Thesis for the degree of Doctor of Philosophy

Entrepreneurship, Technology, and the Growth Process: A Study of Young, Medium-Sized Technology-Based Firms

Rögnvaldur J. Saemundsson

Department of Industrial Dynamics
Chalmers University of Technology
Göteborg, Sweden
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To the people at Flaga
May reinforced fun be with you

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Rögnvaldur J. Sæmundsson
Department of Industrial Dynamics
Chalmers University of Technology

Abstract

The purpose of this thesis is to contribute to the study of the growth process in young technology-based firms. Two sets of issues are addressed in the thesis which are related to one another by using a conceptualization of Penrose's theory of the growth process. The first set of issues concerns how young technology-based firms achieve reinforced growth. It is investigated how the characteristics of start-up opportunities may constrain firms from attaining reinforced growth, how specific actors – such as venture capital firms and large corporations – help firms to avoid resource constraints, and finally whether the growth orientation of the firms is affected by these actors. The second set of issues concerns how the growth process affects the development of technical knowledge in young technology-based firms, and hence, their ability to create and detect new opportunities for further growth.

In order to investigate the above issues, two empirical studies have been conducted. Both focus on the population of new technology-based firms in Sweden established between 1975 and 1993. A mixture of quantitative and qualitative data collection methods is used in both studies. Analysis of quantitative data is used for comparing firms that have become medium-sized with those that have not. Interviews in medium-sized firms are used to analyze the growth process.

The main findings can be divided into two parts. First, it was found that differences in the novelty of opportunities at start-up may influence the probability of attaining reinforced growth. Additionally, a relationship was found between access to resources, ownership changes and growth orientation. New owners both provide access to resources necessary for growth and increase the growth orientation of the firm. Hence, they may enable growth in two ways. Second, the study found that growth affects the organization of technical knowledge as well as the incentives for seeking new technical knowledge. The number of distinctive fields of technical knowledge was found to increase during growth, but this increase was limited by the characteristics of the firms' technology and by growth itself. Incentives for knowledge-seeking were also found to change during growth, leading to problems related to retention of technical employees and updating of the technical knowledge base.

The chief contribution of this thesis is the conceptualization of the growth process that is used to connect the two sets of research issues. The study also provides empirical support for the need to consider multiple intentions and incentives when examining growth in young technology-based firms. Intentions and incentives are not predetermined, but are among the variables that may change and are to be explained. Finally, the study empirically demonstrates some aspects of the interaction between technical knowledge and growth.

The findings of the thesis point to tensions, inherent in the growth process in young technology-based firms, that must be attended to by management in order to attain and sustain reinforced growth.

Keywords: Entrepreneurship, technology-based entrepreneurship, management of technology, firm growth, the growth process, small and medium-sized firms.

List of Appended Papers

This thesis is based on the work contained in the following papers:

Paper I

Saemundsson, R. J. and Kirchhoff, B. A. "Economic Development, Technological Innovation and Entrepreneurship", an earlier version is found in Kuopusjärvi, P. *RENT XV Research in Entrepreneurship and Small Business*, Turku, Turku School of Economics and Business Administration, 2002.

Paper II

Saemundsson, R. J. and Lindholm Dahlstrand, Å. "Breaking the Entrepreneurial Growth Barrier: The Role of Venture Capital and Acquisitions for the Emergence of Medium-Sized Technology-Intensive Firms". In Reynolds, P., Bygrave, W. D., Maingart, S., Mason, C.M., Meyer, G.D., Sapienza, H.J. and Shaver, K.G. (eds.), *Frontiers of Entrepreneurship Research*, Babson Park, MA, Babson College, pp. 637-651, 1999.

Paper III

Saemundsson, R. J. and Lindholm Dahlstrand, Å. "How Business Opportunities Constrain Young Technology-Based Firms From Growing Into Medium-Sized". Revised and resubmitted to *Small Business Economics*.

Paper IV

Saemundsson, R. J. "On the Interaction between Growth Intentions, Access to Resources, and Growth in New Technology-Based Firms". Accepted for publication in *The International Journal of Entrepreneurship and Innovation*.

Paper V

Saemundsson, R. J. "On the Interaction between the Growth Process and the Development of Technical Knowledge in Young and Growing Technology-Based Firms". Submitted to an international journal for review.

Paper VI

Saemundsson, R. J. "Technical Knowledge Seeking in Young and Growing Technology-Based Firms: Incentives and Direction". Submitted to an international journal for review.

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Göteborg, January 2003

Rögnvaldur

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1 Introduction

In Sweden, and in most of Northern Europe, there has been for some time an on-going debate about slow economic growth, high unemployment rates and the uncertain future of the welfare state. While many possible solutions have been discussed, few have been as popular as the calls for increased technology-based entrepreneurship. Based upon the assumption that technological change is one of the main drivers of economic growth (Solow 1957), great expectations have been placed on the growth potential of new technology-based ventures. While the original enthusiasm about the direct effect of new technology-based firms on employment and growth has been overly optimistic (Oakey 1994), new technology-based firms have an important role for industrial renewal. New technology-based firms not only have the potential of creating new industries. They also provide innovation inputs to established industries and contribute to their revitalization. There is some evidence that the indirect effect which new technology-based firms have on employment and growth is larger than the direct one (Smith 1999). The strength of this indirect impact is nevertheless likely to be related to the number of new firms and their growth.

This thesis addresses the growth process in young technology-based firms. It is concerned with the process by which recently established technology-based firms attain reinforced growth, i.e. a state where internal pressures are exerted for further growth, and with how reinforced growth is maintained.

There are several growth-related management challenges that are specific to young technology-based firms. The technical knowledge possessed by employees and management plays a prominent role for the identification of business opportunities in technology-based firms. Due to the inherent uncertainty of technical knowledge development and the uncertainty of the value that technical knowledge has for customers, technology-based firms face more uncertainty than many other types of firms. In the young firm this uncertainty is exaggerated by the volatile nature of inexperience (Slatter 1992) and the pervasive rate of technological change (Hitt, Ireland, and Lee 2002). The rate of technological change makes it necessary to continually identify new opportunities for growth, at the same time that the inexperienced firm has to deal with the increased complexity of a larger organization.

The studies conducted for this thesis have resulted in six research papers, which are connected together in this introductory paper. Rather than only recapitulating the

starting points for the research, the introductory paper more rightly presents the destination of that research and the starting point for further inquiry. This starting point consists of theoretical ideas which Loasby (1991) would call ‘connecting principles’, and which link together investigations of different aspects of the growth process in young technology-based firms. It is hoped that these connecting principles can increase the understanding of the challenges in managing growth in young technology-based firms and will stimulate further research on the subject.

The thesis consists of this introductory paper and, appended at its end, the six research papers (numbered I-VI). The structure of the introductory paper is as follows. In Chapter 2 the research problem is specified and related to previous research. In Chapter 3 the research problem and the contributions of this thesis are explored further, linking together the research questions of the individual papers. Chapter 4 provides an overview of the methodology used in the thesis, including description of the two empirical research projects that were conducted. In Chapter 5 the appended papers are summarized and, finally, the implications of the thesis for management and future research are discussed.

2 Research Problem

"In the organic complex of habits of thought which make up the substance of an individual's conscious life the economic interest does not lie isolated and distinct from all other interests."

Torstein Veblen

In this chapter the research problem will be specified and related to previous research. Key concepts will be defined and linked together, leading to the purpose of the thesis at the end of the chapter.

In the first section it will be explained how the thesis relates to entrepreneurship research. The section describes different starting points for studies of entrepreneurship, and differences in the conceptualization of the entrepreneurial process. This thesis is positioned as having technological innovation as its starting point and studying one particular aspect of the entrepreneurial process, which is firm growth. In the second section, the starting point of technological innovation is further clarified as well as the role of young technology-based firms. In the third and final section, the research problem of the thesis is related to previous studies of firm growth. It is argued that previous studies of growth in young technology-based firms have paid relatively little attention to the process of growth and the specific characteristics of technology-based firms. Furthermore, research on growth within entrepreneurship is fragmented due to the lack of converging conceptual development. There is therefore a need for conceptual development of the growth process that takes the specific characteristics of young technology-based firms into account.

2.1 Relation to Entrepreneurship Research

Researchers have used the concept of entrepreneurship in many different ways. Despite this variety one can discern three different starting points that affect the focus of inquiry: the aggregate outcome of entrepreneurship, the personal characteristics of the entrepreneur, and the entrepreneurial process[1].

Within economics the starting point is usually the aggregate outcome, or function, of entrepreneurship. Entrepreneurship can be seen to induce change in the economic system through innovation (Schumpeter 1934, 1942), to be the source of profits by

[1] In its most general form, entrepreneurship refers to a certain type of activities and behavior that is relevant for all kinds of human endeavor. In this thesis, entrepreneurship refers only to economic or business activities.

providing direction under uncertainty (Knight 1921), or to increase the efficiency of an economic system through reallocation of resources and diffusion of information (Casson 1999, Kirzner 1973, 1997).

Within entrepreneurship research, the personal characteristics of the entrepreneur are a popular starting point. The basic idea is that entrepreneurs share a personal disposition that explains why they, and not others, conduct various forms of enterprising behavior (Carland, Hoy, Boulton and Carland 1984). Despite much effort, this research has had difficulties in discerning a set of characteristics that are specific to entrepreneurs as a distinct group of individuals (Brockhaus and Horwitz 1986, Gartner 1988).

The entrepreneurial process can be a starting point in itself, or the link between the other two starting points. The entrepreneurial process provides a conception of the activities and contexts that constitute entrepreneurship. In its most general formulation the entrepreneurial process refers to the identification and exploitation of economic opportunities. More often, researchers use a narrower formulation, constraining their domain of investigation with regard to the process of opportunity identification, type of opportunities, and forms of exploitation.

How researchers view the process of opportunity identification is closely related to their assumptions about the nature of opportunities. Some researchers assume that opportunities exist 'out there' to be found if sought. To search for opportunities is therefore an important part of the entrepreneurial process (Khilstrom and Laffont 1979, Shaver and Scott 1991). In the most extreme versions, it is assumed that the profitability of the opportunity is known before its exploitation is started.

Other researchers assume that opportunities exist 'out there', but that they will not be found by deliberately searching for them. Opportunities are discovered, identified "out of the ambiguities and clouds of an infinite array of alternative prospective futures" (Kirzner 1997, p. 33), based on previous knowledge and experience (Kirzner 1973, 1997; Shane 2000). It is not known beforehand whether the exploitation of the opportunity will be profitable or not.

Still other researchers assume that not all opportunities exist 'out there', and that some economic opportunities are created through innovative action, communication and learning (Schumpeter 1934, Baumol 1993). It is not known beforehand whether the exploitation of the opportunity will be profitable, and it is not even known if certain commercial activities, such as founding a firm to develop a certain technological idea, will lead to economic opportunities.

What types of opportunities are considered entrepreneurial differ among researchers. One can discern a different degree of inclusion ranging from narrow to general. Some include only opportunities related to the introduction of new products and services (Kirchhoff 1994, Shane and Venkataraman 2000). Others include all opportunities for innovation – both new products and changes in the production process (Schumpeter 1934). Yet others limit themselves to technological innovation excluding changes related to the organization of production (Cooper 1986, Roberts 1991). Still others include all types of economic activity that can return a profit, including innovations, arbitrage, and speculation (Kirzner 1973, 1997).

The final dimension of the entrepreneurial process is the form of exploitation. Exploitation is the commercial action towards realizing the profits of an opportunity or towards the creation of a profitable opportunity. Most researchers consider the firm as the main venue of exploitation of opportunities, while, for example, Kirzner (1973,1997) makes no distinction between different economic actors, be they individuals or firms.

Regarding exploitation in firms, one can discern different domains of inquiry by using two dimensions. First, researchers may be concerned with new firms or existing firms. Second, they may be concerned with selling off the results of the exploitation, or using it as a means for growth. The focus can vary between researchers. Those who are most general will include all forms.

Some researchers emphasize entrepreneurship as the creation of new organizations (Schumpeter 1934, Gartner 1985, Bygrave and Hofer 1991), while others stress entrepreneurship as a general aspect of management of all firms (Knight 1921, Stevenson and Jarillo 1997). Within both contexts, the exploitation of the opportunity may be through selling of the new organization, or the idea on which the opportunity is based, or through growth. Long-term growth (or sustained growth) can also be seen as continued entrepreneurship (Davidsson 1989, Davidsson, Delmar, and Wiklund 2002), i.e. serial or successive opportunity identification and exploitation.

This thesis focuses on the entrepreneurial process, but has its starting point in technological innovation as an aggregate outcome of entrepreneurship. The thesis is therefore only concerned with those activities and contexts of entrepreneurship that relate to the identification and exploitation of opportunities for technological innovation.

There are a number of actors that take part in the process of technological innovation (Freeman 1994, Rickne 2000). They include existing firms, new firms and various supporting organizations. In this thesis the focus is on one particular actor, the new technology-based firm (NTBF).

Within the context of NTBFs this thesis is concerned with particular aspects of the entrepreneurial process. The thesis is not concerned with the creation of the new firm or the preceding stages of preparation. It deals with the growth of recently established firms. To make clear that we are not referring to the creation of technology-based firms, the concept of the young technology-based firm (YTBF) will be used in the thesis to denote a recently established technology-based firm. Although the concept of YTBF will be central here, especially in relation to the empirical material in the thesis, references will be made to research on NTBFs as this research is very often concerned with the development of the recently established firm.

2.2 Technological Innovation and Young Technology-Based Firms

Most definitions of technological innovation are related to Schumpeter's (1934, 1939) ideas of innovation as the introduction of new combinations of methods for supplying commodities in the economy. Innovation is therefore related to changes in the production structure of the economy. It is thus only one part of a more general socio-economic change, which apart from innovation involves changes in technology, consumer taste, institutions, demographics and size of populations, etc. (Schumpeter 1939, Nelson 1994).

Technological innovation is commonly used in a narrower sense than Schumpeter's concept of innovation. Rather than referring to all changes in the production system, technological innovation only refers to the introduction of new products/services and new methods of production (Abernathy and Utterback 1978, Teece 1986). This view of technological innovation is connected with the view of technology as artefacts or methods of production.

In this thesis the concept of technological innovation refers to the introduction of new products and services whose creation is based on technical knowledge. The concept of technical knowledge is closely linked to the concept of technology. Literarily, technology means the "study of techniques", where the word 'technique' derives from the Greek word 'téchne' (Granstrand 1979, p. 4). According to Aristotele, 'téchne' is the knowledge of how to make things "whose origin is in the maker and not in the thing made" (Aristotele 1998, p. 141). Correspondingly, while the scope and emphasis may differ, researchers of technology are likely to agree that technology is somehow related to artefacts, the methods of producing artefacts, and knowledge of artefacts and their production (Schon 1967, Rosenberg 1976, Vincenti 1990, Dasgupta 1996). Thus, technical knowledge has a close relation to the creation of the artificial (Simon 1996). This can be contrasted with scientific knowledge that is related to the understanding of the natural world, of which the artificial is a part (McKelvey 1996,

pp. 52-53). While scientific knowledge has an important influence on technical knowledge, technical knowledge is more than knowledge related to the application of science, and does not have to rely on science at all (Layton 1974, Rosenberg 1976, Vincenti 1990).

NTBFs are one of the venues for the introduction of new products and services based on technical knowledge. The concept of NTBF, like other related concepts[2], has been used in a number of different ways in previous research, even if they share a similar core. Most, if not all, authors agree that NTBFs base their operations on technology. In that respect the definitions of NTBFs relate to definitions of technology-based firms as firms that perform in-house research and development (R&D) (Ansoff and Stewart 1967), as a consequence of being dependent on technology for exploiting business opportunities (Granstrand 1998). Additionally, most authors are considering independent start-up firms, i.e. new and small firms that are not a part or subsidiary of existing firms. Besides agreeing that the concept of NTBF refers to independent, technology-related start-ups, researchers make different, and often ambiguous, assumptions regarding the origin of the firm and the newness of its technology.

Roberts (1991) refers to new technology-based firms as spin-offs from university settings that exploit advanced technology. Autio (1995) includes all spin-offs, both from universities and from existing firms, exploiting advanced technical knowledge. Cooper (1971) defines new technology-based firms as new firms that place major emphasis on exploiting new technical knowledge. Bollinger, Hope and Utterback (1983) define new technology-based firms as new firms that are established in order to exploit a technological innovation independently of the "newness" of the innovation.

In this thesis the concept of YTBFs is related to that of NTBFs. The concept of a YTBF here refers to a recently established firm, independent at start-up, that relies on the technical knowledge of employees for identifying and exploiting economic opportunities. Hence, YTBFs rely on the identification and exploitation of opportunities for technological innovation. This conceptualization focuses on the knowledge and skills of the employees, regardless of the novelty of the technical innovation and the amount, novelty, or existence of systematic R&D.

To focus on the technical knowledge and skills of the employees, rather than the amount or newness of the internal R&D or the origin of the firm, fits well with the observation, mentioned in the Introduction and in Paper I, that young technology-based firms have both direct and indirect effects on economic growth and

[2] Related concepts include technology-based SMEs (Mason and Harrison 1994), high-technology new firms (Oakey 1995), and small innovative firms (Barber, Metcalfe and Porteous 1989).

development. Young technology-based firms may take on different roles in the technological innovation process, either generating new technological ideas and opportunities, or aiding in their diffusion. The new technological ideas can have their origins in universities or existing firms, and they can be diffused either by the manufacturing and marketing of new products in these firms, or by innovation-related services offered to other firms. Whether the effects are direct or indirect, the effects of each firm are likely to be proportional to firm growth.

2.3 Relation to Previous Studies of Firm Growth

Growth of firms is not a new research problem. It has been studied extensively ever since the birth of the independent firm as an economic institution. Originally the study of growth was confined to economics but, in the last 50 years or so, several interdisciplinary fields have emerged that have supplemented the purely economic perspective on firm growth. Of those, we can delineate three additional fields that are of interest for this thesis. First, organization studies with their focus on organizational aspects of growth. Second, studies on strategy and management with focus on growth strategies and the management of growth. Third, entrepreneurship studies with focus on the growth of small and young firms. These three interdisciplinary fields are related since they all include basic theories of economics, sociology and psychology. Moreover, many researchers are active in more than one field. There is therefore a large amount of overlapping between these three fields. Within each field there exists a small group of researchers who are specifically interested in technology-based firms.

Despite the number of fields studying firm growth, and their various differences, one can roughly divide the studies of firm growth into two categories. The first category is interested in explaining and predicting changes in firm size[3]. The second is interested in the internal process leading to changes in size. One could say that the former is concerned with growth as a result, while the latter is concerned with what happens in firms as they grow. Below, a short account will be given of the research within each of the four disciplines mentioned above (economics, organization studies, strategy and management, entrepreneurship) for each category. Special attention will be given to studies of growth in young technology-based firms. In the following, *studies of growth* refer to the former category, and *studies of the growth process* to the latter.

Studies of growth come in various flavors and large amounts. Economists have traditionally devised formal theories for explaining the optimal size of the firm, to

[3] Size can mean different things in this context, such as the amount of output by the organization, the amount of resources controlled, number of employees, sales etc. See section 3.1 for further discussion on the concept of growth and its relationship with the concept of size.

which firms will move if given some maximizing decision criteria and environmental conditions (Marris 1971, Geroski 2000). In addition to formal theories, more empirically oriented economists have investigated the post-entry performance of new firms in different industries (Audretch and Mata 1995) and the relationship between growth rate on one hand and size and age on the other (Evans 1987).

Strategy and management scholars have searched for strategic alternatives, given conditions of internal resource endowments and of the external environment, which can help reach the goals of the corporation (Andrews 1971). Growth can be either a separate goal or a means towards other performance-related goals (Child, Francis, Kieser, Nyman and Silberston 1975)

Organization theorists have mainly investigated growth in relation to population dynamics (e.g. Carroll and Hannan 2000). These studies have been interested in explaining different growth rates in firms and the relationship between growth, mortality, and organizational forms.

