attitude of the owner to many aspects of management, ranging from the conducting of research, through fund raising, to the hiring of new staff.

The particular market segment in which the high technology small firm operates may also influence the viability of specific motivational tendencies. As Fig. 1 indicates, firms may be established in "niche", "me too" or "new" areas of high technology production. For the first two of these categories (i.e. "niche" and "me too"), it is more likely that autocratic control may be safely maintained because both these activities are slower areas of technology change, where consequent risks and rewards also gradually accrue. The niche producer, perhaps manufacturing in batches (for example) a specialist gas detection instrument, will need to technically improve this product only slowly, while large firm competition in such a low volume "niche" areas of production rarely occurs. Similarly, "me too" firms tend to operate in generic, often sub-contract, areas of high technology where, although price competition is strong, R&D costs are low, while a "known" ore technology means that barriers to entry are also low (e.g. printed circuit board making; component insertion). In both these instances, lower levels of risk and reward make it easier for an entrepreneur, keen on internal autocratic control, to maintain a "slow growth" introspective management style (Oakey, 1995). However, for technical entrepreneurs developing "new production" in the form of high technology products, with mass market potential (e.g. a "world beating" new treatment in the biomedical area), the scope for maintaining long-term autocratic control is much reduced. This is mainly because the propensity to develop financial problems associated with either R&D cost over-runs and/or later production "scale up" costs are both very high as strong market demand and technically-based competition "pulls" the firm into rapid (often uncontrollable) growth. Interestingly, in *both* these cases of rapidly escalating costs, a sudden and unavoidable need for a rapid external injection of capital is engendered (Oakey, 1995). As will be discussed in detail below under "business skills", this eventuality may trigger the unavoidable involvement of external investors (e.g. venture capitalists), thus causing a conflict between the imperative of autocratic independence and the urgent need for investment funds, a scenario that independently minded entrepreneurs have every reason to fear (see "business skills" below).

3.3. Technical management skills

Clearly, the technical skills of an entrepreneur strongly *determine* the product or service that he or she offers in the market place. For highly gifted scientists, a new product might be developed at the leading edge of technology (e.g. in biomedicine—which would equate to "new" in Fig. 1), while, as noted above, "me too" and "niche" potential offerings to the market constitute products types of lesser technological sophistication, that none the less, may remain viable vehicles for firm formation and growth. The ability to develop and manage a *team* of researchers, as the firm grows, is a skill that the technical entrepreneur might not readily possess, as noted in the introduction with regard to William Shockley (Cardullo, 1999). This observation leads to a key point concerning a major competence that a technical entrepreneur *must possess.* This is an ability to see the key functional relevance of complimentary business management skills in support of technical innovation as part of the overall "success equation". Although this key insight would be implicit to entrepreneurs with *balanced* technical and business management skills, the previously noted prejudice of physical scientists towards social science in general, and an unwillingness on the part of technically qualified scientific entrepreneurs to understand the key relevance of, for example, marketing to product innovation success, is a well documented "blind spot" (Moenart and Souder, 1990; Oakey, 1991).

Neglect of marketing is partly caused by technical entrepreneurs who have a "technology push" view of invention in which technical elegance is often valued more than customer need. Marketing staff, however, who constantly deal with customers, often irritate technical entrepreneurs because of a contradictory "demand pull" view of innovation in which customer requirements are seen as paramount. However, the ultimate value of marketing expertise is witnessed by the fact that, even in cases where there is no customer demand for a new pro-

duct because it has not previously appeared in the marketplace (i.e. an invention push example—e.g. word processors; personal computers), marketing experts can play a key role in *creating new markets* that previously did not exist. This is often termed educating the market "ahead of itself".

The enthusiasm of the Steve Wasniak for the help provided to Apple Computers by Regis McKenna in developing the personal computer market out of a hobbyist "niche" into a mass-market is convincing proof of how important marketing can be. The critical point here, however, is that technical entrepreneurs, in order to be successful (as in the case of Wasniak), must be able to embrace best practice technical management techniques themselves, and be willing to hire or take advice from specialist experts in all areas of business management as the firm grows. Critically, this is the major reason distinction between the motivations of "freedom" and "control" in Fig. 1. "Freedom" implies a willingness to use the new enterprise to create a learning organisation in which an "open minded" view of entrepreneurship is taken, while "control" in based upon a greater tendency towards introspection and a "not invented here" denial of alternatives.