Entrepreneurship scholars have searched for factors that can explain, and predict, different growth rates in start-up firms (e.g. Cooper and Gimeno Gascón 1992) and small firms (e.g. Wiklund 1998). This search has mostly been empirical, lacking a convergent conceptual development (Davidsson and Wiklund 2000).

Compared to the vast amount of studies of growth, there have been relatively few studies of the growth process. Within economics the growth process has not received much attention. An important exception is Penrose's (1959) theory of the growth of the firm. Penrose was interested in limits to the growth of firms, and in order to investigate these she constructed a theory of the growth process.

Within strategy and management, the growth process has attracted more attention related to the management of organizational change and development. An influential study is Chandler's (1962) historical study of the development of the 'managerial firm' linking growth strategies and changes in administrative structure. Much of later research within management has been focused on how to manage organizational change and development rather than the growth process *per se* (e.g. Pasmore and Fagans 1992).

Organization studies of the growth process have focused on structural changes during growth. These studies usually are based on the life-cycle metaphor, where the structural changes unfold according to an internal logic of organizing at different sizes and ages (e.g. Greiner 1972, Churchill and Lewis 1983, Garnsey 1998). These studies describe the effects of growth on various aspects of organization and management, and prescribe how they should be dealt with in order to sustain growth.

Studies of the growth process within entrepreneurship usually are also based on the life-cycle metaphor (e.g. Hofer and Charan 1984, Hanks 1990) or concerned with growth constraints facing small firms (e.g. Barber, Metcalfe and Porteous 1989). These constraints may be related to properties of the environment, endowments of the firms, or the process of growth.

While most of the studies on firm growth and growth processes investigate firms in general, a number of studies have investigated technology-based firms in particular.

Scholars studying the economics of innovation have investigated the growth of NTBFs and their impact on industrial dynamics (e.g. Rickne 2000). Many studies within strategic management are interested in the strategic management of technology, i.e. how technology-related resources are to be managed for competitive advantage and growth (e.g. Dussauge, Hart and Ramanansota 1992, Granstrand 1998). Many studies within entrepreneurship research have also investigated technology-based start-ups, trying to explain the conditions for their growth (see Autio 2000 for a review). Autio (2000) argues that while many aspects of growth in technology-based start-ups have been investigated, the interaction between technology and growth has not received much attention.

Very few of the studies on NTBF growth have been concerned with the process of growth. Important exceptions are the life-cycle studies of Kazanjian and Drazin (Kazanjian 1988, Kazanjian and Drazin 1989, 1990), the studies of Dodgson and Rothwell (Dodgson 1989, 1990, 1991, Dodgson and Rothwell 1991) on technology strategy in young and growing technology-based firms, and the studies of Meyers and Roberts (Meyer 1986, Roberts and Meyer 1991) on the relationship between growth and the process of market and technological diversification.

Despite the vast research on the subject of firm growth, the results to date have not been too encouraging. Geroski (2000) argues that econometric data on firm growth fail to support the most prevalent economic theories of firm growth. Cooper (1993) notes that entrepreneurship research has not advanced very far in its quest of predicting new venture performance and growth. While the failure of economists is attributed to unreasonable assumptions about the nature of the firm due to the strict formality of their models, the failure of entrepreneurship scholars is attributed to lack of theory-building! What may be common to both cases is the lack of attention to the process of growth (Penrose 1959, Woo, Dellenback and Nicholls-Nixon 1994, Davidsson and Wiklund 2000). Growth is a process and better understanding of the process itself is likely to lead to better understanding of its outcome.

A missing step towards better understanding of firm growth within the field of entrepreneurship is the development of a conceptualization of the growth process.

This is especially true for the study of YTBFs, where studies of the growth process are few. For a conceptualization of the growth process to be appropriate for YTBFs it has to take into account the relationship between technical knowledge and growth. This interaction is of special importance for this type of firm, and has not attracted much attention in previous research.

The purpose of this thesis is to contribute to the study of the growth process in YTBFs. More specifically the aim is to contribute to the development of a conceptualization of the growth process that takes into account the special characteristics of YTBFs. In the next chapter, the nature of this contribution will be developed further and related to the research questions of the individual research papers.

3 Development of Research Questions

"The question is not how things stabilize themselves in a 'static state', but how they endlessly grow and change"

Torstein Veblen

In this chapter the research questions of the thesis will be developed. In the first section we set out by describing the nature of the growth process and its empirical manifestations. The great variety of outcomes and paths taken characterize a process that is multi-processual, recurrent and cumulative. The interesting challenge then becomes to identify the important sub-processes, including the basic process of accumulation, and to understand how the process of accumulation is initiated, and how growth can lead to further growth.

Penrose (1959) was considering similar questions when constructing her theory of the growth process. In her theory she was explicitly concerned with the identification and exploitation of opportunities, and the role of knowledge in that process. Her theory is therefore used as a point of departure for investigating the growth process in young technology-based firms.

Finally, Penrose's theoretical framework, coupled with recent research, is used to derive and link two sets of research questions related to how a process of growth is initiated where growth leads to further growth.

3.1 The Concept of Firm Growth

According to the Merriam-Webster Online Dictionary (2002) the verb 'to grow' has several different connotations. First, it can refer to passing into a condition, e.g. maturity. Second, it can refer to an increase or expansion in some dimension, e.g. size. Hence, the concept of growth may refer to the process of growing or the results of growing. The process of growing may or may not lead to qualitative changes in the growing object.

Studies of firm growth refer to either the process leading to an increase in size, or changes in size as a result of growing. But the concept of size is ambiguous. Assets, sales, and the number of employees are all commonly used measures of firm size, even if they represent fundamentally different concepts (Weinzimmer, Nystrom, and Freeman 1998). These measures may be seen as belonging to three of the four general aspects of organizational size suggested by Kimberly (1976). Assets are related to 'discretionary resources available to an organization'. They represent the outcomes of

past activities and the potential of future ones. Sales relates to 'organizational inputs and outputs' reflecting the level of activity in the organization. Number of employees is related to 'personnel available to an organization'. This is the number of people that have to be organized – the amount of people available to take part in the firm's productive activities. Finally, Kimberly adds the 'physical capacity of an organization' reflecting physical constraints on its activities, e.g. production capacity.

Increase in size may therefore refer to increase in the amount of resources available to the firm, increase in the level of firm activity, increase in the number of people involved, and increase in physical capacity. While the different dimensions can be related empirically, they do not have to, because they are conceptually different. Some previous studies of early growth concentrate on only one aspect of growth, usually sales, while others use multiple indicators (Delmar 1997, Weinzimmer et al. 1998). Which approach is used should depend on the purpose of the study and its theoretical rationale (Kimberly 1976, Davidsson and Wiklund 2000).

It is important to note that growth is conceptually different from the concept of economic performance. Economic performance is related to returns on capital invested in the firm, and growth is neither a necessary, nor a sufficient, condition for high return[4]. In entrepreneurship research, firm growth is nevertheless often used as a measure of firm performance. The rationale is that traditional measures of performance, such as market value, return on investment, or profits, do not apply for new ventures in their early phase (Chandler and Baucus 1996).

3.2 The Process of Firm Growth

The literal meaning of the concept of process is more often related to progress, or an activity towards some end (Merriam-Webster 2002). In research on management and organization, the concept seems to be used in a more neutral way referring to a temporal sequence of events (Van de Ven 1992). If the results of growth are increases in size, then the growth process is a temporal sequence of events leading to an increase in size.

A temporal sequence of events can have several basic properties (Van de Ven 1992, Abbott 1995). First, events, or patterns of events, within a sequence can be recurrent or non-recurrent, i.e. they can be repeated or not. Second, sequences can have a varying degree of dependence between their events, i.e. a given event may be more, or less, dependent on previous events. Third, a sequence can be single, or consist of two

[4] Firm growth may actually be one of the mechanisms that managers can use for appropriating some of the return on shareholder investment in the firm (Scott 1998).

or more sequences that occur in parallel. The parallel sequences can have varying degrees of dependence between them.

Empirical observations indicate a great variance in the patterns of growth. Delmar, Davidsson and Gartner (forthcoming) used six growth measures to identify seven patterns of growth in their sample of high-growth firms. Garnsey (2002) identifies six basic patterns of early growth in firms. These and other empirical observations show that:

- Some new firms grow very quickly to considerable size while for others it takes a long time.
- Firms may grow fast or they may grow slowly.
- Firms may grow steadily or they may grow episodically.
- Periods of growth may be of greatly different length.
- Firms may experience serious growth reversal after a period of fast growth.
- Some firms attain growth while making profits, and others do not.
- Firms may grow organically, or by acquisition.
- Firms may show different patterns of growth along different dimensions of size.
- Firms can grow by doing more of the same, or by adding something new to existing operations.

That firms may show different patterns of growth along different dimensions indicates that the growth process is composed of *multiple sub-processes* and that the interaction between them can differ.

That firms can experience periods of different growth rates, and periods of growth followed by stagnation or decline, indicates that the growth process is fundamentally a *recurrent* process, where patterns of events repeat themselves. This does not mean that the exact same sequence of events will repeat itself, but rather that the phenomenon of growth repeats itself. This conclusion is based on the assumption that there are some fundamental aspects of growth that are common to all periods of an increase in firm size; even the source of growth and the unfolding of the growth process may differ.

The sequence of events will not repeat themselves due to the *cumulative* nature of the process. The growth process is cumulative in two ways. First, it is cumulative in the sense that something is added to existing operations. The firms become larger. Second, it is cumulative in the sense that each event is dependent on previous events, even across sub-processes. This dependency can nevertheless differ greatly, e.g. between organic growth and growth by acquisition.

The above description provides three important guidelines for studying the growth process. First, one has to identify the important sub-processes. This involves developing a conceptualization of firms and firm processes that are related to increase in size. Second, one has to identify the basic process explaining recurrent accumulation. Third, one has to identify how this basic process of accumulation is initiated in the new firm and how it is maintained and revived. The latter issue relates to how the time dependencies of events and interaction between different sub-processes of growth will affect further growth.

Life-cycle conceptualizations, or models, of the growth process, which have been popular in previous research (e.g. Greiner 1972, Quinn and Cameron 1983, Churchill and Lewis 1983, Hofer and Charan 1984, Hanks 1990, Kazanjian and Drazin 1990, Garnsey 1998), have partly dealt with these issues. Most of these conceptualizations are concerned with identifying conditions which need to be fulfilled before firms reach a stage of growth. They also consider how the growth process creates problems that need to be solved by changes in organizational structure or management in order for firms to grow further.

Many of the early life-cycle models (see the review in Quinn and Cameron 1983) described growth as a single stage that firms deterministically go through during their life cycle. Recent models, such as Kazanjian and Drazin (1990), follow Miller (1987) when arguing that firms do not necessarily demonstrate a progress through a linear sequence of stages, but rather that certain configurations of problems, strategies, structures and processes represent an appropriate organizational response to imperatives facing the firms. Some of these imperatives are created through the growth process.

The ideas of imperatives and configuration are closely related to Chandler's (1962) idea of the need for matching the organizational structure with the growth strategy of the firm. Chandler (1962, p. 16) argued that "Unless new structures are developed to meet new administrative needs which result from an expansion of a firm's activities into new areas, functions, or product lines, the technological, financial, and personnel economies of growth and size cannot be realized."

Even though life-cycle studies address the initiation and the continuation of growth, they have important limitations. First, they do not pay much attention to the basic process of accumulation. They are more concerned with the organizational results of accumulation and how it should be effectively dealt with by management. Second, and related to the first, they do not address the recurrent nature of the growth process. Third, with the exception of Kazanjian (1988) and Kazanjian and Drazin (1989, 1990) little attention has been given to the specific situation facing young technology-based

firms. While Kazanjian and colleagues investigated technology-based firms, they paid little attention to the relationship between technical knowledge and growth.

Two early studies of the growth process were more concerned with the basic process of accumulation and the relationship between knowledge and growth. Chandler (1962, 1992) argued that knowledge accumulation of management was essential for developing the organizational capabilities needed for taking advantage of external opportunities made available by demographic and technological changes. In Penrose's (1959) theory of growth, much attention is given to the basic process of accumulation of resources and the related accumulation of knowledge.

The studies of Chandler and Penrose are therefore more appropriate as a starting point for the inquiry in this thesis than the literature on life-cycle models. Of these two studies Penrose's study is more appropriate for the purpose of this thesis for two main reasons. First, Penrose was more concerned than Chandler with how knowledge development within the firm is central for the identification of opportunities for further growth. While stressing knowledge development within the firm, Chandler was more concerned with knowledge development related to the administration of the firm, rather than knowledge development for identification of further opportunities[5]. Second, while both Penrose and Chandler were concerned with large industrial firms, Penrose paid more attention to the growth process, whereas Chandler was more concerned with the institutional history of management and the management of the large industrial firm as such.

Penrose's theory is to a large degree based on her empirical observation of large industrial firms (Penrose 1959, 1960). This focus may explain the lack of attention that her theory of growth has received within entrepreneurship research. In the next section Penrose's theory will be summarized and its usefulness for the current study critically evaluated.

3.3 Penrose's Theory of the Growth Process

Penrose's (1959) theory of the growth process is appropriate for this study for three reasons. First, Penrose was specifically concerned with the process of growth and what would limit growth. Second, her theory was explicitly concerned with issues that are central in our definition of the young technology-based firm. She was explicitly concerned with the identification and exploitation of opportunities and the role of

[5] Chandler (1962) was well aware of the importance of the entrepreneurial function of management. For example, he argues that one of the factors that initiated the changes from a centralized functional structure to a decentralized multidivisional structure was that top management expected to be better able to fulfill its entrepreneurial role in such an administrative structure, at the same time that the effective operation of the firm was ensured.

knowledge in that process. Nevertheless, she did not study technical knowledge specifically. Third, Penrose's theory is a theory of innovative enterprise and thus appropriate for analyzing firms and industries that are characterized by innovation (Lazonick 2002). Technology-based firms are an example of such firms.

Penrose's theory will provide a guide for identifying the internal sub-processes that constitute the growth process of firms. After a brief account of the basic concepts of the theory and its core arguments, the sub-processes will be identified. Then the further development and use of Penrose's theory will be discussed as well as the theory's limitations.

Penrose's theory is very much built upon her conceptualization of the firm. She viewed the firm as an *administrative structure* and a bundle of *productive resources*. The primary function of the firm is "to make use of productive resources for the purpose of supplying goods and services to the economy in accordance with plans developed and put into effect within the firm." (Penrose 1959, p. 15.) It is the role of the administrative structure to develop these plans and put them into effect at a profit.

The administrative structure has some form of central management direction. Central management is responsible for establishing and altering the administrative structure, is responsible for general policy, and has authority in matters where no policy exists. Apart from that, administrative decisions regarding the operations of the firm and adaptation to changes may be taken at different levels in the administrative hierarchy (Penrose 1959, pp. 15-17).

But a firm is more than its administrative structure. It is also a collection of productive resources (Penrose 1959, pp. 24-26). Productive resources are physical or human. Physical resources consist of tangible things, such as plants, equipment, raw materials etc. Human resources include both skilled and unskilled labor. The firm also uses financial resources, but mostly to acquire productive resources and enable their use at one point or another.

Resources can yield services that are used in the production process. The services that a resource can yield are a function of the way it is used and how it is combined with other resources. Resources, therefore, consist of a bundle of potential services (Penrose 1959, p. 25).

The services that can be provided by a bundle of resources are dependent on the characteristics of the resources as well as the *knowledge* of these characteristics and how they can be combined. This knowledge can be obtained through experience and be very specific to the firm, and even to the individual person, or it may be obtained through deliberate and voluntary search for knowledge about these characteristics.

Consequently, there is a close relationship between the knowledge possessed by the personnel of the firm and the services obtainable from its resources (Penrose 1959, p. 76).

The disposal of resources between different uses and time is determined by management decision. *Management* refers to individuals and groups that, independent of their position within the administrative structure, provide entrepreneurial or managerial services. *Entrepreneurial services* are related to "the introduction and acceptance on behalf of the firm of new ideas" (Penrose 1959, p. 31) while *managerial services* are services related to the execution of entrepreneurial ideas and supervision of existing operations.

Penrose describes the process of growth as recurrent periods of expansion of firms' resource base. This expansion is based on productive opportunities identified by the firm's entrepreneurs and the managerial capacity to implement them and integrate them with current operations.

Productive opportunities are all productive possibilities that the firm's entrepreneurs can see and take advantage of, and are willing to act upon (Penrose 1959, pp. 31-32). Entrepreneurs even have a role in obtaining the financial capital needed for the expansion[6].

The rate of expansion in any time period is limited by the available managerial services in the given period. There are two reasons for this managerial limit. First, expansion plans are limited by managerial capacity to deal with risk and uncertainty. Management will only execute plans whose risk and uncertainty the current supply of management services can overcome in a satisfactory way through preparation and refinement (Penrose 1959, p. 64). Second, due to the special nature of managerial resources, new management capacity can only be developed within the firm by using current managerial resources. Only by being a member of the management team can new managers learn what is needed for creating and executing expansion plans for a particular firm. As a result there is a trade-off between using the capacity of the current management team in planning for expansion during the given period and the amount of new management capacity that can be added in the next period (Penrose 1959, pp. 51-64).

After a period of expansion, an increase in resources and knowledge will provide incentives, as well as opportunities, for further expansion. First, the managerial limit recedes after the period of growth. Management resources that were used for planning and executing growth are released. While some of them may be used to manage the

[6] In a sense this can be seen as a part of the role of gaining acceptance for new ideas, but extending outside the firm.

current, larger, operation, new management resources are recruited during growth and old ones are redistributed through changes in the administrative structure. Second, during the period of growth, management will increase its knowledge about the resources belonging to the firm, and the possible services it can yield. Third, due to properties of resources and their use, e.g. their indivisibility, more resources will be acquired during growth than are strictly needed by the firm's operations. These unused resources provide both incentives for using them, and a direction for further expansion.

Penrose is aware that there may be external, as well as internal, inducement for growth. The point she tries to make is that irrespective of the external inducements for growth, there will always be internal inducements for growth (Penrose 1959, 65-66).

To simplify, one could say that Penrose describes the process of growth as three interacting processes. At the center is a process of *cumulative causation between productive opportunities and increase in resources*. Closely related are a process of *cumulative knowledge development* and a process of *changes in the administrative structure*. The process of cumulative knowledge development is of special importance. One could say that new knowledge makes it possible to identify new opportunities, while the stock of knowledge makes it possible to exploit them within the existing firm. Changes in administrative structure are related to the integration of new operations with existing operations, and are needed for the effective management of firm operations.

Central concepts of Penrose's theory have been used and developed further within three highly related research streams: the resource-based view of the firm (Wernefelt 1984, Barney 1991, Peteraf 1993), the knowledge-based view of the firm (Kogut and Zander 1992, 1996; Spender 1996, Grant 1996, Loasby 1998, Nonaka, Toyama and Nagata 2000) and the competence-based view of the firm (Prahalad and Hamel 1990, Teece, Pisano and Shuen 1997, Dosi and Marengo 1994, Foss and Knudsen 1996). While these research streams share much common ground, they differ in their background and the questions they are devised to answer[7].

What is common to all three fields is the assumption that firms are heterogeneous entities that evolve in a cumulative way. Hence, their competitive advantage is based on the results of this evolution in terms of their resource and knowledge endowments.

The resource-based view has mainly been concerned with two things. Firstly, much effort has been put into specifying the criteria for a resource in order for it to yield sustainable competitive advantage (rents) (Barney 1991, Peteraf 1993, Dierickx and

[7] In practice, the difference between the three perspectives may be difficult to discern, especially in studies that apply ideas from all perspectives to investigate competitive advantage.

Cool 1989). Secondly, a number of researchers have examined how rent-yielding resources can be exploited, and new resources created, by diversification (Wernefelt 1984, Montgomery and Wernefelt 1988).

The knowledge-based view has mainly been concerned with providing a knowledge-based rationale for the existence of the firm and its boundaries. The main argument is that firms exist because of their superior ability, as compared to markets, to efficiently coordinate knowledge exploitation and creation. Additionally, it is argued that differences in performance are related to differences in this ability. Much attention has been given to the characteristics of knowledge and mechanisms of its coordination and creation.