3.4. Business management skills

A major factor that encourages technical entrepreneurs to believe that business management skills can be self taught is the frequent reality that businesses, when begun by technical entrepreneurs, initially survive because the founder takes on *all* the business functions illustrated in Fig. 1 out of necessity (i.e. accounting, marketing, fund raising, personnel management, and strategy). This arrangement has a major early advantage of low cost and, congruity of purpose (since one person performs all functions). However, as the firm grows these key individual tasks become increasingly important and will progressively suffer from not receiving adequate attention if the founder does not delegate to "hired in" specialists.

Given that technical entrepreneurs often have primary responsibility for R&D, it is critical that other business management support, when rapid growth occurs is provided particularly in the finance, marketing and personnel areas. As the firm expands, technical entrepreneurs can either adopt an enlightened attitude to such specialist needs (and make the necessary appointments), or the inadequate performance of such functions will become a "bottleneck" to growth (Oakey et al., 1988). Indeed, when external venture capital *has been* taken "on board" in exchange for equity, the original technical entrepreneur may clash with external investors if he or she is unwilling to allow the development of formal management structures. In extreme cases, external investors may remove such founders, or "side line" them to work as a technical expert, while management is handed to professional managers (Bullock, 1983; CBI, 1997; Oakey, 1984b). Significantly, however, it is fear of such an eventuality that is a major reason why technical entrepreneurs are often unwilling to involve external investors, since such involvement is seen as a "slippery slope" towards a total loss of independence (or control), which (as noted above) may have been the founder's main motive for beginning a business (Fig. 1). It is certainly true that technical entrepreneurs who refuse to *consider* external involvement are behaving sub-optimally, at least in a strategic sense, in that they are *not* seriously evaluating the *full range* of options open to them. Also, myopic and introspective technical entrepreneurs who resist external involvement during the early life of the firm, perversely, often do not have the experience with which to handle external involvement when they are *forced*, during a crisis of rapid growth ***or*** decline, to negotiate with (originally unwanted) external partners (Oakey and Mukhtar, 1999).

3.5. Joint entrepreneurship

It is advantageous to pursue the above arguments on the deficiencies of the lone entrepreneur, particularly where they relate to autocratic tendencies and an inability to delegate key tasks, in the context of joint acts of entrepreneurship. There are at least as many instances of joint entrepreneurship as there are examples of individual entrepreneurship although, as noted above, the media often prefer the lone example (Oakey et al., 1988). However, it is clear that venture capitalists are often more comfortable with funding a *team* of founding entrepreneurs, who jointly seek to establish a new high technology venture; typically in high technology small firms, a scientist, production engineer and salesman (Bank of England, 2001).

In terms of Fig. 1, joint entrepreneurship achieves most of the benefits of "freedom", while the danger of damaging autocratic control is reduced, from the outset, by multiple ownership of the firm. However, because each owner may have differing views on what the firm should seek to achieve (e.g. either grow fast to sell or grow slowly by remaining strongly independent), there may be no *agreed* view on strategy. None the less, in general terms, joint owners tend to have a greater propensity to view the firm, from the outset, in terms of ways in which their shares can be made to rapidly maximise returns (usually implying a "grow to sell" approach), than do individual entrepreneurs. This may be a more "healthy" stance when judged in terms of the future of the firm, since external involvement may become unavoidable. As noted above, it is certainly an attitude that venture capitalists would applaud, since share value appreciation and a safe "exit route" is a motive that they strongly share (Murray and Lott, 1995).

Most importantly, multiple-ownership may more often encourage a consideration of the future of the firm that involves, from the outset, an aggressive "grow to sell" approach in which maximum added value is necessary in order to reward *multiple* owners of the firm. Indeed, most successful high technology small firms are eventually absorbed into large global giant firms of any given sector (Granstrand and Sjolander, 1990; Oakey, 1993).

4. Forward planning

4.1. Strong control and the problem of succession

A final consideration for this paper on the role of technical entrepreneurs in the functioning and growth of high technology small firms concerns various aspects of the forward planning process. First, at a most simple level, a major weakness in the above noted frequently *strong* desire for control among many firm founders is their own mortality. Given that the most usual age among founders for the formation of a high technology small firm is between thirty-five and forty years old, his or her involvement in the firm (assuming it survives) is between twenty five and thirty years. While at the point of formation retirement might appear remote, it will become a major forward planning problem after fifteen to twenty years. For example, should the owner seek external finance during this latter period, the management succession issue will be of critical concern to potential lenders or investors.