The competence-based view is more concerned with dynamic issues than the other two are. Researchers have stressed the importance of competences and capabilities that are dynamic, in the sense that they enable the firm to adjust to changing environments. The competence view is concerned with sustainable competitive advantage, similarly to the resource-based view, and stresses the knowledge-coordinating aspect of the organization that is central in the knowledge-based view.

While these new approaches have firmly established Penrose's view of the firm as an administrative unit and a bundle of resources, as well as adding insights into the link between resources, knowledge and competitive advantage, they have yet to provide new insights into the growth process. That it can be understood more deeply is nevertheless very likely. Loasby (1991) and Foss (2002) have argued that the essential Penrosian point is the importance of knowledge development and management for growth. In fact, Penrose was not at all concerned with sustainable competitive advantage, or rents, in terms of value appropriation, which is at the core of the resource-based view (Rugman and Verbeke 2002). Penrose nevertheless emphasized the importance of the resource base and adaptive capabilities for competitive advantage. In her own words: "In the long run the profitability, survival, and growth of a firm does not depend so much on the efficiency with which it is able to organize the production of even a widely diversified range of products as it does on the ability of the firm to establish one or more wide and relatively impregnable 'bases' from which it can adapt and extend its operations in an uncertain, changing, and competitive world. It is not the scale of production nor even, within limits, the size of the firm, that are the important considerations, but rather the nature of the basic position that it is able to establish for itself." (Penrose 1995, p. 137)

Penrose's (1959) theory has had more impact on theorizing about strategy and competitive advantage than on studies related to growth. In fact, the impact on studies of growth within the entrepreneurship literature may owe more to her impact on the

strategy literature. For example, when Wiklund (1998) reviews the resource-based perspective on small firm growth, he refers to Penrose's theory as a foundation for research that applies recent theorizing within strategy, e.g. the resource-based view of the firm.

Considering the emphasis on the identification and exploitation of opportunities in Penrose's theory, it is somewhat surprising that it has not drawn more attention within entrepreneurship research. Below we will examine the reasons why this may be so. We will investigate three issues: lack of attention to the growth process, dominance of life-cycle perspectives, and limitations of the theory.

As mentioned earlier, the majority of studies on firm growth have focused on explaining changes in size, rather than understanding the growth process. These studies are likely to be interested if certain endowments, such as resources, or certain properties of the environment can explain why some firms grow while others do not. In such an approach, process-related issues are likely to be treated as a certain endowment, i.e. organizational capability. For these types of studies, a process theory has limited value.

When process issues have been taken into account, the life-cycle perspective has been very popular (see Section 3.2). It is a perspective that focuses on the transformation of the organization, which is very visible in early growth. But there is a fundamental difference between Penrose's theory and life-cycle approaches. Life-cycle theories are basically deterministic theories, where firms follow a certain path according to a logic that is implicit in the firms (Van de Ven and Poole 1995). Penrose (1952) was strongly opposed to such a perspective and argued that the lack of concern for human motives implicit in these theories was not constructive for theorizing in economics. Due to these fundamental differences it is difficult to combine Penrose's general process of growth and some inherent logic of unfolding.

Penrose made some key assumptions in her theory that limit its application. Here, we will discuss four sets of possible limitations related to her assumptions: the fact that the theory is not a general theory of change, lack of attention to the employee contract and conflicting goals, assumptions about availability of resources and opportunities as well as the competence of management, and lack of attention to early growth.

Penrose's theory is not a general theory of change and therefore has limited value for understanding survival and decline. Hernes (1976) argues that one of the requirements for a theory of social change is that the same approach should be used for studying constancy and change. Freeman and Hannan (1975) also argue that processes of growth and decline are not symmetric, especially not the changes in administrative structure. Penrose (1959, pp. 7-8, pp. 31-33) is explicit that she is not attempting to

create a general theory of change. She is not concerned with explaining whether a particular firm can grow or not. She is only concerned with firms that grow and is assuming that the firm has the ability and the willingness to grow.

The assumption of the willingness to grow is related to Penrose's lack of attention to conflicting goals in the organization. Penrose assumes that there is an alignment between the goals of management and owners towards growth. She also seems to assume that management, *ex ante*, can devise methods to eliminate friction of growth, e.g. intra-firm conflicts of interest. While Penrose considered the administrative hierarchy to be a central part of the firm, labour and its relationship with the firm are more or less absent (Pitelis 2002). Conflicting goals, both between owners and managers and between managers and employees, have received a lot of attention since Penrose wrote her book, particularly through the effects of behavioral theory of the firm (Cyert and March 1963), transaction cost theory (Williamson 1979) and principal agent theory (Jensen and Meckling 1976). Recently there has been some effort to combine the latter two with the competence-based view of the firm (Hodgson 1998, Foss and Foss 2000). These attempts have aimed at an improved theory of the firm and are not explicitly concerned with growth of firms.

One of the main goals that Penrose had when designing the theory was to derive the ultimate limits to growth in firms. Her main argument was that, given that the external supply of resources and profitable opportunities is not absolutely fixed, the firm would always have possibilities to expand. In other words, opportunities will always exist and resources for pursuing them are always available at a price. In such a situation, the limits to expansion are dependent on the ability of the firm's entrepreneurs to identify opportunities and the firm's managerial capacity to implement them. Managerial capacity is based on the competence of managers and the amount of available managerial services. Having made assumptions about the competence of management, both regarding entrepreneurial and managerial services, she focused on the amount of managerial services. Through her assumptions and arguments about the nature of the growth process, she came to the conclusion that the ultimate limit to growth was the rate at which the firm could develop its managerial services.

One can question the appropriateness of the above-mentioned assumptions for understanding the growth process in young and small firms. At start-up, the new firm is very much dependent on the access to external resources for survival and growth (Pfeffer and Salencik 1978). New firms experience liability of newness, i.e. they must create and learn new roles both within the firm and in their connection with the environment (Stinchcombe 1965). This may lead small firms to experience difficulties

related to both access to resources and the lack of management competence. As Penrose (1959, pp. 39, 44) points out, these issues are nevertheless related. A part of the competence of management is the ingenuity to raise funds or to match opportunities and resources with prices. This ability, or lack of ability, is not specific to young firms. But on the other hand, as the ability to identify opportunities, access resources and plan for growth is dependent on the experience of firms' management with the particular situation of the firm, one would expect young firms to encounter other growth constraints than the managerial limit during the time it takes to build up such experience. Empirical research on growth constraints in small firms seems to confirm this (Barber et al. 1989). This lack of experience, or competence, can also be expressed by problems in controlling the rate of growth, which may lead to serious growth reversals (Garnsey 1998).

Based on the above discussion of Penrose's theory, one can make the following conclusions. Penrose's theory is a theory that describes the growth process as the interaction of three processes, where the process of cumulative causation between opportunities and increasing resources is in focus. As such, it is a theory of recurrent cycles of opportunity identification and exploitation. Such a conceptualization is a good foundation to build on within entrepreneurship for understanding the growth process in young firms.

While it provides the basic sub-processes of growth, there are limitations to her theory for young firms. In deriving the ultimate limits to firm growth, Penrose makes some key assumptions that may not hold for young firms. One of these is the unlimited access to resources in the market. Additionally, there are key processes, such as the development of goals and intentions, which are not included in the theory. This thesis will attend to some of these issues with a special focus on young technology-based firms. The next two sections will investigate the initiation and continuation of the growth process in further detail, leading to the research questions of the thesis.

3.4 Initiation of the Growth Process

The initiation of the growth process concerns the period and activities before the firm reaches reinforced growth as described by Penrose's theory. Before unused resources and increase in knowledge can fuel further growth, the firm must have acquired resources and started operations.

Garnsey (1998, 2002) argues that the new firm has to go through a sequence of steps before reaching reinforced growth. First, in a preparatory phase the founding team is formed and the focus of activities selected. Second, before the firm has developed viable operations and can generate own resources through exchange, it is highly

dependent on external resources. There is therefore a need to identify and mobilize external resources to ensure survival and development of resource-generating operations. Technology-based firms may, for example, be dependent on external resources for the development of a new product or service. Third, the firm has to develop operations that can generate resources and experience. This involves the mobilization of physical and human resources, learning, and synchronization with the external environment. In a manufacturing firm, this corresponds to being able to produce and sell a product.

While the three steps are analytically distinct, their distinction may not be so clear in reality (Bhidé 2000). The time spent in each step may differ between firms, and some firms may repeat the steps. Firms may switch their focus of activity after having started operations, and firms may need external financing even after having started operations. Firms may realign their focus of activities in order to mobilize external resources, to target a more profitable market, or just to survive. Technical consulting, for example, is a common method of obtaining early revenues in new technology-based firms (Roberts 1991).

Despite the possibility of different patterns, each step is important for attaining reinforced growth. Without selecting an activity to focus on, without being able to mobilize external resources before entering operations, and most definitely, without being able to create viable operations, the firm is unlikely to reach the process of reinforced growth. Instead of prescribing what sequence firms should follow, it is more important to understand what obstacles can hinder firms from reaching reinforced growth.

Garnsey (1998, 2002) provides a rich characterization of each of the three steps, which firms need to take before they attain reinforced growth. The richness of the characterization provides a picture of the multitude of paths that firms can follow, and the variety of actors that may be involved. It adds to Penrose's (1959) theory in two ways. First, by providing a framework for analyzing the initiation of reinforced growth, including the specific situation of the small firm regarding access to resources. Second, by exemplifying the inherent uncertainty and learning related to the exploitation of opportunities.

But Garnsey's account also stimulates further development. Two threads are of interest for this study. First, it is of interest how the characteristics of firms' opportunity at start-up influence the obstacles facing the firm in mobilizing resources and the creation of viable operations. Second, it is of interest to understand the relationship between resource mobilization and the growth orientation of firms. Below, each thread will be elaborated, leading to research questions.

While Garnsey (1998, 2002) acknowledges that firms may move through the three steps in different ways, she only discusses indirectly what influences such patterns. She is aware that the novelty of a firm's opportunity may differ and this difference will influence the prospects of the new firm, but she does not discuss how the nature of the opportunity at start-up influences further development.

Previous research on the relation between business opportunities and growth has been focused either on differences across industries (Audretcsh and Mata 1995), on differences across populations of firms (Carroll and Hannan 2000), or on the superior ability and willingness of individuals to search for and exploit profitable market opportunities (Shaver and Scott 1991). Not much attention has been given to the nature and quality of the opportunity identified by the founding team.

New technology-based firms are new ventures where the nature of the opportunity at start-up is likely to affect the obstacles facing the founders when pursuing its profitable exploitation. This is due to two reasons. First, the focus of activity in the new technology-based firm is on the exploitation of a business opportunity that is based upon the technical expertise of the founders (Oakey and Cooper 1991). The flexibility of this technical expertise may differ, but founders who base their opportunity on their knowledge of semiconductors are unlikely to switch to opportunities based on biotechnology. Second, the degree of novelty of the business opportunity is likely to differ greatly among firms. New technology-based firms may be involved in different stages of the diffusion of new technology – involved at once in the creation, maintenance, and renewal of markets and industries (Rickne 2000). Hence, due to their knowledge base the founders may be confined to a certain range of opportunities, and the nature and quality of these opportunities may have an important influence on what it takes to pursue them in a profitable way.

Investigating how the novelty of the opportunity influences the growth constraints faced by new technology-based firms is thus important for understanding how young technology-based firms attain reinforced growth. Hence, the first research question (RQ) becomes:

> *RQ 1: How does the novelty of business opportunities at start-up constrain young technology-based firms from attaining reinforced growth?*

Like Penrose (1959), Garnsey (1998, 2002) has a simple view of the growth orientation of firms. Either the firm is growth-oriented and is therefore of interest when studying growth, or the firm is not growth-oriented and will not grow. This dichotomy is common in entrepreneurship research and has led to a situation where growth orientation of firms is studied separately from other conditions for growth.

The separation of growth orientation from other conditions for growth is implicitly based on two assumptions. First, the growth orientation of firms is assumed to be determined by the growth intentions of a single individual, or by shared intentions of many individuals. Second, it is assumed that individual growth intention, or the growth orientation of firms, is stable and not influenced by conditions facing the firms.

This separation is unfortunate when studying new technology-based firms. Previous research has shown that most new technology-based firms are established by a team of founders (Cooper 1986, Utterback and Reitberger 1982). Hence, there are a number of individuals involved who may not share the same growth intentions. In addition, previous research has shown that new technology-based firms are likely to add new owners who may affect their growth orientation. The inherent uncertainty of technical development makes it difficult for new technology-based firms to obtain external financing through traditional bank financing before viable operations are in place (Garnsey 1995, Westhead and Storey 1997). New technology-based firms are therefore more likely than other firms to be dependent on external actors specializing in high-risk equity investments, such as venture capital firms or business angels (Murray and Lott 1995), or through actors, such as industrial corporations, that are interested in the new firm as a source of new technology (Lindholm 1994). These actors are likely to take an ownership position in the firm, and thus affect the direction of the firm.

The above reasoning leads to the conclusion that the growth orientation of new technology-based firms may be subjected to change through ownership changes. It opens up the possibility that firms having low growth orientation at start-up may nevertheless attain reinforced growth. The possibility of changes in growth orientation is related to the importance of ownership changes for access to resources.

Investigating the relationship between access to resources, ownership changes, and growth orientation is a first step for integrating the study of growth intentions with studies of other conditions constraining firms from attaining reinforced growth. In order to do so, four research questions are stated.

> *RQ 2: What is the role of ownership changes in new technology-based firms that have attained reinforced growth?*
>
> *RQ 3: Is the growth orientation of new technology-based firms subject to change?*
>
> *RQ 4: If the growth orientation of new technology-based firms is subject to change, how are these changes related to the addition of new owners?*
>
> *RQ 5: Is it possible that firms having low growth orientation at start-up may attain reinforced growth after adding new owners?*

The research questions 1-5, which were developed in this section, will be addressed in Papers II-IV. A summary of the results is found in Chapter 5. The contribution of the results to the thesis and their implications for management are discussed in Chapter 6. In the next section the research questions about the continuation of the growth process are developed.

3.5 Continuation of the Growth Process

After the firm reaches reinforced growth, internal pressures are exerted for further growth. According to Penrose (1959) unused resources and increase in knowledge would provide incentives and direction for further expansion.

A central theme in Penrose's (1959) theory is that the continuation of the growth process is based on the identification of new opportunities for growth. While these new opportunities could be based on changes in the external environment, she argued that even without any changes in the environment the firms' entrepreneurs would be more knowledgeable of new opportunities after a period of expansion than before it. This is due to an increase of human resources[8] and learning by existing ones during expansion.

Penrose (1959) argues that the increase in knowledge comes in two ways. First, knowledge increases due to learning by experience. This experience may be gained from the operations of the firm, or interaction with its customers. Much of this knowledge is specific to the situation of the particular firm and will remain unused if the firm does not expand (Penrose pp. 52-53). Second, knowledge increases due to search for new knowledge (p. 78).

Penrose is ambiguous about the incentives to search for new knowledge. At one point she argues that the "incentive to search for new knowledge are, as it were, 'built into' the very nature of firms possessing entrepreneurial resources of even average initiative." (Penrose 1959, p. 78). At another point she states that firms have incentives to conduct industrial research as "the logical response of the individual firm to the challenge inherent in the Schumpeterian 'process of creative destruction'." (Penrose 1959, p. 112). A resolution of this ambiguity is to assume that there may be incentives to seek new knowledge at different levels in the organization. At the firm level there are incentives to seek new knowledge for competitive reasons. At the individual level the incentives may be dependent on the individuals themselves or the administrative structure.

Despite stressing the importance of knowledge development for the identification of new opportunity for growth, Penrose did not discuss how this development is

[8] The human resources includes all employees, even management.

influenced by other aspects of the growth process, such as the direction of expansion and the administrative structure of the firm. This is consistent with her assumptions of management's ability to ensure smooth operations during growth and the related lack of attention to administrative conflicts.

Other studies of the growth process have focused on changes in direction and administrative structure during growth. Chandler (1962) found in his study that management had to make structural adjustments when facing inefficiencies that followed from pursuing certain growth strategies. Greiner (1972) also found that organizations were likely to experience crisis during growth when the existing administrative structure did not match the increased scope and scale of their activities.

While previous research has identified a number of management challenges related to growth, it has mostly focused on how new types of activities, or the need for effective operations of existing activities of increased volume, prompt managers to change the administrative structure. Little attention has been given to how managerial challenges during growth relate to the development of new knowledge, and thus, how these challenges influence firms' ability to identify further opportunities for growth.

In technology-based firms the identification of opportunity is dependent on technical knowledge. In these firms it is therefore of interest to investigate management challenges related to the development of technical knowledge.

Within entrepreneurship research, little attention has been given to interaction between technology and growth (Autio 2000). An important exception is research carried out by Meyer and Roberts (Meyer 1986, Roberts and Meyer 1991) and Dodgson and Rothwell (Dodgson 1989, 1990, 1991, 1993 Dodgson and Rothwell 1991). Meyer (1986) followed changes in product markets and technologies in young and growing technology-based firms. He argued that firms which had a focused product strategy based upon moderate changes of their technology base and targeted markets were more likely to attain high growth than firms which made no changes or large changes. Dodgson (1990) investigated technology strategy in small and growing technology-based firms. He argued that successful small and growing firms use explicit technology strategy for building up technical competence, both internally and through collaboration with other actors. The technology strategy provides a high degree of integration between different activities of the firm, even if this integration becomes problematic during growth.

The research of Meyer, Roberts, Rothwell and Dodgson points to the importance of the interaction between the development of new technology and other aspects of the growth process. Their findings show that the development of new technology is important for identifying and exploiting new opportunities for growth in young and

growing technology-based firms. They are, on the other hand, not concerned with how the growth process influences the development of technical knowledge. A study of such influences would increase the understanding of how the interaction between the growth process and the development of technical knowledge enables, or constrains, continuation of the growth process.

Three issues are of importance when investigating the effects of the growth process on the development of technical knowledge: the administrative structure of knowledge development activities, the incentives for knowledge-seeking, and the direction of knowledge-seeking.

The administrative structure of knowledge development activities involves the management and organization of these activities. Specialization within a field of knowledge is likely to have a positive influence on the development of knowledge within that field, and the methods of integration will influence the effectiveness of this knowledge development for the firm as a whole (Loasby 1998). Addition of new fields of technical knowledge (technological diversification) may also be needed in response to external technological development or the diversification of the product and service offerings (Granstrand and Sjölander 1990, Pavitt 1998). While technological diversification is likely to increase opportunities for growth it also increases R&D costs. The challenge of management is to balance the tensions between opportunities and costs in favour of profits and growth (Granstrand 1998).

The cost and effectiveness of knowledge development within each distinctive fields of technical knowledge, as well as the cost and effectiveness of coordination between fields, are likely to be dependent on the cognitive characteristics of the particular knowledge fields. Stankiewicz (2000, 2002) uses the concept of design space to describe the cognitive characteristics of technologies and how these characteristics affect technological development. On one hand technologies can be characterized by a poorly structured search space. Development of these technologies, which Stankiewicz terms discovery-driven, is characterized by long duration, high costs, and high uncertainty. On the other hand technologies can be characterized by a well-structured search space. Technology development cycles for these technologies, which Stankiewicz terms design-driven, are relatively short and costs and uncertainty are relatively low. These two ideal types define a continuum. Most technologies contain elements of both, but in different proportions. Different proportions are likely to affect the management challenge of balancing between opportunities and costs. The more discovery-driven a technological field is, it becomes more difficult and costly to develop and integrate with other fields.

The intensity of knowledge-seeking is determined by incentives for knowledge-seeking. These incentives are likely to be affected by the direction of expansion and the administrative structure of the firm. As the direction of expansion may differ and the administrative structure will change as firms grow, one would also expect that the incentives to seek new technical knowledge change as firms grow.

But the development of technical knowledge is not only dependent on whether employees (including management) will seek new knowledge or not. The direction of their knowledge-seeking is also important. Employees may seek new technical knowledge within the firms' existing knowledge fields, or within new ones. In the former case the technical knowledge base of the firm becomes more refined, while in the latter case it becomes broader.