Moreover, unlike many small firms where the technology involved is simple and generic (e.g. baking; furniture making; delivery services), technical entrepreneurs may find it difficult to pass on their business, either within the family or to others, because in complex areas of high technology manufacture, other potential managers of the firm (e.g. family members) often do not have the core technical skills of the technical entrepreneur founder. Put simply, the "brain" of the founding entrepreneur is often the firm's main asset. Thus, perversely, if the high technology small firm entrepreneur achieves his or her goal of remaining in independent control of the firm for several years, including remaining the sole source of its technical competence as a technical innovator, severe problems can arise when this individual *approaches* retirement. Despite the above caveats, while it is always possible that he or she could seek to sell the business, at or near retirement as a "going concern", it probably would make better sense (and this is a *key strategic point* to be drawn from this paper), for an entrepreneur with a strong tendency for autocratic control, to temper this tendency and seek to share responsibility with others *from the outset*, both within the firm, and externally.

However, retirement is only one simple example of an exit crisis. Because this eventuality can hardly be described as a strategic choice (and although it can be planned for), it would be a contradiction in terms to describe coping with this eventuality as an exit "strategy". None the less, the succession problem implies that efficient firm owners should *constantly* consider the merits of continuing autonomously against various shared management and/or exit options *throughout the life of the firm.* Indeed, such efficient "exit" considerations might even *precede* the existence of the firm in that a potential technical entrepreneur (e.g. an academic) could decide directly to sell intellectual property he or she has developed (e.g. in a university department) to a large existing firm *before* formation, thus negating the need to found a new business. However, once begun, a technical entrepreneur founder of a firm in the "new" product category of Fig. 1 with a "world beating" technology, will be constantly approached with offers of part or total ownership of the nascent enterprise by large firm competitors (Oakey et al., 1990). Deciding on whether to sell or continue is a consideration for the remaining parts of this section on forward planning.

4.2. Exit strategies

For many technical entrepreneurs who begin new firms, stability of demand for their products or services and a good "living wage" is sufficient. In the slower moving "niche" and "me too" areas of production, noted in Fig. 1, problems associated with "new product" technological developments, by definition, rarely apply since such firms occupy relatively low-risk low-reward areas of high technology production. While issues of price and quality (which also involve elements of avoiding obsolescence) provide constant challenges to firms competing at the "leading edge" of technology, competition in these more generic areas of technology are less onerous (Oakey, 1984b, 1995). Therefore, because in these "niche" and "me too" areas of technology the value of companies are generally lower and stable, issues surrounding possible exit strategies are less acute.

However, in the "new product" technology instances of Fig. 1, where technologies of extremely high *potential* worth are in the process of development, often within a new high technology small firm, the perceived value of an evolving technology might fluctuate wildly in circumstances where comparatively long lead times on R&D development are common (i.e. up to ten years) (Oakey, 1995), depending on scientific progress, competition, government regulations, intellectual property protection problems, and the ill-informed whims of non-scientifically informed investors (Rothwell and Zegveld, 1981). This problem is also common to large pharmaceutical firms in instances where their share prices can be radically influenced by a rumour in the financial press that development of a key new drug is not progressing well.

As noted above, although entrepreneurs in such elite areas of technological development *may* be emotionally inclined towards autocratically maintaining control over a new business that they have established to exploit a "leading edge" technology, in most cases, the power of the technology under development will attract strong external competitive interest (Oakey et al., 1990). Such interest may be direct in that a large competitor company might offer to buy the new firm in question, or it might be indirect in cases where a large firm will deliberately infringe any intellectual property protection enjoyed by the new firm, and effectively illegally acquire the technology concerned by purchasing examples and "reverse engineering" a competing product (Macdonald and Lefang, 1998). Faced with such extreme competition from a large, often multi-national competitor, for most technical entrepreneur founders of new firms, it is not a case of *"if"* to sell out, but more importantly, *"when"* to sell in order to maximise the value of any surrendered intellectual property embodied in the nascent enterprise.

This dilemma for the high technology small firm is expressed in diagrammatic form in Fig. 2. This diagram expresses the strong functional relationship between the value of any given technology under development and "confidence" in its ability eventually to technically perform efficiently (and by implication) sells in the competitive marketplace over time. The key strategic risk for any technical entrepreneur developing such a technology is that he or she cannot be sure that further development of the concept will guarantee further success (and implied value). Various scenarios expressed in Fig. 2, ranging from options A–D, are discussed in turn.

Scenario A is similar to the strategic option discussed above in which an inventor of a new concept sells the new idea at a very early stage. Unlike the above case, however, where an inventor did not even begin a new firm, in case A the technology is sold at a very early stage after formation, possibly providing funds for the development of another product idea within this nascent enterprise. The main problem with such an approach is that, as indicated in Fig. 2, the value acquired by the firm is far less than would have been achieved had the product been further developed and sold when development had reached a point further up the development curve (e.g. points B or C). Such observations imply the potential for both possible positive or negative correlations respectively between risk and reward as a product is (or is not) successfully developed.