It is likely that incentives to seek new technical knowledge, both at the firm level and at the individual level, are not only related to the intensity of the knowledge-seeking but also its direction. If there are incentives to respond to external changes in science and technology, knowledge-seeking may enter new domains of knowledge. If there are incentives to incrementally improve current operations, knowledge-seeking may be confound to existing knowledge domains.

Based on the above reasoning, five research questions are stated for investigating the effect of the growth process on the development of technical knowledge:

> *RQ 6: How does the growth process influence the development of distinct fields of technical knowledge in young technology-based firms?*
>
> *RQ 7: How is the influence of the growth process on the development of distinct fields of technical knowledge in young technology-based firms moderated by the characteristics of their technical knowledge base?*
>
> *RQ 8: How do incentives for technical knowledge-seeking change during growth in young technology-based firms?*
>
> *RQ 9: How does the direction of technical knowledge-seeking change during growth in young technology-based firms?*
>
> *RQ 10: What is the relationship between incentives for technical knowledge-seeking and the direction of such activities during growth in young technology-based firms?*

Research questions 6 and 7 will be addressed in Paper V, and research questions 8-10 will be addressed in Paper VI. A summary of the results is found in Chapter 5. The contribution of the results to the thesis and their implications for management are discussed in Chapter 6.

4 Methodology

"The tools we use have a profound (and devious!) influence on our thinking habits, and, therefore, on our thinking abilities."

Edsger W. Dijkstra

This chapter provides an overview of the methodology used in this thesis. First, the methodological point of departure will be discussed as well as its implications for research methods used in the thesis. Second, an overview of the research process resulting in this thesis will be provided. Third, the empirical studies are described, and finally, the methodological strengths and weaknesses of the thesis are discussed.

4.1 Methodological Point of Departure

The methodological point of departure will be presented along three lines. In the first two subsections the basic epistemological and ontological assumptions will be described, and in the third section the implications of these assumptions for research will be discussed.

4.1.1 Epistemology

The methodology in this thesis is based on three assumptions about the nature and limits of knowledge: that knowledge is fallible, that knowledge is created and validated by experience, and that knowledge is context-specific but partly transferable to different contexts.

The assumption that knowledge is fallible refers to the idea that what we know about the state of things is never final or certain. There will always be an inherent uncertainty in knowledge, especially about its validity in the future. New experience may lead to new knowledge refuting previous knowledge. That knowledge is fallible does not mean that knowledge is arbitrary, or constructed at will, but rather that there is no way of asserting the future validity of knowledge[9].

The fallible nature of knowledge is related to the role of experience for creating and validating knowledge. Knowledge is not a passive mirror of the world, or the result of deductive reasoning based on internally generated truths, but is related to our actions and experience in the world. Knowledge refers to beliefs about the correspondence

[9] This does not imply that justification is not used for asserting the validity of knowledge, only that there is no 'certain' method of justification. Tell (1997) provides a discussion of different methods of justification that may be used in different contexts.

between ideas and reality, in the sense that what "a man really believes is what he would be ready to act upon, and to risk much upon." (Charles S. Peirce as cited by Menand 2001, p. 226.) These beliefs are based on experience of reality and will be validated by experience of reality. In this sense experience is not confined to sensory observation, but refers to a cumulative "invasion of the inner world of ideas by independent reals which modify our ways of thinking in accordance with what is really there" (Smith 1992, p. 22).

Individuals confront reality with more than one purpose. The chosen purpose will affect the context of their knowledge creation and validation. Hence, the usefulness of the knowledge, in terms of correspondence between ideas and reality, may depend on the context in which it is created and used. Knowledge created and validated in one context may not be useful in another context. This does not imply that each individual will experience the world in a wholly unique way or that each instance of reality is unique. It only implies that certain perspectives on reality, i.e. ideas about reality that may be shared by many individuals, may be useful for one purpose and not for another. Some purposes can be very narrow, referring to only particular aspects of reality. Others can be broader, aiming at more general aspects.

Knowledge is not only context-specific due to differences in purpose. Knowledge is also context-specific because parts of experience are personal and may be difficult to communicate to others (Polanyi 1962). These difficulties of communication owe more to unconscious knowing based on previous experience, than to a purely subjective nature of personal knowledge. If this knowledge is made conscious, it is likely to be at least partially communicable to others.

4.1.2 Ontology

The methodology in this thesis is based upon three assumptions about reality: that reality exists independently of humans but is affected by human action, that reality is not fully accessible by humans, and that reality is based upon regularities in both time and space.

That reality exists independently of humans merely states that the existence of reality is not based on the existence of humans. It does not mean that humans can view reality from an objective point of "nowhere", but rather that reality is based on properties and events that cannot 'decide upon'. These properties and events provide the bases for our experience and influence the outcomes of our actions.

Even if humans, in principle, cannot alter the basic mechanisms of reality they can affect how reality is experienced. They can create artefacts and social structures that affect how reality is perceived and how it responds to human actions. In this respect,

reality, as a context for knowledge creation and validation, is changing. While these changes may be purposeful and directed towards the fulfillment of certain goals, the basic foundations of reality, being independent of humans, does not have any inherent process of universal progress (Veblen 1898).

Despite being 'out there' for humans to experience through their actions, reality is not accessible in its totality. A conception of reality that is in accordance with this view is the concept of 'transcendental realism' (Lawson 1997). The basic idea is that reality is stratified into three distinct domains:

1. The empirical, which is accessible through experience and impression.
2. The actual, which comprises actual events and states of affairs that are experienced through the empirical.
3. The real, which consists of the structures, powers, mechanisms and tendencies that govern the actual.

It is therefore assumed that what are experienced through the empirical are the results of the interplay between human action and some underlying regularities that govern how reality expresses itself, both in space and through time.

4.1.3 Implications for Research

The epistemological and ontological assumptions made above have implications for the nature and limitations of the research presented in this thesis. In particular, they have implications for the relationship between practice in firms and research on firms, the nature of the research task, and validation of results.

Practitioners and researchers tend to confront reality with different purposes. The practitioner, in our case someone working in a young and growing technology-based firm, is more likely to be interested in the particulars of his or her firm, while the researcher is more likely to be interested in firms in more general terms. These differences in purpose create differences in context and experience that affect sources of ideas and beliefs as well as the measures of their usefulness. If the ambition of the researcher is to provide guidelines for practitioners, as it is in this study, he or she has to take these differences into account when conducting the research and provide a bridge between the two.

In the research presented in this thesis, these differences in purpose have been accounted for by approaching a research problem that is relevant for practitioners using theoretical ideas that have more general applicability than for any particular firm. The theoretical ideas may provide practitioners with new ideas whose usefulness can be validated in the context of the particular firm, and researchers with tools for

further research on the general nature of the research problem. The research task then consists of generating theoretical ideas that can be useful for both practitioners and researchers.

Differences in purpose are not the only aspects of context specificity that need to be bridged. Knowledge within each context can be built on unconscious knowing based on previous experience. This can hinder communication and understanding. The role of the researchers is to increase the consciousness of knowing and thereby facilitate communication and understanding. This is very important both for learning from practitioners through empirical inquiry, and being able to make the results intelligible and useful to practitioners.

As the empirical part of reality is the only part that is accessible, all inferences about reality are based upon experience. The deeper strata of reality that explain experience are not accessible. Hence, there is a need to pass from observation of empirical facts to general principles that can account for the facts. This type of inference is what Peirce[10] calls abduction. This is the basic process by which theoretical ideas originate from empirical data. But such ideas will always be based on pragmatic belief, i.e. the betting on the usefulness of such belief for action and its future correspondence with experience, and need to be validated.

Peirce's concept of abduction refers to the logical analysis of the reasons for proposing an explanation of empirical observations. This logical analysis is based upon previous experience, which also includes theoretical ideas. The analysis consists both of constructing theoretical ideas and selecting among alternative ones. While there is no determined logic for such analysis of theoretical ideas, the resulting ideas have to fulfill three conditions: (1) they have to explain the empirical observation, (2) they have to be capable of verification through experience, (3) they have to be economical to verify. Peirce was very clear that abduction does not provide any verification of a theory, only a reasonable suggestion that needs to be verified by different types of inference.

While experience provided for Peirce the ultimate verification of knowledge, he suggested a methodological process for scientific verification. Whereas abduction provided theoretical ideas, involving concepts that may not be directly observed, deduction should be used to derive consequences that can be empirically observed or experienced. Finally, induction should be used to test the general prevalence of the consequences, confirming or refuting that the empirical consequences follow logically, either necessarily or probably, from the theoretical idea.

[10] In this section Fann (1970) is used as a reference to Peirce's theory of abduction and his classification of inference.

Peirce mentions three types of induction that differ in their utility and the security of the resulting conclusions. The first and weakest one he calls 'crude induction' and is exemplified by generalizing about future events based on past experience, e.g. because the sun has risen every day it will continue to do so. This type of inference has low scientific value because of its uncertainty and can be shattered by a single experience. The second and strongest one he calls 'quantitative induction'. It uses statistical inference to determine the probability that a member of a given experimental class will have certain characteristics that can be quantified. Peirce argues that the conclusions from this type of inference have the highest scientific value. The third type of inference Peirce calls 'qualitative induction'. He argues that this type of induction lies between the other two in terms of both scientific value and the security of its conclusions, but is of more general utility. This type of induction "consists of those inductions which are neither founded upon experience in one mass, as Crude Induction is, nor upon a collection of numerable instances of equal evidential values, but upon a stream of experience in which the evidential values of different parts of it have to be estimated according to our sense of the impressions they make upon us" (Charles H. Peirce as cited by Fann 1970, p. 33). Qualitative induction tests a theoretical idea by sampling the possible consequences that it can lead to, and estimating their relative value for verifying the theoretical idea. This type of induction is similar to the process of triangulation as described by Yin (1994, p. 94) where multiple sources of evidence provide converging lines of inquiry. It is a type of inference that is based on the critical judgment of the researcher and the research community, rather than on probabilities.

The selection among different types of induction for verifying theoretical ideas is based on the research task at hand and the available experiences. In some cases it may be difficult to obtain "a collection of numerable instances of equal evidential values" for quantitative induction, either because there is a limited number of instances for providing reliable statistical inference, or because the empirical phenomenon does not lend itself well to quantification. Pettigrew (1997) argues that processual analysis is an example of the latter. A process of deduction and qualitative induction seems to be more appropriate for verification of theoretical ideas in such studies. This does not exclude the use of quantitative data or the use of statistical inference, but it is useful only as a particular aspect of experience that is to be combined with other aspects of experience, whether based on qualitative data or practice, by the critical judgment of the researcher.

From the above one can conclude that both the abductive process of generating theoretical ideas, and the process of scientific validation, are based on critical reasoning by the researcher and the community of researchers. This particular

validation determines the usefulness of the particular theoretical ideas for research; their ultimate usefulness in practice is determined by their use in practice.

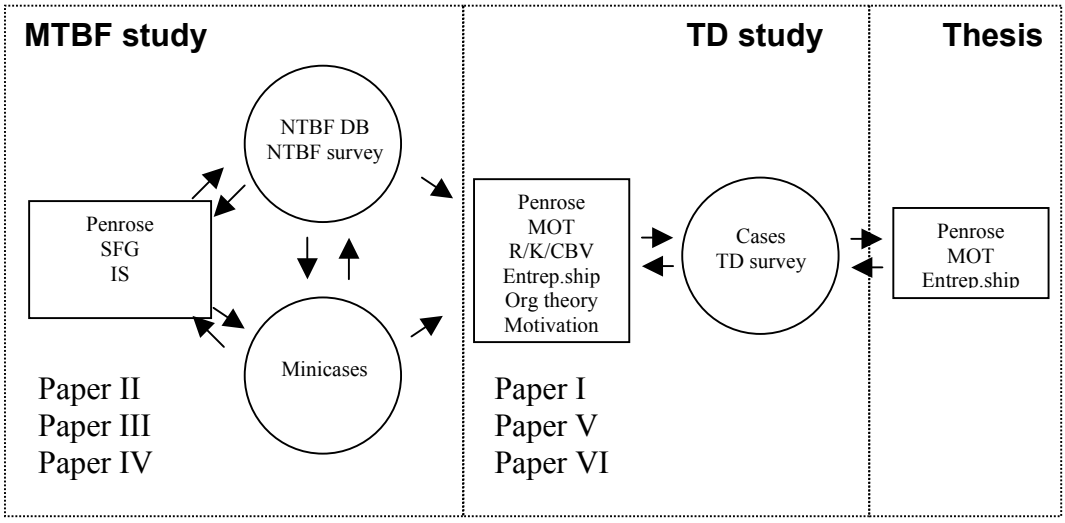
These measures of validity are a combination of three of four common measures of validity that Kvale (1997) identifies as being common in the social sciences: internal consistency, communication with researchers, and utility. The only measure of validity that is excluded is what Kvale calls correspondence with reality. By correspondence with reality Kvale refers to the positivistic tradition that the only meaningful knowledge is of phenomena that can be directly observed in the empirical world. Hence it refers to knowledge as a passive mirror of the empirical world available for observation by the senses, rather than including useful ideas about deeper strata of reality. According to the epistemological and ontological assumptions mentioned above, correspondence with reality is implicit in the criteria of usefulness, but there is no requirement that the ideas have a corresponding empirical counterpart. Even though the theoretical ideas do not have to be observable, they must be linked to the empirical world if needed by deduction.

To summarize the discussion in this section, it has been argued that the basic research task in this thesis is to generate theoretical ideas about the practical problem under study. The scientific validity of these ideas is determined by the empirically based critical reasoning behind the generation of those ideas, as well as by their deductive/inductive validation. The deductive/inductive validation is also based upon critical reasoning using multiple sources of empirical evidence. As knowledge is fallible, there is no single and final method of validation. This thesis is an input into a dialog between researchers, and hopefully, an input into practice as well. Only through continued dialog, increased consciousness and experience can the results be improved and made more valid and general. Or they can be totally dismissed.

In the next section an overview of the research process leading to this thesis will be provided, tracing the type of inferences drawn and the interaction between the generation of theoretical ideas and empirical experience.

4.2 Overview of the Research Process Leading to This Thesis

The research process leading to this thisis can roughly be divided into three phases: work on the Medium-sized Technology-Based Firms (MTBF) study, work on the Technological Development (TD) study, and the writing of the introductory part of the thesis (see Figure 1). Both the MTBF study and the TD study are empirical studies that are described in more detail in the next section.



SFG: Small Firm Growth, IS: Innovation Systems, MOT: Management of Technology, R/K/CBV: Resource-Based, Knowledge-Based, Competence-Based Views of the Firm.

Figure 1. Overview of the research process. Theoretical framework is included in the boxes, empirical material in the circles.

When I entered the PhD program in 1997, I became a part of an existing research program on new technology-based firms and industrial renewal in Sweden. My role was to work on a sub-project concerned with the question why some Swedish new technology-based firms grow into medium-sized firms while others do not. The theoretical framework used was based on Penrose's (1959) theory of growth, literature on small firm growth, and literature on innovation systems. Empirical data originated from the NTBF database (NTBF DB, see Section 4.3.2), a survey to the firms in the database (NTBF survey), and interviews in eight medium-sized firms and one small firm found in the database (Minicases). The MTBF study resulted in a Licentiate thesis (Saemundsson 1999) and Papers II-IV.

After finishing the licentiate thesis a new study was initiated (the TD study). This study was oriented towards understanding the effects of growth on the technology development and innovative capability of young technology-based firms. The ideas for this project came from the MTBF study and a perceived need for further research on technology development during growth. The theoretical framework was extended to include a resource-/knowledge/competence-based view of the firm, entrepreneurship, management of technology, organization theory, and theories of motivation. Penrose's theory was still in focus, but less emphasis was put on literature about innovation systems and small firm growth. Empirical data came from case studies of eight medium-sized firms that were found in the NTBF database and a short web-based survey (TD survey) of a sample of medium-sized firms found in the database. Six of the case firms were also included as minicases in the MTBF study.

The TD study resulted in Papers V and VI. While working on the proposal for the study, the first version of Paper I was written.

In the final period the resulting six papers from the two studies were combined into the thesis. At this point the core of the theoretical framework for the whole thesis was reduced to Penrose's theory of growth, literature on the management of technology, and literature on entrepreneurship.

During the entire research process the focus has been on the growth of young technology-based firms. In different periods there have been differences in the kind of research questions that have driven the process, and in how and what empirical data were used. Even if specific research questions have driven the process there has been flexibility towards understanding the nature of the technology-based firm and the growth process. This flexibility has created new empirical questions and triggered searches for new theoretical ideas. The focus has become more and more on the growth process and knowledge development during that process. The final results are a number of narrowly specified empirical papers and a common theoretical framework based on Penrose's theory of growth.

Each paper uses a separate type of inference. Some of the papers, such as Paper I, Paper IV and Paper VI, are mainly concerned with the generation of theoretical ideas. Other papers, such as Paper III and Paper V, use deductive reasoning followed by statistical inference to test a single idea. Paper II is of more descriptive nature. Despite the narrow, and separate, focus of each paper, the collection of papers as a whole represents a form of abductive reasoning leading to theoretical ideas about the growth process. These ideas provide the frame of reference of the study, but are more the results of the study than they are ideas which each paper seeks to validate.

4.3 The Empirical Studies

In this section the two empirical studies on which this thesis is based are described. First, it will be shown how the key theoretical concepts used in the thesis were linked to the empirical world. Second, the NTBF database, which was used in both of the studies, is described. Finally, the different data sources within each study are described separately.

4.3.1 The Link between Key Theoretical and Empirical Concepts

Empirical concepts need not correspond to theoretical concepts, as explained in Section 4.1. But obviously they have to be somehow related in order to provide a connection between the theoretical and the empirical. Below, the empirical connection for five key theoretical concepts used in this thesis will be described.

Growth: Growth is a multifaceted concept as discussed in section 3.1. Various measures have been devised for capturing different aspects of growth. Usually, changes in size, absolute or relative, are measured, irrespective of the qualitative changes in the firm. The most common measures of size are number of employees and sales (Delmar 1997, Weinzimmer et al. 1998). In life-cycle studies, growth is measured through identification of growth stages having particular characteristics related to qualitative changes in the firm, often closely related to changes in size (Kazanjian and Drazin 1989).

This thesis is concerned with investigating aspects of reinforced growth, i.e. when internal pressures are exerted for further growth. It is concerned with how young firms reach reinforced growth, and how such growth is continued. It is therefore not concerned with all changes in size in the young firm, but only with the cumulative changes that lead to reinforced growth, and with reinforced growth itself.

Attaining reinforced growth is, in principle, not related to specific firm size. It is nevertheless to be expected that firms which have attained substantial increases in size are more likely to feel internal pressures for further growth. They have obtained more resources and knowledge, which provide, according to Penrose's (1959) theory of growth, incentives for further growth.

To attain reinforced growth takes time. Studying firms from their founding until they reach reinforced growth would be a preferable method for investigating how firms reach reinforced growth. Such a method would make it possible to include both firms that attain reinforced growth and those who do not. It would also make it possible to account for differences in size when such a transition happens. Such longitudinal study in real time nevertheless has several practical difficulties. First, it may take a long time for firms to reach reinforced growth, and the time it takes cannot be determined at start-up. It is likely to take more time than is practically feasible during a PhD study. Second, it is not possible to know beforehand which firms will reach reinforced growth or not. Due to this fact it is necessary to include a large number of firms in the study. Both of these practical difficulties make a study using this method very time-consuming, expensive, and inappropriate for this thesis.

An alternative approach is to investigate firms that have already attained reinforced growth, examine their growth process in retrospect, and compare their characteristics with firms that have not attained reinforced growth. This approach was selected in this thesis. The practical problem then becomes how to identify the firms that have attained reinforced growth before studying them.

In knowledge-intensive firms, such as technology-based firms, the amount and diversity of knowledge available to the firm is closely related to the number of

employees in the firm. Hence, the number of employees is an indication of both the resources and knowledge available to the firm. Additionally, Hofer and Charan (1984) have emphasized a transition from being a small founder-managed firm into being a professionally managed and growth-focused firm. This transition is related to changes in organizational structure. The firm changes from being informal and focused on innovation, into a considerably more formalized and functional structure focused on operation (Hanks and Chandler 1994). These organizational changes are likely to be related to the number of employees.

The number of employees is therefore an appropriate measure for estimating when firms have attained reinforced growth. While it is impossible to determine the exact point of transition that fits all firms, it was decided to use the EU definition of medium-sized firms (50-249 employees) as a breakpoint (Commission of the European Communities 1996). This decision was based on two arguments. First, it was assumed that all firms having become medium-sized or larger have reached the stage of reinforced growth. Results from both case studies and quantitative studies confirmed this assumption. Second, the use of an EU definition makes comparison with other studies easier.

Van de Ven (1992) discerns three ways to study processes empirically. First, process logic can be used to explain the relationship between independent and dependent variables. In this case the process itself is not directly observed. Second, process is used as a category of concepts of individual and organizational action that is distinct from other concepts such as structure, environment, and performance. These concepts are subsequently operationalized into variables having numerical attributes that may change through time. Third, process is understood as a sequence of events or activities that describe how things change over time. These sequences and how they unfold over time are then empirically observed, either historically or in real time.

In this study the first and third ways of empirically studying processes are used for studying the growth process. In Paper III and Paper V deductive reasoning about the process of growth is used without observing the process itself to explain the relationship between independent and dependent variables. Paper VI describes how the process of growth, and particular sub-processes, unfold over time. Paper IV uses a mixed approach.

Technical knowledge: Knowledge is a concept that is difficult to address empirically. Knowledge cannot be measured as such, only as expressed by knowledgeable actions or reports of them. Moreover, knowledge is not a stable phenomenon, but is constantly evolving.

Technical knowledge refers to certain types of knowledge related to the artificial (see Chapter 2). While technical knowledge is a type of knowledge that all people hold, people hold it in different degrees. Some people are specially educated in developing and using technical knowledge. In this study technical knowledge refers to knowledge held by such employees or employees that may lack the formal education but are preoccupied with developing technical knowledge or the management of such activities. These two groups of employees are termed technical employees. This study does not consider technical knowledge held by other employees in the firm, such as parts of top management that do not have a specific education related to the development and use of technical knowledge, or are not preoccupied with the development of technical knowledge.

The special education in the development and use of technical knowledge is in this study confined to university education in engineering, natural sciences and medicine. All employees holding a university degree within these three fields are considered technical employees.

In this thesis technical knowledge has been investigated at the firm level. In the case studies, domains of technical knowledge available within the firm have been investigated, rather than the 'amount', or competitive position, within each domain. This includes both knowledge about solutions (solution knowledge) or knowledge about user problems (problem knowledge). The estimation of these knowledge domains in the case studies is mostly based on questioning the respondents about the technical knowledge base found within the firms. My conceptualization of technical knowledge has been explained to the respondents, including the distinction between problem knowledge and solution knowledge. This has been followed by questions about the knowledge base available to the firm, how this knowledge base has evolved through time, and how it is related to the firms' products and services.

Opportunity: An opportunity refers to a profitable productive possibility that is perceived by an entrepreneur (see Section 3.3). In this study individual opportunities are not observed directly, nor is their quality. Instead the characteristics of opportunities are judged by the characteristics of the technical knowledge base of the firm. The reason for this is that individual opportunities are likely to come and go, while the underlying knowledge base is more stable (even if it is evolving too). The close connection between the two is based upon the assumption that the opportunities which are available to the technology-based firm are based on the technical knowledge available to it.

Young technology-based firms: In the conceptualization of young technology-based firms provided in Chapter 2, the emphasis was on the technical knowledge held by the

employees and the young age of the firm. In correspondence with the empirical use of the concept of technical knowledge, young technology-based firms were identified as recently established firms that base their competitiveness on the knowledge and skills of their employees within engineering, natural sciences and medicine, and the subsequent transformation of this knowledge into products and services (Klofsten 1992, Rickne 1996, Rickne and Jacobsson 1999).

While the study is concerned with the growth process in firms while they are recently established and until they become medium-sized, it is important to have access to firms that have reached sufficient age for becoming medium-sized, even firms that have become medium-sized at different ages. At the same time it may not be suitable to use firms that have become too old, as retrospective information about their early years is less reliable due to the amount of time elapsed and because key actors may have left the firm. Hence, it is preferable to have access to a population of firms established relatively recently in time, but including firms that are of sufficient age to have become medium-sized. The use of the NTBF database established by the CREATE group at Chalmers University of Technology provides access to such a population. In the next subsection this database is described in more detail.

4.3.2 The NTBF Database

Both of the empirical studies in this thesis are based on a database of Swedish new technology-based firms[11], which was prepared by the CREATE group at the Department of Industrial Dynamics at Chalmers University of Technology (see Rickne 1996 and Rickne and Jacobsson 1999 for details).

The database includes all Swedish firms that fulfill certain criteria of size, year of foundation, independence at start-up, and industry classification:

- The firms should be founded between 1975 and 1993.
- In 1993 the firms should have at least three employees, of whom at least one should have a university degree in engineering, one of the natural sciences or medicine.
- The firms should not have been established as a foreign direct investment or as a diversification from a larger firm.
- The firms should belong to industries, both manufacturing and industry-related services, that can be termed knowledge-intensive[12].

[11] Rickne (1996) and Rickne and Jacobsson (1999) used the same operationalization for new technology-based firms as was used for young technology-based firms in section 4.3.1.
[12] These industries were ISIC 341, 35, 37, 38, 6112, 72002, 8323, 83249, 83292, 83299 and 932. Special rules were applied in ISIC 61120 and in ISIC 83292 and ISIC 83299 for selecting the relevant firms. See Rickne and Jacobsson (1999) for further details.

Around 1,350 firms were identified as fulfilling these criteria in 1993. The database included information about educational background of the employees, year of foundation, size, industry, location, etc.

The database was used in both of the empirical studies for selecting both case firms and samples used for surveying. In order to do this, the firms have been traced through time after 1993 and parts of the database have been updated and added to.

There are several difficulties in tracing firms through time, especially those that grow. Firms may change or lose their identity through changes in organization structure and incorporation, mergers and acquisitions. As a firm grows larger its structure of incorporation may change. A firm may create a number of subsidiaries, either wholly owned or owned jointly with other actors. Some of these subsidiaries may be acquired, while some are start-ups or operations at different locations that have become a separate firm. A firm may also merge with another firm taking on a totally new identity. Finally, a firm may be acquired and be integrated into the acquiring firm, or continue as a separate firm.

When tracing the firms in the database through time, care was taken that firms maintained their identity. Hence, a firm that merged with another firm of similar size and subsequently received a new identity was considered a new firm and was removed from the database. The same was done with firms that were acquired and integrated into other firms. Firms that added new subsidiaries, or changed their structure of incorporation, but kept their identity continued in the database. Firms that were acquired, but were still run as separate entities with their older identity, were also kept in the database.

4.3.3 The MTBF Study

The main purpose of the MTBF study was to investigate why some Swedish new technology-based firms have managed to grow into medium-sized firms (MTBFs) while others have not. For a more detailed description of the study and its results see Saemundsson (1999).

The empirical analysis in the study was based on both quantitative and qualitative data. A questionnaire sent to the whole population of surviving firms in the NTBF database was the source of the quantitative data, and mini-case studies of eight firms found in the database were the source of qualitative data. This design allowed statistical comparison between firms that had grown to medium size and others that had not, as well as some understanding of the growth process in individual firms.

The questionnaire was sent to the 1,194 firms that were still registered in January 1998. It contained questions on the background of the firm, turnover and employment,

internationalization, financing, cooperation, acquisitions and spin-offs. Among the 364 (35% response rate[13]) usable answers to the survey were answers from 44 medium-sized firms. In order to increase the response rate for the medium-sized firms, 17 additional firms were telephone-interviewed, using the original mail survey. In total, 61 medium-sized (or larger) firms were analyzed and compared with firms smaller than medium-sized.

Mini-case studies were performed for eight firms found in the NTBF database. Seven of those had become medium-sized, while one was still a small firm. The small firm case was selected in order to understand factors hindering growth.

Selecting an appropriate number of cases is a balance between effort and results. It was decided to start out with eight cases and see if there would be a need to add more cases later on for exploring certain aspects in more detail. After completing eight case studies it was judged that the information was sufficient in order to give the qualitative understanding needed for this study.

Individuals in eight firms, in all but one case including the Managing Director, were interviewed at the company premises on the background and the development of the firm in 1998-1999. In total 11 people were interviewed, each for 2-4 hours. The questions, which were open-ended, concerned organizational changes, products, markets, technology, financing and acquisitions. The interviews were complemented by secondary information, such as the firm's web pages, written material from the firm (financial statements and product descriptions) and articles from the business press.

Table 1 gives an overview of the firms interviewed.

Name	Business description
Helax AB	Information system for radiotherapy
IFS AB	Enterprise Resource Planning System (software)
Karobio AB	Development of pharmaceuticals
Markpoint AB	Industrial printers
Mecel AB	Development of automotive electronics
Mydata AB	Pick and place machines for printed circuit boards
Semcon AB	Technical consulting
Sintercast AB*	Production process for compact graphite iron

*Was not medium-sized.

Table 1. The mini-case study firms.

[13] The adjusted sample base after removing those that were wrongly included in the population (either terminated or wrongly classified) was 1047 firms. Of those firms, 420 (40%) responded to the survey and 364 responded with completed questionnaires.

4.3.4 The TD Study

The purpose of the TD study was to investigate how growth affects the development of technical knowledge and the motivation of technical employees.

The empirical analysis in the study was based on both qualitative and quantitative data. Eight firms from the NTBF database were selected for case studies. Of those firms, six were already included in the MTBF study. In addition to the case studies a sweb questionnaire was prepared in 2001. Firms in the NTBF database that had become medium-sized in year 2001 were asked to answer the questionnaire. The questionnaire contained questions on the development of the technical knowledge base during growth.

The selection of the eight firms for the case studies was based on previous contacts and knowledge of the firms, as well as expected contingencies related to different domains of technical knowledge. Two dimensions were used to classify these contingencies, based on expected differences in the sources of technology, the user requirements, and the means by which technological benefits are appropriated (Pavitt 1984) (see Table 2). First, they were classified according to the nature of the output (physical products, software, and service). Second, they were classified according to whether they were science-based or not.

Output	Not science-based	Science-based
Physical product	Markpoint AB* MyData AB*#	N/A
Software	Citat Solutions AB[1)] IFS AB*#	Helax AB*
Service	High Tech Engineering AB [2)] Semcon AB*#	Karobio AB*

*Were included in the MTBF study. #Have grown beyond medium-sized.
[1)] Develops software for market communication. [2)] Technical consulting related to mechanical design.

Table 2. Classification of case study firms.

In order to get a better understanding of the effects of growth, firms were selected in pairs within each category: one medium-sized firm and one that had grown beyond medium size. Including firms in two different size groups had the objective of creating two perspectives on the effects of reaching reinforced growth. Based on observations from the MTBF study, it was judged that the medium-sized firms were likely to be in the middle of dealing with effects of having reached reinforced growth. Firms that had grown beyond medium size were likely to have already (successfully)

dealt with these effects. Including both was expected to give insights from both real-time and retrospective experience.

Due to the characteristics of the population, it was impossible to fulfill the design of the study. While it worked for the non-science-based firms, no science-based firm in the population had yet grown beyond medium size, and no science-based firm was found that focused on the production of a physical product and fulfilled the size requirements. Despite these difficulties it was decided to continue the study with the selected design, studying the firms that were available. As more than one firm was found along each of the three dimensions (size, output, science-base), idiosyncrasy of single firms was avoided. The case studies included interviews with CEOs, technical directors, and other technical employees (engineers and scientists). In total 24 people were interviewed (some twice), each for 1-2 hours. The interviews were complemented by secondary information, such as information available from the firms' web pages, written material from the firms (financial statements and product descriptions) and articles from the business press.

In addition to the case studies a short web survey was administrated. Based on the population of Swedish NTBFs described above and data from the Affärsdata database, 94 medium-sized or larger firms were identified at the end of year 2001. Technical directors of these 94 firms were contacted by email and asked to answer a short web-based questionnaire. If the firm had no such position, e.g. in many consulting firms, the CEO was contacted. The questionnaire included questions on the technology base, the degree of science-related activities, as well as questions on changes in the technical knowledge base as the firm had grown.

Of the 94 firms asked, 72 responded and answered the survey. Of these, 70 answers were useful for analysis, resulting in a response rate of 74%. The high response rate can be attributed to two factors. First, the conciseness of the questionnaire, which could be answered in less than 10 minutes, and second, the use of email and the World Wide Web, which made it easier to reach directly to the technical directors and allowed them to respond instantly.

4.4 Strengths and Weaknesses

The methodology used in this thesis has both strengths and weaknesses. The main strengths of the thesis are good access to empirical data, the variety of the empirical data sources, as well as the multidisciplinary and theoretical nature of the thesis. The main weaknesses of the thesis are related to difficulties in properly investigating the growth process in the short time frame set by the PhD period. Below, these strengths and weaknesses will be described in more detail.

Good access to empirical data: Generally speaking there were few problems related to access to empirical data. Management of all case firms, except one, that were asked to take part in the study did so and provided generous access to respondents within the firms as well as secondary material. The firm that did not want to participate in the TD study had gone through management changes, and the CEO did not believe that he could contribute to the study. Regarding the survey studies, the response rate in the MTBF study was relatively low for Sweden, which might be explained by the size of the questionnaire. The response rate in the second, shorter, survey was very high, reducing the risks of non-respondent bias.

Variety of data sources: Another strength of the study is the multiplicity of data sources that were used. By using both qualitative and quantitative data it was possible to combine understanding of the process with understanding of the characteristics of the population. Such an approach makes deductive reasoning prior to statistical inference more reliable, and increases the quality of abductive inference.

Multidisciplinary approach: Another strength of the thesis is its multidisciplinary approach. By combining insights from different research fields, such as entrepreneurship, management of technology and growth, it is possible to investigate aspects that are usually not attended to within each separate research field.

Theoretical approach: Finally, the theoretical approach to the growth process taken in this thesis is one of its strengths. Research on small firm growth has been fragmented because of a lack of attention to the conceptualization of the growth process (Davidsson and Wiklund 2000). The research in this thesis contributes to such a conceptualization, even if much more needs to be done.

Censoring: As in many studies of firm growth, the empirical investigations in this thesis do not take censoring into account. There are two types of censoring that are important for this thesis (Carroll and Hannan 2000, pp. 101-109). The first type is the omission of non-surviving firms in the analysis. By not including non-surviving firms, the studies miss the information about firms that grow and fail. The second type of censoring is the uncertainty about the future of the firms in the sample. Firms that may have grown at a certain point may fail very quickly. The effects of censoring are especially critical when using inductive inference to generalize from a small sample of firms to the population as a whole. It also has an effect on abductive inference, as the proposed explanation may only be valid for surviving firms and may not be able to account for firms that fail later. The effects of censoring can be taken into account in longitudinal studies of populations. Due to the time limits of the studies presented in this thesis, such a longitudinal study was not possible. Reinforced growth takes

time to materialize in firms. Most of the firms in this study that have become medium-sized are more than ten years of age.

Retrospective information: Another weakness related to the short time frame of the study is the necessity to use retrospective information about events in the past. Reconstruction of history, failed memory and the establishing of myths can bias retrospective information. The effect of retrospective information was somewhat offset in the TD study by the use of multiple respondents in the case studies. The use of multiple respondents reduces the risks of single informant bias and failed memory, but may not reduce the risk of myths. Additionally, it may be difficult to estimate changes in certain variables through time using retrospective information, such as intentions or motivation. Despite these weaknesses, retrospective information also has some strengths, which may be useful for abductive inference. Interviewing practitioners about events that happened in the past increases the probability that they have reflected on how these events relate to other events. Such linking may provide a clearer picture of the interactive nature of the growth process and generate useful ideas for further investigation.

Quantitative measurements: The quantitative measurements used in the study have two main weaknesses, which are difficult, or costly, to eliminate in a quantitative study. First, there is a risk of common method bias as single informants were used and the same survey measured independent and dependent variables. While the risk of common method bias inherent in the quantitative data is not reduced, the case studies reduce the risk that such bias contaminates the inferences drawn from the quantitative data. Second, the measurement tool used in the study has not been validated, i.e. the validity and reliability of the measurement tool have not been investigated. It is obviously important to know what the measurement tool is measuring and if there are any systematic biases in the measure. But as explained in section 4.1 it is not necessary that there is a direct correspondence between theoretical concepts and empirical concepts; hence, the question of validity is not a question about the truth of the measure, but rather a question of whether we know what it is measuring and how it relates to the theoretical concepts used in the study. It follows that traditional methods (see e.g. Neuman 1997) for matching the conceptual domain and measure domain are not as relevant. As with common method bias, the risk of biases in final conclusions due to non-validated measurement tools is reduced by the use of qualitative data in conjunction with quantitative data.

Lack of depth in case studies: To study a process is usually very complex as one is studying the interaction of many concepts through time (Hinings 1997). Case studies are always a balance between time and effort on one hand and the general application

of the findings on the other. In the TD study it was decided to prioritize the possible contingencies due to the different nature of technical knowledge, rather than addressing the full complexity of the growth process. This led to reduced depth of the case studies, which can be seen as a weakness when studying the growth process. But considering the purpose of generating ideas that have more general applicability than for the particular firm, this lack of depth is a necessary trade-off which may be remedied in later studies.

Many of the weaknesses of the thesis are balanced by its strengths and its particular purpose. There are nevertheless opportunities for methodological improvements that can increase the validity of the results of this thesis, but these improvements are likely to be costly. To use longitudinal studies is tempting but their cost/benefit balance is uncertain. Such studies are expensive, take a long time when studying growth, and are inflexible to changes in design if their strengths are to be fully utilized. Longitudinal studies therefore need strong theoretical foundations to reduce the risk of failure. Before embarking upon such a study it may be cost-effective to use abductive reasoning based on other methods to provide stronger foundations for such a study than is possible today. This study is hopefully a contribution to such reasoning.

5 Summaries of Appended Papers

"Málið er að ég vil ekki búa til skáldsögu,
ég vil að veruleikinn sé skáldlegur."

Pétur Gunnarsson

5.1 Paper I

Title: Economic Development, Technological Innovation and Entrepreneurship

Authors: Rögnvaldur J. Saemundsson and Bruce A. Kirchhoff

Status: Manuscript. Earlier version found in Kuopusjärvi, P. *RENT XV Research in Entrepreneurship and Small Business*, Turku, Turku School of Economics and Business Administration, 2002.

The paper is a contribution to the prevailing discussion within entrepreneurship research about the concept of entrepreneurship. Recently, there seems to be a convergence towards seeing the process of the identification and exploitation of opportunities as a focusing device for delineating entrepreneurship research as a distinctive field of inquiry. At the same time little distinction is made between entrepreneurship in small and large firm. This convergence on opportunity is a welcome one as the plurality of definitions within entrepreneurship research has hindered a cumulative development of the field. Nevertheless, the authors feel that researchers tend to use too narrow a conceptualization of opportunity identification, focusing only on opportunity recognition. This limited conceptualization is based on Kirzner's (1973, 1997) concept of entrepreneurial discovery, which only tells a part of the story that entrepreneurship should be concerned about.

The purpose of the paper is to argue that opportunity creation should be included in the concept of entrepreneurship and special attention should be given to new and small independent firms.

The argument is based on the previous economic literature on entrepreneurship and the literature on technological innovation. It is argued that this literature has included opportunity creation as an important aspect of entrepreneurship and innovation, which is distinct from opportunity recognition. Both opportunity recognition and opportunity creation are important in the innovation process, but opportunity creation is one of the major mechanisms behind the process of creative destruction. By omitting opportunity creation from the concept of the entrepreneurial process, entrepreneurship research limits its attention to incremental changes. Consequently, wealth

redistribution effects of radical changes are only partially addressed by entrepreneurship research.