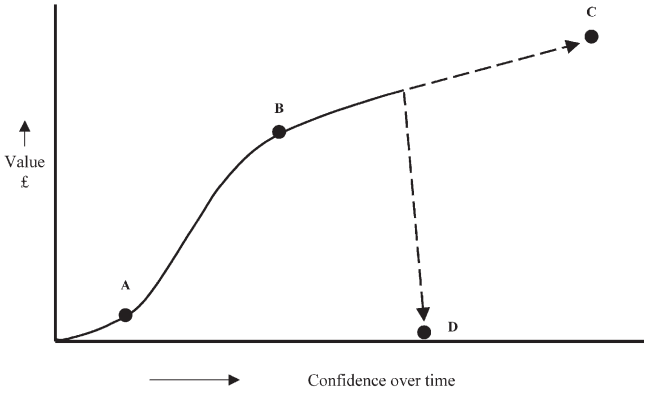

Fig. 2. Value versus confidence product life cycle.

The position of point B can be simply described as better than A but not as good as C. While the technology concerned has undergone value-adding development that, through a reduction in technical uncertainty, has increased its worth to a potential buyer, the attractiveness of further developing the new technology to point C might render selling out at point B a wasteful strategy. However, as noted in the discussion above, increasing certainty over the potential of a new technology development is a very fragile phenomenon in that there are many technical (e.g. the technology proves dangerous or unreliable) and/or economic (e.g. price and competition) factors that may destroy improving confidence "overnight". Thus, in seeking to reach point C on the product development curve, an aggressive entrepreneur might, for the above reasons, cause the demise of his whole business by arriving at point D, following a collapse in confidence that would have a sudden disastrous impact of the value of the technology (and the firm) under development. Clearly, in the absence of a "crystal ball", the key problem for the technical entrepreneur is that future progress cannot be predicted at any given point reached on the growth curve. Further development of any given technology might either prove that it is a new "world beating" approach or a technical "dead end". Unfortunately, *in both cases*, substantial amounts of R&D development investment are necessary to reach *either* points C or D in Fig. 2. The only personal attributes of the entrepreneur (or entrepreneurs) that might reduce risk and increase confidence in technical entrepreneurs taking strategic decisions in this area are technical excellence, either existing or acquired management expertise, and luck!

5. Conclusions

This paper must conclude that, although the tendency for technical entrepreneurs to take an independent, or perhaps myopic, approach to high technology small firm management is understandable, in virtually all the instances discussed above, such behaviour is misguided. The failure of a physical scientist with technical management success to acquire business management training is clearly a sub-optimal approach to business development and control. In particular, an unwillingness to hire specialist business management skills, as the business grows, is also likely to inhibit the survival of the enterprise concerned in the medium term, particularly if

external financial assistance becomes an unavoidable need. In cases where both individual and joint entrepreneurship are involved, a flexible approach to the often conflicting merits of internal or external solutions to internal resource bottlenecks, in which *both* options are seriously considered, must lead to a safer business development strategy, and a more democratic work environment in which tasks are determined on the basis of the best (either internal or external) business solution, rather than being driven by the personal prejudices of the technical entrepreneur owner.

Much the same can be concluded regarding exit strategies. Whether to continue or to sell a business should be a *constant* consideration for the technical entrepreneur (or entrepreneurs) from the first day of trading. While the desire to be independent *if possible* can be built into any strategic equation designed to determine whether to continue to own or sell a business, it should not be allocated an unreasonably high value such that it overwhelms or has a veto over all other options. As Fig. 2 implies, the best time to sell a business depends on many factors that are difficult to determine in advance. However, Fig. 2 also implies that the right time to sell might occur *at any time* during the life of the firm. To only consider an exit strategy when it is too late to do anything else is, in a strategic sense, a contradiction in terms.

This is not to imply that making strategic decisions regarding undertaking management training, seeking external advice, or selecting the correct exit strategy are simple tasks. Rather, it is reasonable to assert that if the technical entrepreneur opens his or her mind to this full range of intellectual, human and financial resources available to assist management from an early stage in the new high technology small firm's life, on balance, decisions made under this more expansive management regime will be more efficient and likely to succeed. It should be a key role for policy makers at both regional and national levels within the United Kingdom to encourage, often reluctant, technical entrepreneurs to embrace management training. The development of such management skills can prove a powerful and valuable adjunct to technical expertise when applied in a business context, where they can provide a balance that, on average, is likely to reduce introspection, increase acceptance of external resources, and consequently lead to better success.

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