The authors argue that opportunity creation should be included in the concept of the entrepreneurship in order to better capture the nature of entrepreneurship within the process of innovation. Additionally, the authors stress the importance of the role of entrepreneurship research for understanding redistribution of wealth through the growth of new and small, independent firms.

The paper contributes to the thesis by providing an overview of the context of entrepreneurship and technological innovation used for the specification of the research problem. It also provides the arguments for extending the concept of entrepreneurship to include opportunity creation as well as opportunity discovery. While the importance of this extension may be limited for certain types of firms, it is especially important when studying technology-based firms.

5.2 Paper II

Title: Breaking the Entrepreneurial Growth Barrier: The Role of Venture Capital and Acquisitions for the Emergence of Medium-Sized Technology-Intensive Firms[14].

Authors: Rögnvaldur J. Saemundsson and Åsa Lindholm Dahlstrand

Status: Published in Reynolds, P., Bygrave, W. D., Maingart, S., Mason, C.M., Meyer, G.D., Sapienza, H.J., and Shaver, K.G. , (eds.) (1999), *Frontiers of Entrepreneurship Research*, Babson Park, MA, Babson College, pp. 637-651.

The purpose of this paper is to investigate the importance of different sources of financing in Swedish new technology-intensive firms that have grown into medium-sized firms. Special focus is on the importance of venture capital and acquisitions and the relationship between the two.

The paper is based on a descriptive analysis of empirical data from the MTBF study. Only the medium-sized firms were used in the analysis.

Self-financing and loans were the most common way of financing in the studied firms. Roughly one fourth of the firms had received venture capital financing, and one third had obtained financing from the government. Very few had received financing from private investors and business angels.

[14] In this paper the concept of the 'technology-intensive firm' was used to emphasize that the firms under study were characterized by the technical knowledge of their employees rather than the newness of their technology or the amount of R&D. The concept of the 'technology-intensive firm' in the paper therefore has the same connotation as the concept of the 'technology-based firm' in this thesis.

Venture capital financing was perceived as highly important for the development of those firms which had received it, especially in the early phase. Acquisitions were also found to be an important source of financing. One third of the firms had been acquired, and 44% of these mentioned the lack of capital as an important reason for selling the firm. There was no clear connection found between having obtained venture capital financing and later being acquired.

Selling minority shares was common for the firms in the sample. Around half of the firms had sold minority shares. While not directly observable from the data, it is likely that these ownership changes were related to access to finance.

The study points to differences between manufacturing and service firms. Manufacturing firms were dependent on a larger number of sources for their financing. They were also more dependent on loans and financing from customers. Finally, acquisitions were found to be more frequent for manufacturing firms than for service firms, while the selling of minority shares was more frequent for service firms than for manufacturing firms.

The paper contributes to the answer of research question 2. It shows that over half of the firms attaining reinforced growth have added new owners. It also shows that venture capital and acquisitions are important sources of financing for young technology-based firms in Sweden. While they are not the most common sources of financing, they are important for the firms who receive it.

5.3 Paper III

Title: How Business Opportunities Constrain Young Technology-Based Firms From Growing Into Medium-Sized.

Authors: Rögnvaldur J. Saemundsson and Åsa Lindholm Dahlstrand

Status: Revised and resubmitted to *Small Business Economics*.

The purpose of the paper is to investigate how the characteristics of business opportunities at start-up constrain young technology-based firms from attaining substantial growth[15].

A framework for analyzing these constraints is developed in the paper. The focus is on the novelty of the founders' knowledge base as a characteristic of the business opportunity. This novelty has been classified into four different categories along two dimensions of the founders' knowledge base: novelty of technical knowledge and novelty of market knowledge. Consequently, this leads to four ideal types of business opportunities that founders of new technology-based firms seek to exploit at start-up.

[15] In this thesis the concept of reinforced growth is used instead of the concept of substantial growth.

Through conceptual analysis based on Penrose's (1959) and on previous empirical research, two sets of hypotheses are formulated. The empirical testing of these hypotheses is based on the estimation of a logit regression model using survey data from the MTBF study.

The results show that firms that seek to exploit opportunities based on new market knowledge are less likely to attain substantial growth than firms that seek to exploit opportunities based on existing market knowledge. The former class of firms can nevertheless increase the probability of such growth by actively seeking external financing. The novelty of technical knowledge was not found to affect the probability of attaining substantial growth.

The paper contributes to the thesis by answering research question 2. It shows that the novelty of opportunity affects the obstacles that the firm has to overcome in order to grow. It also points to the difficulty of pursuing opportunities based on new market knowledge.

5.4 Paper IV

Title: On the Interaction Between Growth Intentions, Access to Resources and Growth in New Technology-Based Firms

Authors: Rögnvaldur J. Saemundsson

Status: Accepted for publication in *The International Journal of Entrepreneurship and Innovation*.

The purpose of the paper is to demonstrate that the common separation between growth intentions and other conditions of growth is unfortunate, at least when studying the relationship between access to resources and growth in new technology-based firms.

It is argued that new technology-based firms may have to add new owners in order to get access to resources, independently of the growth intentions of their founders. New owners may provide necessary resources for survival, but their growth intentions may differ from those of the founders. To capture the possibility of different growth intentions within the founding team, and differences between internal and external actors, it is helpful to use the concept of dominant coalition. Instead of individual intentions, the dominant coalition determines the growth orientation of the firm.

To investigate the relationship between access to resources, ownership changes, growth orientation and growth, the paper seeks to answer three questions:

1) Is the growth orientation of new technology-based firms subject to change?

2) If the growth orientation of new technology-based firms is subject to change, how are these changes related to the addition of new owners?

3) Is it possible that firms having low growth orientation at start-up may attain actual growth after adding new owners?

A framework for analyzing these questions is developed in the paper. At the heart of the framework is the use of the dominant coalition model (Cyert and March 1963). The analysis is based on the combination of mini-cases and survey data from the MTBF study.

The empirical analysis confirms that the growth orientation of new technology-based firms can be subject to change. The analysis also confirms that new owners may have an important role in bringing about this change through their own goals and intentions. New owners were found to influence growth orientation in both positive and negative ways. It was found that new owners with high growth orientation can make it possible for firms with low growth orientation at start-up to attain reinforced growth.

The paper contributes to the thesis by answering research questions 3-5. The paper also provides a rationale to take changes in growth orientation into account when investigating growth in young technology-based firms, especially when studying the role of external actors, such as equity investors.

5.5 Paper V

Title: On the Interaction Between the Growth Process and the Development of Technical Knowledge in Young and Growing Technology-Based Firms

Authors: Rögnvaldur J. Saemundsson

Status: Submitted to an international journal for review.

The purpose of this paper was to investigate the interaction between growth and the development of technical knowledge in young technology-based firms. More specifically the paper investigated the tensions in young and growing technology-based firms between (1) increasing technological opportunities for further growth by increasing the number of separate fields of technical knowledge developed within the firm, and (2) the cost of developing and integrating knowledge from multiple fields.

A framework for analyzing these tensions is developed in the paper. By conceptually investigating the interaction between the development of technical knowledge and the growth process and how it is affected by the cognitive characteristics of technical knowledge two hypotheses are proposed. The empirical testing of the hypotheses is based on statistical analysis of survey data from the TD study.

The results show that the number of separate fields of technical knowledge is likely to increase during growth. Moreover, the increase is likely to be negatively moderated by the degree of the firm's dependence on discovery-driven technologies.

The paper contributes to the answering of research questions 6 and 7. The results imply that tensions between technological opportunities and the costs of technological development in young technology-based firms are created not only through the progress of science and technology but also through the growth process itself.

5.6 Paper VI

Title: Technical Knowledge Seeking in Young and Growing Technology-Based Firms: Incentives and Direction

Authors: Rögnvaldur J. Saemundsson

Status: Submitted to an international journal for review.

The purpose of the paper is to investigate technical knowledge-seeking activities in young and growing technology-based firms. More specifically the purpose is to answer the following questions:

1) How do incentives for technical knowledge-seeking change during growth?
2) How does the direction of technical knowledge-seeking change during growth?
3) What is the relationship between incentives for technical knowledge-seeking and the direction of such activities during growth?

A framework for analyzing these changes is developed in the paper. The framework adapts Stankiewicz's (2000, 2002) notion of design space to the firm level in order to analyze the direction of knowledge-seeking activities in firms. The firm's design space delineates a search space where technical knowledge-seeking within the search space is related to refining the existing technical knowledge base (both problem and solution knowledge). Knowledge-seeking outside the firm's design space may extend the knowledge base of the firm and, hence, the available search space for refining.

Incentives for knowledge-seeking are assumed to exist both at the firm level and on the individual level. At the firm level, the firm is assumed to have incentives either to proactively prepare for future competition and growth, or to react to current competitive pressures. At the individual level, individuals are assumed to have incentives to seek for new knowledge due to commitment to the firm, commitment to an external group of peers, or self-interest.

The empirical analysis is based on a single case study, which was carried out as a part of both the MTBF study and the TD study.

The study found that incentives for technical knowledge-seeking became more diverse during growth. New employees had incentives to seek new technical knowledge that fitted their own interest besides working for the firm, as compared to the original group of employees who were committed to the firm or the research community. The direction of knowledge-seeking was also found to change during growth. From an emphasis to extending the firm's design space, the pressures of growth led to an emphasis on refining the design space. Incentives of new employees had an important role in renewing the technical knowledge base of the firm by further extending the firm's design space. This extension of the design space was important for further sales and growth.

The study contributes to the thesis by answering research questions 8-10. While the results are preliminary, they point to the importance of multiple incentives for balancing the short- and long-term development of the firm.

6 Contributions, Implications, and Further Research

"Tidningarna missförstår det svåra – och ger det tio rader. Det enkla får fyra sidor."

Berglin

In this chapter the contributions of the thesis will be discussed as well as their implications for management and further research.

6.1 Contributions

The contributions of the thesis will be discussed along three lines: analytical, empirical and methodological.

Analytical contributions

The main contributions of this thesis are related to the conceptualization of the growth process in young firms. The conceptualization of the growth process has received relatively little attention within entrepreneurship research. This has led to fragmented studies that may be difficult to compare with each other (Delmar 1997, Davidsson and Wiklund 2000). In this study Penrose's (1959) theory of growth, which to date is the boldest attempt to create a theory of the growth process, is aligned with current entrepreneurship research. The thesis puts into focus the process of opportunity identification and exploitation, which is central both in Penrose's theory and in current entrepreneurship research.

The thesis also points to the importance of not only considering opportunity detection when investigating the opportunity identification process. It is argued in Paper I that opportunity detection is but one way of identifying opportunities, and opportunity creation is also important, at least regarding opportunities for technological innovation. In Paper III this was developed further, not explicitly using the language of opportunity detection and opportunity creation, by linking different types of opportunities to differences in the novelty of the knowledge they are based upon.

Penrose (1959) describes the process of growth as three interacting processes. First, there is a process of cumulative causation between productive opportunities and increase in resources. Second, there is a process of cumulative knowledge development. Third, there is a process of changes in the administrative structure. This thesis provides an attempt to add the process of changes in goals and intentions as a fourth process. Using the idea of the dominant coalition (Cyert and March 1963) and simple motivation theory (Decci 1975), the thesis addresses two issues. First, it takes

into account that there may exist conflicting growth intentions or incentives for knowledge-seeking in young technology-based firms. Second, it addresses the possible change in the growth orientation of the firm and incentives for knowledge-seeking. These specific issues are examples of a larger class of issues related to multiple goals and incentives and their interaction with other aspects of the growth process.

Finally, the thesis contributes to the study of the interaction between the development of technical knowledge and other processes of growth. These issues, which are of special interest when studying growth in technology-based firms, were not directly addressed by Penrose (1959) and have been neglected in previous research on growth in young and small technology-based firms (Autio 2000). Papers V and VI provide conceptualizations for analyzing this interaction, most notably the concepts of problem and solution knowledge as well as the adaptation of the concept of design spaces to the firm level. Using these concepts, changes in technical knowledge domains and technical knowledge-seeking in growing young technology-based firms are investigated.

Empirical contributions

This thesis has a slightly different empirical focus when studying growth than is common in studies of growth in start-ups, or small firms, within entrepreneurship. Instead of seeking to explain differences in growth rates between two points in time (like e.g. Wiklund 1998, Almus and Nerlinger 1999), this thesis is concerned with the growth process by which recently established firms attain substantial size and how such growth is continued. To empirically analyze growth in this way is a contribution to empirical research on growth.

The thesis also provides some empirical observations that support the applicability of Penrose's (1959) theory and the proposed extensions when studying the growth process in young technology-based firms. They also point to the need for further research.

The empirical observations add to our understanding of growth constraints in young technology-based firms. Most importantly, they point to the importance of investigating how the different sub-processes of growth interact with each other. The nature of the opportunity at start-up was found to influence the difficulty of attaining reinforced growth (Paper III). This difficulty affected the need to obtain external financing. Separately, it was found in Paper IV that the need for external financing could moderate, or jointly determine, the growth orientation of the firm. Firms with high need for external financing were likely to add new owners which not only can

provide the resources that are needed, but may also increase the growth orientation of the firm.

The empirical observations also add to our understanding of how the development of technical knowledge interacts with other aspects of growth (Papers V and VI). They suggest that the growth process constrains the development of technical knowledge, i.e. that there is an inherent conflict between the growth process and the development of new technical knowledge, which can disturb the positive feedback needed for continuous growth.

Multiple intentions and incentives have been found to be one mechanism for keeping this feedback open. In Paper IV it was ascertained that founders who had low growth intentions might accept the high-growth orientation of the firm in return for opportunities to focus on the development of technical knowledge. In Paper VI it was found that new employees who did not share the same incentives for seeking technical knowledge as the core team played an important role in renewing the firm's technical knowledge base.

Methodological contributions

This study contributes to the study of growth by its use of multiple methods. By mixing both qualitative and quantitative methods, the empirical studies give different views of the growth process along time and across a population of firms. Hopefully, this study demonstrates how these different methods can be seen as tools for investigating complex phenomena. Each method has its own strengths and weaknesses, which in many cases are complementary. Combining them provides a richer experience of the growth process.

The use of multiple methods is an important tool for the abductive reasoning used in this thesis. The abductive reasoning, where theoretical ideas are created through empirical reasoning, is likely to be a cost-effective way of investigating complex phenomena like the growth process. This type of abductive reasoning is an important input into larger studies of longitudinal nature, either qualitative or quantitative, which take much time, are expensive to administrate, and are less flexible than retrospective studies.

Longitudinal studies would benefit from simpler and less expensive ways of collecting data. The use of a short web survey was found to be a very cheap, quick and effective way of obtaining data with a high response rate. Such an approach can be helpful in many respects. First, it can be suitable for obtaining information from multiple respondents within firms, which might be difficult to administrate otherwise. Second, it can be an effective way of administrating longitudinal information

collection. Both are important when studying the interaction between different sub-processes of growth.

6.2 Implications for Management

The implications for management, of the ideas put forward in this thesis, are best judged by managers themselves. There are nevertheless two issues that warrant special attention. These issues are related to differences in the characteristics of opportunities at start-up, and the role of multiple intentions and incentives.

A common image of the new technology-based firm is the image of a firm introducing a new technology to a market that has not existed before. This image is strengthened by stories of a handful of extremely successful firms, such as Apple, Microsoft and Sun, and by management literature concerned with strategic advice for success. The popular books by Moore (1991,1999) on high-tech marketing provide advice for firms introducing discontinuous innovation to the market, i.e. firms seeking to exploit opportunities based on new market knowledge and new technical knowledge. As shown in Paper III, these firms are only a small part of new technology-based firms in general, and only a small part of the firms that grow to become medium-sized or larger in particular.

The results from Paper III also indicate that the business models of firms which base their opportunity on new market knowledge may differ from the business models of those firms that base their opportunity on existing market knowledge. It was argued that it takes longer time and more learning for firms that base their opportunities on new knowledge to adjust, or find, a business opportunity that is profitable, and hence they become more growth-constrained than firms that base their opportunities on existing knowledge. Hence, firms that base their opportunity on new knowledge need more flexibility in their business models to account for learning, e.g. from lead users (von Hippel 1988) or early adopters (Moore 1991), while it may be more important for firms that base their opportunity on existing knowledge to focus on taking advantage of their existing knowledge of the market.

The results from the thesis also point to important tensions inherent in the growth process that may influence whether firms attain or continue a process of reinforced growth. These tensions relate to the existence of multiple intentions and incentives among the members of the firms – both external members such as owners, and internal members such as employees.

While these tensions may be challenging to manage, they may have important implications for the long-term survival and growth of the firm. Their existence may be the only way to attract and keep key technical employees, which may provide

important services for ensuring opportunities for further growth. It may also be an important source of flexibility that is needed for adapting the strategy of the firm during growth cycles.

While the existence of multiple intentions and incentives is important for long-term growth, they may be costly to maintain, both in terms of their influence on the effective management of current activities, and in terms of the resources that are needed to support activities which may have little relation to the current bottom line. These costs are often used as arguments for the competitive importance of building a shared culture (Prahalad and Hamel 1990) and tightly controlling the integration between the strategic direction of the firm and its technological development (Coombs 1994).

To lower these costs is an important concern for any firm, but being able to afford them may be essential for breaking the "Tyranny of the OR" (Collins and Porras 1997, pp. 43-45) and simultaneously pursuing various contradictions. Collins and Porras argued that the ability to do so was an important characteristic distinguishing firms that were built to last from other firms. Rather than being a cost that can easily be removed, the cost related to multiple intentions and incentives may be a cost that young technology-based firms have to be able to afford and manage in order to maintain reinforced growth.

6.3 Further Research

The contributions of the thesis point to a number of interesting directions for further research.

More research is needed on the sub-processes of growth. Changes in growth intentions and incentives were only explored in this thesis, and more work is to be done in order to understand how they interact with other processes of growth. Of particular interest would be to investigate how changes in growth intentions and incentives for technical knowledge-seeking are related, e.g. how changes in growth orientation at the firm level influence individual incentives for technical knowledge-seeking. Such work is very challenging and difficult to do unless through longitudinal studies including both individual and firm levels of analysis.

The interaction between the process of technical knowledge development and growth is also an interesting field of inquiry that has not drawn much attention to date. This thesis has provided some tools for such research, but these tools need to be refined and developed further. Of special interest are issues related to the development and changes of the distinctive domains of technical knowledge in growing firms. For example, it would be interesting to know more about reformulations of knowledge

domains and the changed role of problem knowledge and solution knowledge following a reorientation or a refocus in the strategic scope of firms.

In this study the focus has been on the internal aspects of the process of growth in young technology-based firms at the firm level. In order to be able to use the results of this thesis for explaining growth in young technology-based firms, they have to be linked to the individual level and the external environment. The conceptualization of the growth process provided in this thesis provides ample opportunities for such linking.

That the identification and exploitation of opportunity are at the center of Penrose's theory opens up for connecting with the current research within entrepreneurship focusing on the interaction between opportunities and enterprising individuals (Shane and Venkataraman 2000).

Garnsey (1998, 2002) also argues that while, Penrose (1959) focused on the internal process of growth, her theory is a good foundation for connecting internal and external aspects of growth. This provides opportunities to combine issues related to the growth process with broader issues related to competitiveness and changes in the environment (Teece et al. 1997), and to differences in growth rates across industries (Audretch and Mata 1995) or populations (Carroll and Hannan 2000).

The combining of the results of the thesis with other streams of research is one way of working towards the further validation of the theoretical ideas put forward in the thesis. Such a synthesis is also likely to increase the understanding of why some young technology-based firms grow while others do not.

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Paper I

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ECONOMIC DEVELOPMENT, TECHNOLOGICAL INNOVATION AND ENTREPRENEURSHIP

Rögnvaldur J. Saemundsson
Industrial Dynamics, Chalmers University of Technology
412 96 Göteborg. Sweden.
Tel: +46 31 772 5121, Fax: +46 31 772 1234.
Email: rjs@mot.chalmers.se

Bruce A. Kirchhoff
School of Management, New Jersey Institute of Technology
University Heights, Newark NJ 07102-1982, USA
Tel: +1 973 596 5658, Fax: +1 973 596 3074
Email: kirchhoff@njit.edu

ABSTRACT

Recent attempts to define entrepreneurship research focus on opportunity recognition. This focus omits entrepreneurship's important link to economic development. The purpose of this paper is to argue that in order to be able to study this link the concept of entrepreneurship has to include both opportunity creation and opportunity recognition, and special attention needs to be given to the establishment and growth of new, independent, firms.

INTRODUCTION

The widespread interest in entrepreneurship today arises from the recognition that it is an activity that is important for economic growth. But, economic development is not often mentioned. Moreover, the widely different and broad use of the entrepreneurship concept leads to problems when doing research on the subject. It is difficult to create theories that capture all the different, and even conflicting, usages, and are at the same time helpful on specific issues. Additionally, empirical inquiry becomes fragmented, as it is difficult to compare studies based on different definitions of entrepreneurship.

Two recent attempts to evaluate and guide researchers in the field are provided, on one hand, by Shane and Venkataraman (2000), and on the other hand, by Wennekers and Thurik (1999). Both attempts strive for a comprehensive definition of entrepreneurship based on a careful and thorough review of the previous literature, but with slightly different concerns. Shane and Venkataraman (2000) are concerned with establishing entrepreneurship as a legitimate field providing distinctive contributions to the field of business research. They argue that entrepreneurship involves the discovery, evaluation and exploitation of lucrative opportunities by enterprising individuals, unrelated to the setting of that interaction (e.g. non-profit organizations, new businesses or existing firms). Wennekers and Thurik (1999), on the other hand, are concerned about the link between entrepreneurship and economic growth. They view entrepreneurship as activities related to perceiving and creating new economic opportunities and exploiting them in the market. These activities are linked to economic growth through the processes of new business creation, innovation and competition.

Even though these theorists have exercised thoroughness in reaching their definitions, they do not attend to the link between entrepreneurship and economic development, or in other words, between entrepreneurship and wealth distribution. According to Schumpeter (1942) [1]

this link was fundamental in the capitalist system and a condition for its existence. Schumpeter argued that without creative destruction, wealth would become increasingly concentrated in the hands of a few large firms and this would destabilize society. Entrepreneurship, or innovations by new firms, 'discipline' the incumbent firms and can lead to a process of creative destruction with corresponding redistribution of wealth. Schumpeter prophesized that entrepreneurship would decline and the legitimacy of capitalism as an economic system would be seriously undermined, leading to the emergence of socialism (Schumpeter 1942:. 132-134).

To date Schumpeter's pessimistic prophecy on the future of capitalism has not come true. The prophecy was based on the assumption that large firms would become much more efficient innovators than entrepreneurs and wealth would become more concentrated thereby requiring emergence of a socialistic system to equitably redistribute wealth[2]. His assumption about the decline of entrepreneurship has been rejected by empirical evidence that has shown small firms are major innovators (Gellman, 1976; Futures Group, 1984). Furthermore, small firms are important for job creation and economic growth as shown by Birch (1979, 1987) and Kirchhoff (1994) in the U.S. and Storey (1994) for the U.K.. Even if Schumpeter's prognosis on the future of capitalism has turned out to be wrong, his logic on the importance of wealth redistribution for the legitimacy of the capitalist system is still valid. Innovation by new, independent, firms is a mechanism for wealth redistribution. While the distribution of wealth may change as established firms 'destroy' competitors by means of innovation, this leads to increased concentration of wealth rather than redistribution. It should be of great importance for researchers and policy makers to make a distinction between the two in order to better understand the nature of the redistribution mechanism and to make sure that it is still at work. This is difficult using the definitions of entrepreneurship provided by Shane and Venkataraman (2000) and Wennekers and Thurick (1999) for two reasons. First, there is no

distinction made between entrepreneurship in new firms and established firms. Second, Shane and Venkataraman only focus on opportunity recognition. Limiting entrepreneurship to opportunity recognition implies that entrepreneurs are only responsive to changes in market equilibrium. This does, according to Schumpeter (1934), not explain the endogenous development of the economy, and, in principle, leaves out the entrepreneur.

The purpose of this paper is to argue that the research theory of entrepreneurship should include the concept of opportunity creation and that special attention should be given to entrepreneurship in new and small firms. These two aspects are central for investigating and understanding the link between entrepreneurship and redistribution of wealth. We base our argument on two different streams of literature. First, we depart from Schumpeter's concept of innovation but take into account later research on the economics and management of technical innovation. Second, we review the theoretical literature on entrepreneurship, emphasizing the contrast, and the complementaries, between Kirzner's alert entrepreneur and Schumpeter's innovating entrepreneur.

The paper will be structured in the following way. First, the concept of economic development will be described with particular emphasis on the theory difference between it and economic growth and its close connotation with wealth distribution. Second, the literature on the economics and management of technical innovation will be reviewed with emphasis on how it relates to economic development. Third, the current literature on entrepreneurship will be reviewed, emphasizing the difference between Schumpter's and Kirzner's theories of entrepreneurship as evident in contemporary views. Finally, the different threads will be pulled together by summarizing the argument.

THE CONCEPT OF ECONOMIC DEVELOPMENT

The gain in social well being within nations is often referred to in a dual statement: "economic growth and development." By this economists mean to draw attention to their two main measures of economic welfare – growth in wealth and distribution of wealth. For reasons long lost in history, distribution of wealth is referred to as "development." In today's social melee, there is so much focus on growth in wealth that we often forget the importance of wealth distribution, a field of study Marshall (1886) referred to as "welfare economics." One of Marshall's (1886) motives for developing the neo-classical theory was his concern for the inadequacy of wealth distribution evident in the slum sections of England's cities and the misery of the people who lived there. This inequitable distribution of wealth was within the nation with the greatest per capita wealth and the fastest growing wealth in the world at the time.[3] Marshall argued that markets could function so as to distribute wealth. Marshall's perfectly competitive markets would adjust prices to equate supply and demand, not just in commodities but also in labour. In his model, markets will adjust prices such that consumers pay fair prices for goods and services; all workers will receive fair wages for their labour; managers will receive fair compensation for their risk taking and organizing of effort; and investors will receive a fair return to their invested funds.

Today, Marshall's neo-classical theory is widely known and underlies the whole area referred to as "general equilibrium theory." But general equilibrium theory has significant weaknesses that are important in this context. First, it addresses wealth distribution far more specifically than wealth creation. Second, the theory provides no explanation for the process of growth but only for the process of equilibrating markets if and when they grow. Third, the theory assumes that generation of new technology is external to the economic system, i.e. not affected by economic system factors. Finally, there is no room for the entrepreneur as all suppliers offer undifferentiated products and have equal information.

Recent developments in general equilibrium theory, most notably within a field termed 'new growth theory' (see Scherer 1999 for a review) have tried to amend these weaknesses but still there is no role for the entrepreneur in the theory. As Kirzner (1997) persuasively notes, although most economists today agree that markets work, general equilibrium theory does not explain how they work (p. 9). He suggests an explanation were the entrepreneur is a central actor (Walsh, 1970).

Inequitable wealth distribution is the essence of most criticisms of capitalism. Social critics have long considered capitalism to be "unjust" because of the widely differing shares of wealth held by different segments of society. Perhaps the best known critic, Karl Marx (1845), was concerned about the concentration of wealth in the hands of a few under capitalism due to economies of scale. He believed that the largest firms would continue to grow and come to dominate all markets.[4] Perhaps Marx's most important point was that if the distribution of wealth does not meet widespread societal acceptance as a fair, equitable or just phenomena, there will be social unrest and eventually an upheaval (revolution) in the society. Schumpeter (1942) had similar concerns as Marx, but for different reasons. He argued that economies of scale would not threaten the legitimacy of the capitalist system as long as innovations by new firms bring with them the gale of creative destruction, leading to wealth redistribution.

Schumpeter, as well as researchers within new growth theory (see e.g. Romer, 1994), put innovations in focus as the most important contribution to economic growth and development. More recently, technological innovations have begun to be recognized as a major source of innovation in industrialized societies (Scherer, 1999). Since entrepreneurship theory does not provide any guidance on the role of innovation and entrepreneurs in social economics, we select look at the literature on economics and

management of technological innovation for help wi the belief that this major source of wealth creation can effectively demonstrate the importance of opportunity creation. Much of this literature is built on the foundations laid out by Schumpeter (1942).

TECHNICAL INNOVATION AND ECONOMIC DEVELOPMENT

Schumpeter (1964: 46-47) defined technological innovation[5] as the introduction of new combinations of methods for supplying commodities in the economy. Give special attention to this definition since introduction means entry into the market, commercialization in today's terms. An invention is the new idea but a new idea is of no value to society until it is introduced in the market. Combinations, or inventions, could consist of: (1) a new good, (2) a new method of production, (3) a new market, (4) a new source of supply of raw material or half-manufactured goods, or (5) a new organization of any industry (Schumpeter 1934: 66). According to Schumpeter, entrepreneurs introduce new combinations to the market and enter into competition with existing firms. Unlike Marshall's (1920) model, competition is not from lower prices, but rather from ". . . the new commodity, the new technology, the new source of supply, the new type of organization (the largest-scale unit of control for instance) – competition which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the output of the existing firms but at their foundations and their very lives" (Schumpeter 1942: 84). In the process the entrepreneur gains a temporary monopoly situation, which transfers market shares (and wealth) from existing, declining firms to the entrepreneur (Schumpeter, 1942).

Schumpeter's description of innovation process is not without critics. Rosenberg (1982) has criticized the distinction that Schumpeter makes between invention and innovation, and between innovation and imitation or diffusion. Rosenberg sees the innovation process as a continuous process that proceeds in small steps where there are feedbacks and interactions

between the steps. It is not so easy to find finished inventions and introduce them to the market. In many cases there are complementary inventions that have to be made before a certain invention can be commercialized. Imitation is also very often a creative and innovative process, improving on the original innovation. Additionally, the imitators might have much greater impact on market structure and capture the lion's share of the rent created by the innovation (Kline and Rosenberg 1986).

These insights have lead to richer, endogenous models of economic change as an interactive learning process involving a number of different actors, within a specific context, e.g. geographical, institutional or technological, that affect economic growth and development through innovation (Freeman 1994).

Along with the literature on the economics of innovation there has emerged a discipline interested in the management of technology and innovation. Technology management is based upon the assumption that some, but not all, technology derived inventions become innovations that have major impacts on society. The differences between those that do and those that do not have such impact are the focus of a great deal of literature in this discipline. However, the technology management literature has not consolidated into a consistent use of terminology let alone a well formulated theory. Thus, it is necessary to examine the literature and use it to define terminology that can provide a basis for our further discussion.

Morone (1993), Bower and Christensen (1995), Bitindo and Frohman (1981), SEST-Euroconsult (1984) and many others identify two classes of technology: (1) disruptive, radical, emergent or step-function technologies; or alternatively (2) evolutionary, sustaining, incremental or "nuts and bolts" technologies. We will use disruptive and evolutionary.

The definition of disruptive technologies can be found in the strategy categorization scheme developed by Bower and Christensen (1995). They view technologies as two categories and

define one as ***disrupting*** the current capability set required by a given market. Disruptive technologies are those that do not support current firm based manufacturing practice. Bower and Christensen (1995) note that disruptive technologies may not be "... radically new from a technological point of view" but have superior "performance trajectories" along critical dimensions that customers value.

Abernathay and Clark (1985) do not agree on this latter point. They argue that, due to disruptive technologies' radical newness or emergent character, robust manufacturing infrastructure does not exist or is very limited in any commercial firm or industrial setting. Actually, a careful comparison of Bower and Christensen (1995) and Abernathy and Clark (1985) reveals that neither believes that their theory is without alternative forms. In other words, they agree that both forms of disruptive technologies exist.

Abernathy and Utterback (1988) confirm this as they describe disruptive technologies as those that create entirely new technology-product-market paradigms that create new to the world markets that may be opaque to customers. Opaqueness, they note, constrains customer enthusiasm for changing their established behavioral habits. Moore (1991) clarifies this aspect of disruptive technologies by noting that they generate discontinuous innovations that require users/adopters to change their behavior in order to use the innovation. Bower and Christensen (1995) state that a technology is considered disruptive when its utility generates products with different performance attributes that may not be valued by existing customers.[6] Thus, there is a clear understanding among these writers that a category of technology exists that serves as the basis for development of innovations that are radically different, are resisted by the existing market structures and create entirely new market structures.

It is the impact of these innovations on society that returns us to our discussion of economic development. Schumpeter (1934) describes capitalism as an economic system that finds its

competitive strength in innovation. The product innovative activity he describes as creative destruction is clearly driven by what these technology theorists call disruptive technologies and discontinuous innovations -- radically different, resisted by existing market structures and creating entirely new market structures.[7] And, the mechanism for overcoming buyer/user resistance to adopting disruptive technologies is the commercialization process that Schumpeter ascribes solely to entrepreneurs. The entrepreneur must demonstrate that the technologies embodied in a new product provide significant cost reductions and/or performance improvements. But, there may be no existing markets and new markets are opaque to potential customers (Abernathy and Utterback, 1988). Customer resistance to behavioral change must be overcome (Moore, 1991). The entrepreneur must create a commercialization opportunity by pushing the technology upon customers. In this way, customers are found who are willing to take the risks of newness (Mansfield, 1968). But, a truly disruptive technology eventually finds its uses in many product innovations and in different markets among "lead user" groups (von Hippel, 1986).

On the other hand, evolutionary technologies improve incrementally from a body of existing knowledge (Foster, 1986). Bower and Christensen (1995) describe such technologies as "sustaining technologies," that is technologies that sustain the current manufacturing practices and technological capabilities required in an industrial setting. Evolutionary technologies create innovations that are modifications of, improvements to, or replacements for existing products. These are called continuous innovations (Morone, 1995). Evolutionary technologies often change incrementally moving from the simple to the more complex.

Evolutionary technologies do not alter markets the way that disruptive technologies do as they do not require users to significantly change their behavior. Instead, evolutionary technologies often are driven by customer demand for improvements of existing products;

improvements make better products that fit current customer behaviors. Market opportunities therefore arise when customer needs are unmet by existing suppliers in a well defined market structure.

Disruptive technologies create discontinuous innovations that destroy markets. Such discontinuous innovations change the very nature of competition and the overall structure of markets. An example will help illustrate this phenomena. The personal computer changed the entire nature of the computer market. The firms in the market changed; Control Data Inc. is gone; UNIVAC's computer manufacturing division is gone; Digital Equipment Corp. is gone; Data General is gone. Much of their value as operating businesses has been acquired by the start ups -- Gateway Computer, Dell Computer and Compaq Computer who now dominate the market. This truly is an example of Schumpeterian creative destruction.

On the other hand, while evolutionary technologies that underlie continuous innovations may shift market shares among competitors, they do not overturn or destroy the markets. They provide improvements of or replacements for existing products. For example, the ever increasing capacity of personal computers and the added features such as hard disk drives, CD-ROMs, faster processing speeds, flat panel displays, are all improvements important to the industry but have had little impact on determining which computer firms are in the market, how PCs are distributed, or the way people use personal computers.

It has been argued that disruptive technologies arise from outside an existing industry -- exogenous from the existing industry/market structure. This agrees with Schumpeter's view of creative destruction. Examples are given that demonstrate this belief. The personal computer emerges from microprocessor technology invented first by Intel corporation, a three year old manufacturer of semiconductor memory chips. Intel was not in the computer manufacturing business although it did initially find small markets for its microprocessors as

components in mainframe and minicomputers. Nonetheless, Intel today is primarily a PC manufacturing company after working with a variety of companies to develop new markets for a discontinuous innovation (see: Freiberger and Swaine, 2000; Chandler, 2001).

So, disruptive technologies and discontinuous innovations logically embody Schumpeter's concept of creative destruction. Many, but not all, of these disruptive technologies emerge from newly formed firms as Schumpeter believed they would. New firms, when independent from incumbent firms and without an established customer base, are not trapped in an existing stream of evolutionary technology and are free to invent and commercialize for a whole new set of customers. They therefore play a vital role in creating new economic opportunities that can be exploited by themselves or by others that may, or may not, incrementally improve the technology. These initiators of discontinuous innovations were Schmpeter's entrepreneurs.

Just as current views on technological innovation are richer and more inclusive than Schumpeter's so has the concept of the entrepreneur, and entrepreneurship, become broader. It is to the role of entrepreneurs and the concept of entrepreneurship that we turn next.

THE CONCEPT OF ENTREPRENEURSHIP

In their careful review of the economics literature Hébert and Link (1989) identified 12 distinct themes of entrepreneurship. In his survey on how researchers in entrepreneurship, business leaders and politicians define the field of entrepreneurship, Gartner (1990) identified 90 different attributes that were mentioned. From these exercises it is clear that no universally accepted definition of the phenomenon exists.

The concept nevertheless has a common history within the field of economics traced back to the work of Cantillion (1755). As mentioned before entrepreneurs lost their role in Marshall's

(1886) economic analysis and subsequent neo-classical tradition that became dominant in the early 20th century. In this tradition, resource allocation became the focus and under perfect competition it became merely a routine task by managers who exhibited predictable profit maximization behavior. To many economists this result contradicted the experience of the realities of the economic system that was more lively and less deterministic than pictured by equilibrium theory. Three different schools of the concept of entrepreneurship were constructed as a response to this problem in neo-classical theory (Hébert and Link 1989), their most prominent members being Frank Knight, Joseph Schumpeter and Israel Kirzner. Contemporary views are usually related to these three schools, but in different ways.

Knight-Coping with Uncertainty

Knight's concept of entrepreneurship is based on his distinction between risk defined as measurable uncertainty and uncertainty defined as un-measurable uncertainty. The main difference in the economic sense is that uncertainty is the source of imperfect competition and profit in the economic system (Knight 1921: 19-20). Without uncertainty, and as prescribed by neo-classical theory, management of productive resources is merely a routine task. With uncertainty present the primary problem of management is deciding what to do and how to do it. (Knight 1921: 268). Solving that problem, by selecting and implementing a direction is the core of entrepreneurship according to Knight (1921: 276).

In real life, Knight argues, entrepreneurship is seldom carried out in its pure form, i.e. the entrepreneur will in most cases either own part of the business or be the routine manager as well as the entrepreneur. But owners of the productive resources could employ the entrepreneur, and in that case the owners will share the profit and the responsibility (Knight 1921: 288-290 and 299-300). Knight makes no reference to the creation of new business organizations.

Schumpeter – Opportunity Creation

While Knight focused on the entrepreneur as an economic agent that directed action in the face of uncertainty, Schumpeter saw the entrepreneur as the agent that changed the economic system from within. According to Schumpeter, neo-classical theory was unable to describe the whole economic process, especially historic change brought about by changes in methods of supplying commodities (Schumpeter 1939: 46-47 and. 72). The carrying out of these changes, or innovations, Schumpeter called enterprise, and those who carried them out he called entrepreneurs (Schumpeter 1934: 77). These innovations competed on the bases of their performance rather than the price giving rise to a process of "creative destruction" of existing markets bringing with it an increase in and an equitable distribution of wealth. Entrepreneurs, therefore, create new economic opportunities through innovation.

Schumpeter argued that the entrepreneur does not have to be both the inventor and the owner of capital, although s/he could be both (Schumpeter 1939: 78). Actually Schumpeter saw it as a strength of the capitalist system that "there is a machinery, the presence of which forms an essential characteristic of it, which makes it possible for people to function as entrepreneurs without having previously acquired the necessary means." (Schumpeter 1934: 78). Consequently the entrepreneur is not necessarily a taker of monetary risk.

Schumpeter argued that entrepreneurship necessarily was confined to actions of new firms. He stated that "new combinations are, as a rule, embodied, as it were, in new firms which generally do not arise out of the old ones but start producing beside them" (Schumpeter 1934: 66). Additionally, "new enterprises are mostly founded by new men and the old businesses sink into insignificance" (p. 136). He nevertheless did see it as possible that innovations could be done within existing firms. He was therefore not consistent on using the entrepreneur and innovator as synonyms. Actually, some evolution can be seen in his work on the sources of innovations. In his first book, Schumpeter did not see the entrepreneur's

function to “find” or “create” new possibilities to base his/her innovations on. These are always present, abundantly accumulated by all sorts of people and generally known (Schumpeter 1934: 88). Later on he became concerned that innovation would become a routine activity mastered by existing large firms who created their own sources of innovation by organized R&D and marketing departments. While innovations by large firms would result in similar effects on the growth of the economy as those by entrepreneurs in new firms, large firms’ growing dominance would lead to unacceptable wealth concentration, leading to the emergence of socialism (Schumpeter 1942: 132-134).

Kirzner – Opportunity Recognition

Kirzner criticizes mainstream general equilibrium theory for focusing too much on the equilibrium itself rather than the processes by which equilibrium is attained. According to him markets are constantly in states of disequilibrium and the role of the entrepreneur is to bring economic markets into equilibrium by exploiting the opportunities that arise because of the disequilibrium (Kirzner 1997: 27-30). Because of uncertainty the entrepreneur does not just seize any ‘given’ opportunity, but he is discovering and acting on it simultaneously, or in Kirzners words: “To act means to grasp an opportunity; to grasp an opportunity means to discover it, to identify it out of the ambiguities and clouds of an infinite array of alternative prospective futures” (Kirzner 1997: 33). Part of the discovery is realizing undervalued resources and in the process of doing so the entrepreneur brings markets towards equilibrium. This is the process he calls dynamic competition. Dynamic competition and entrepreneurship are therefore two sides of the same coin. To compete is to act by offering buyers a more attractive deal, which means discovering undervalued resources, and to act as an entrepreneur is to enter the market with a new idea or better price, which is an act of competition. An important requisite for this to work is the freedom of entry (Kirzner 1997: 48-49).

In the purest sense, entrepreneurs do not have to own the productive resources, even if in the real world they might. In other words, ownership and entrepreneurship are two distinct and separate roles (Kirzner 1973: 39-45).

Kirzner compares his notion of entrepreneurship with that of Schumpeter. He argues that entrepreneurship is manifested in short-term equilibrium movements as well as long-term development. In that sense Schumpeterian imitators also exercise entrepreneurship when exploiting opportunities created by entrepreneurial activity of innovators (Kirzner 1973: 125-131). But for Kirzner the Schumpeterian innovation processes, that is, introduction of technological progress, are exogenous to the economic system as, "For me the function of the entrepreneur consists not of *shifting* the curves of cost or of revenues which face him, but of *noticing that they have in fact shifted*." (Kirzner 1973: 81). Opportunities are there for the alert entrepreneur to discover and act upon.

Kirzner argues that the entrepreneur has a key role in achieving the efficient allocation of resources in the economy. The entrepreneur makes it possible for equilibrium to be achieved even without perfect information, with product differentiation, and without many competitors. Therefore entrepreneurs have an important function for providing equitable wealth distribution as promised by equilibrating markets. And, they do this while stimulating economic growth (Kirzner, 1997:7-75).

As should be apparent from this discussion of Schumpeter and Kirzner, Schumpeter discards the neoclassical equilibrium model as useless. Kirzner embraces the model. Schumpeter believes entrepreneurs create opportunities for inventions by creating new markets. Kirzner believes alert entrepreneurs discover opportunities in existing markets and opportunity creation occurs outside of the equilibrium model.

Contemporary Views

Although the concept of entrepreneurship originates from economics, the field of entrepreneurship is currently a multidisciplinary field involving researchers with backgrounds in psychology, sociology, economics and management. The interdisciplinary nature of the field has made it open to different interpretations of the concept of entrepreneurship[8].

Much of the early work within the entrepreneurship field focused upon the formation and development of independent new ventures (Cooper, Hornaday and Vesper 1997). In this tradition Gartner (1988) has defined entrepreneurship as the creation of organizations. Bygrave and Hofer (1991) extended that definition to include the identification of opportunities, i.e. the entrepreneur is someone who "perceives an opportunity and creates an organization to pursue it" (Bygrave and Hofer, 1991: 14). Kirchhoff (1994) has similar focus on the creation of new ventures when he defines entrepreneurship as "the process of (1) identifying an invention worthy of commercialization; (2) converting the invention into a salable product/service; (3) creating or finding a *small independent firm* to sell the product/service; (4) obtaining the resources to operate the firm and sell the product/service; and (5) successfully operating the firm and generating product/services sales so as to achieve firm survival and growth." (Kirchhoff 1994: 62).

However, a number of researchers within the field have emphasized entrepreneurial and innovative behavior of managers, whether in start-ups or established firms. Stevenson (1997) defines entrepreneurship as the "pursuit of opportunity without regard to resources currently controlled" and Shane and Venkataraman (2000) define entrepreneurship research as "the scholarly examination of how, by whom, and with what effects opportunities to create future goods and services are discovered, evaluated, and exploited" (p. 218).

The definitions above have focused on entrepreneurship from the view of the individual rather than from the function of the entrepreneur within the economy. Hébert and Link (1989) and Casson (1982) propose similar definitions of entrepreneurship based upon the role of entrepreneurs as decision makers. His entrepreneur is an individual that is specialized in decision making concerning the reallocation of resources. On the other hand, Wennekers and Thurik (1999) propose a definition based on the interaction between entrepreneurship and economic growth. They define entrepreneurship as the "the manifest ability and willingness of individuals, on their own, in teams, within and outside existing organizations, to: "perceive and create new economic opportunities (new products, new production methods, new organizational schemes and new product-market combinations) and to introduce their ideas in the market, in the face of uncertainty and other obstacles, by making decisions on location, form and the use of resources and institutions" (Wennekers and Thurik 1999: 46-47). In similar fashion Baumol (1993) defines the entrepreneur as an individual that locates new ideas and puts them into effects without certainty about the results. This includes all "non-routine activities by those who direct the economic activities of larger or smaller groups or organizations." (Baumol 1993, p 8). To summarize, the entrepreneur is therefore involved in creating changes in the economic system as well as identifying existing opportunities and responding to them in a range of different organizational contexts, facing uncertainty.

The definitions mentioned above relate to Knight, Schumpeter and Kirzner in different ways. The small firm perspective is obviously inspired by Schumpeter but adds the specific aspects of the new organization in a way that Schumpeter did not do. The link is strongest in Kirchhoff's definition that is explicitly inspired by Schumpeter. The focus on opportunity recognition is based on Kirzner´s view of entrepreneurship and his contribution is clearest in the definition provided by Shane and Venkataraman. Like Kirzner, Shane and Venkataraman are true to the neo-classical tradition of not including any intermediate variables between

economic agents and the economy making no difference between the organizational context in which entrepreneurs are working. Wennekers and Thurik´s definition is inspired by Schumpeter´s orignal contribution as well as the subsequent literature on the link between innovation and growth. However, Schumpeter's original emphasis on the wealth distribution function performed by independent entrepreneurs is missing from their definition. Instead their focus is on the increase in output. In that context it is natural to include innovation both within new and established firms, as well as to include all firms that are involved in the innovation process. Baumol's definition is the one that combines the three basic economic perspectives and suggests that they are not incommensurable. He states that the entrepreneur is "incapable to leaving matters where they are." (Baumol 1993: 11) but facing uncertainty, thereby combining Schumpeter´s view on the creative powers of the entrepreneur, Kirzner´s view of the alert entrepreneur, and Knights view on the entrepreneur as an economic actor dealing with uncertainty.

Baumol's synthesis of the three different schools of entrepreneurship is appealing as it can be interpreted to include both innovation based on disruptive technology and innovation based on evolutionary technology as well as the uncertainty inherent in the innovation process. Entrepreneurs can create change through innovation and they can respond to change through innovation. But the synthesis comes at a price for our purposes. No attention is given to the potential effects of the innovation on wealth distribution. We cannot specifically investigate, understand or promote entrepreneurship as a mechanism of wealth redistribution using this definition. It does not allow us to make the distinction between the innovations that can redistribute wealth and those that may concentrate wealth. Successful innovation by large, existing firms may change the wealth distribution but they are more likely to increase concentration of wealth rather than redistributing it. Wealth redistribution is only possible through new, independent firms. Wealth redistribution requires innovation but not all

innovation leads to wealth redistribution. Wealth redistribution is made possible by disruptive technology, but improvements might be necessary before wealth can be redistributed by creative destruction of firms using an older technology. It is therefore uncertain if the entrepreneur that created the opportunity for monopoly rents by introducing an innovation based upon disruptive technology can appropriate that rent. Other new, independent firms recognizing the opportunity made possible by the disruptive technology and improving the innovation may be the one that appropriate the rent. Wealth redistribution may therefore be accomplished both by opportunity creation and opportunity recognition. But only by new and small, independent firms.

CONCLUSIONS

The purpose of this paper has been to argue that the concept of entrepreneurship should include the concept of opportunity creation and that special attention should be given to entrepreneurship in new and small firms if the field of entrepreneurship is to contribute to the understanding of the link between innovation and the redistribution of wealth. The natural starting point has been the work of Schumpeter who stressed this particular aspect of entrepreneurship in the first part of the 20th century.

Schumpeter (1934, 1939, 1942) saw the entrepreneur as introducing new combinations of methods for supplying commodities, or innovations, to the economy. Later work has studied the innovation process in much more detail and painted a more complex picture than Schumpeter did. The innovation process is understood as an interactive process involving a number of different actors, innovators and imitators both of whom improve the original innovation. Nevertheless, there are important differences in the technologies that provide the basis for innovation. Evolutionary technologies provide opportunities for innovations that modify and improve existing products within the existing market structure and thereby create

new wealth. Disruptive technologies introduced by independent new firms organized and driven by entrepreneurs destroy market structures and create and redistribute wealth.

Recently, numerous researchers have emphasized the discovery and exploitation of opportunities as the central theme of entrepreneurship. However, the focus of these contributions is on growth in output (wealth), rather than distribution, so little attention has been given to the specific function of new and small firms.

We argue that these definitions are incomplete for two reasons. First, it is important to pay special attention to new, independent firms. Wealth redistribution is unlikely to happen through existing firms, or through new firms created as components of existing firms. This does not mean that innovation from within existing firms is not important, and no assumptions are made about the ability, or inability, of existing firms to innovate., It only stresses the specific economic role of new and small, independent ventures. Second, both opportunity creation and opportunity detection have to be included in the concept of entrepreneurship. Schumpeter focused primarily on the former and viewed imitators as managers reacting to changes in markets brought about by the innovators. The imitation process is also a creative and innovative process, but it is based more on opportunity recognition than creation. Kirzner focuses only on opportunity recognition and therefore on imitators, arguing that entrepreneurs do not create changes in equilibrium but discover that the change creating opportunities that already exist. Even if Kirzner's "alertness to opportunity" is helpful for understanding the workings of entrepreneurs, it is useful only as related to new entry based on evolutionary technology. It provides an incomplete picture of the establishment of new independent ventures based upon disruptive technologies.

By including both opportunity recognition and opportunity creation in the concept of entrepreneurship, and paying special attention to the establishment and growth of new,

independent firms, it becomes clearer how the subject of entrepreneurship relates to wealth distribution, at least through technological innovation. We believe that the same principles can be applied to non-technical innovations but have not attempted to argue that here. That is the subject of another paper.

Elsewhere, we have reported early findings on opportunity creation in a single industry (Walsh and Kirchhoff, 1998) that suggests that creators have greater survival rates and lifetime profits than opportunity recognizers. The opportunity exists for truly useful research on opportunity creation and recognition; such research challenges all of us. Hopefully, our emphasizing of the role of opportunity creation will stimulate research to identify the different characteristics of creators versus recognizers. Awkward English, perhaps, but an important concept.

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[1] Throughout this paper, we will use the date of the original published version of an author's work so the reader can track the evolution of theory over time. The actual versions of these works that we have used are cited in the list of references.

[2] It is important to note that there are other mechanisms for distributing wealth (or income) than entrepreneurship. For example, in many countries, such as Sweden, the state has an active role in distributing income. These other mechanisms will not be discussed in this paper.

[3] Unfortunately, in the United States, the term "welfare economics" has led to the use of the word "welfare" as synonymous with government funded programs that redistribute wealth to residents who lack adequate income and wealth to afford a minimal life style. This was not Marshall's intent.

[4] Marshall (1886) does not address this problem.

[5] It is important to note on the broad meaning of the word technical in this context. Here it is strongly related to the concept of the production function of the firm, i.e. related to all methods of changing inputs into outputs. In fact Schumpeter defined an innovation as a new production function (Schumpeter 1934, p. 61).

[6] Later, Christensen uses the term "disruptive innovations" rather than discontinuous innovations. See: Christensen (1997).

[7] It is important to note that this description of disruptive technological innovation is not limited to technology alone and can easily be extended to apply to Schumpeter's other four classes of innovation. We will not pursue this digression here.

[8] Concepts related to the traits and/or personality characteristics of entrepreneurs that many have sought after in an effort to predict entrepreneurial behavior are not reviewed here. While these concepts are probably useful to psychologists and sociologists for analytical purposes, inclusion of these here would create a book length manuscript and draw attention away from the emphasis on economics and technology that is our central concern.

Paper II

Saemundsson, R. J. and Lindholm Dahlstrand, Å. "Breaking the Entrepreneurial Growth Barrier: The Role of Venture Capital and Acquisitions for the Emergence of Medium-Sized Technology-Intensive Firms". In Reynolds, P., Bygrave, W. D., Maingart, S., Mason, C.M., Meyer, G.D., Sapienza, H.J. and Shaver, K.G. (eds.), *Frontiers of Entrepreneurship Research*, Babson Park, MA, Babson College, pp. 637-651, 1999. Link to webpage

Paper III

Saemundsson, R. J. and Lindholm Dahlstrand, Å. "How Business Opportunities Constrain Young Technology-Based Firms From Growing Into Medium-Sized". Revised and resubmitted to *Small Business Economics*.

How Business Opportunities Constrain Young Technology-Based Firms from Growing into Medium-Sized Firms

Rögnvaldur Saemundsson
Industrial Dynamics
Chalmers University of Technology
412 96 Göteborg, SWEDEN
Tel: +46 31 772 5121
Fax: +46 31 772 1237
Email: *rjs@mot.chalmers.se*

Åsa Lindholm Dahlstrand
Industrial Dynamics
Chalmers University of Technology
412 96 Göteborg, SWEDEN
Tel: +46 31 772 1206
Fax: +46 31 772 1237
Email: asli@mot.chalmers.se

Abstract

This paper analyses how the novelty of business opportunities at start-up constrains young technology-based firms from attaining substantial growth and becoming medium-sized. Data from 262 young Swedish technology-based firms are used to estimate a logit regression model relating different types of opportunities to the probability of becoming medium-sized. The results show that firms which seek to exploit opportunities based on new market knowledge are less likely to attain substantial growth than firms that seek to exploit opportunities based on existing market knowledge. The former class of firms can nevertheless increase the probability of such growth by actively seeking external financing.

Introduction

Many studies have examined barriers to growth in young and small firms and, generally, found growth constraints to be of three types: lack of management competence or motivation, lack of resources, and lack of business opportunities (e.g. Barber, Metcalfe and Porteous 1989).

The purpose of this paper is to analyse how the novelty of business opportunities at start-up constrains young technology-based firms from attaining substantial growth. Through deductive analysis of the effects of differences in novelty of business opportunities on the build-up of management competence and on the need for external financing, two sets of hypotheses are proposed. These hypotheses are empirically tested by using a logit regression model.

Young technology-based firms (YTBFs) are recently established firms where the novelty of start-up opportunities is likely to affect whether they attain substantial growth or not. YTBFs are likely to be involved in activities of very diverse novelty. They take part in the creation and diffusion of new technology, the creation and early development of new markets and industries as well as the renewal of old ones (Rickne 2000). The degree of novelty of the business opportunity at start-up is likely to affect the obstacles that the founders face when pursuing its profitable exploitation, and hence, to affect their chances of survival and substantial growth.

Young technology-based firms are also likely to be sensitive to start-up conditions regarding the scope of the business opportunities that their founders seek to exploit. This scope is highly constrained by the founders' technical expertise. Due to these constraints, founders are unlikely to make fundamental changes in the scope of the opportunities that they seek, even if conditions turn out to be unfavourable (Oakey and Cooper 1991).

The paper is structured as follows. First, the constraining influences of differences in the novelty of opportunities at start-up will be derived, resulting in two sets of hypotheses. Second, the sample used for estimating the logit regression model is described, as are the variables used in the model. Third, the results are presented,

in terms of both the estimation of the model and analysis of complementary descriptive data. Finally, the results are discussed and further research is outlined.

Frame of reference and the development of hypotheses

This section is organized into two parts. First, the nature of business opportunities in young technology-based firms (YTBFs) and how their novelty can differ will be discussed. Second, it will be analysed, using Penrose's (1959) theory of growth and results from recent research, how these differences in novelty influence the likelihood of being constrained from attaining substantial growth.

Business opportunities in young technology-based firms

At start-up the focus of activity in technology-based firms is on the exploitation of a business opportunity that is based upon the technical expertise of the founders (Oakey and Cooper 1991). This activity can lead to innovation, which in small firms usually is in the form of an introduction of a new product or service (Kirchhoff 1994).

A business opportunity consists of productive possibilities that the firms' founders can identify, take advantage of, and are willing to act upon (Penrose 1959). A business opportunity is believed to be profitable, but its future profitability is impossible to determine beforehand (Shackle 1955, p. 81). This uncertainty is exaggerated in technology-based firms because of the uncertainty inherent in any technological development that may be needed before entering the market with a new product or service (Garnsey 1995).

The novelty of the business opportunity, and the subsequent innovation, may differ greatly among firms. Some firms may introduce products and services that are new to the world, while others may introduce refinements of existing ones, or similar products at a lower price.

The novelty of the business opportunity is closely related to the novelty of the founders' knowledge base. As the opportunities that founders can identify are based on their prior knowledge (Penrose 1959, Shane 2000), novel business opportunities cannot be identified without novel knowledge. Similarly, it is difficult to identify opportunities for refinement without knowledge of what is to be refined.

Two dimensions of the founders' knowledge base are important determinants of the novelty of the opportunities they seek to exploit: technical knowledge and market knowledge (Abell 1980, Autio and Lumme 1998).

The technical knowledge that the opportunity is based on can be well known and common to a large population of experts, e.g. a particular field of engineering. It can also be less well known, at least to the population of experts that are serving particular markets. This may be due to novelty of the knowledge as such, or due to geographical or industrial differences in diffusion. When technical knowledge is less well known, universities may have an important role for both producing and diffusing new technical knowledge (Gibbons, Limoges, Nowotny, Schwartzman, Scott, and Trow 1994).

In the same way, the market knowledge that the opportunity is based on can be more or less well known. The founders, and others, are less likely to have knowledge of markets and industries that are emerging. On the other hand, previous working experience from within existing firms is an important source of knowledge of existing markets and industries (Cooper 1986).

Based on the above two dimensions of knowledge, one can analytically discern four types of opportunities in young technology-based firms, each representing a different degree and type of novelty (Figure 1).

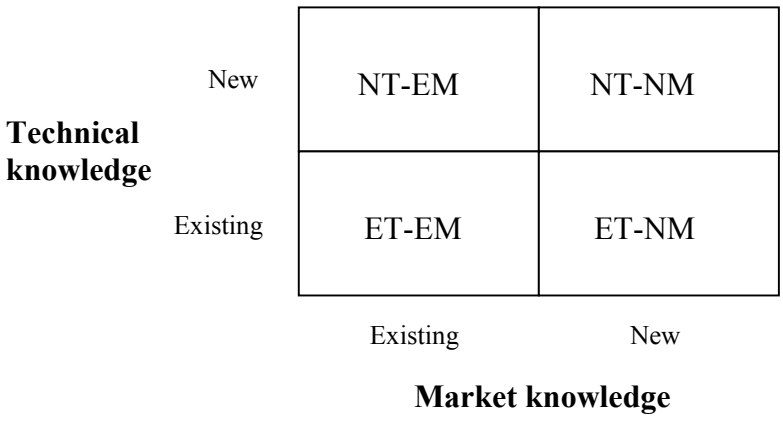

Figure 1. Types of business opportunity in young technology-based firms.

First, opportunities can be based on existing technical knowledge and existing market knowledge (ET-EM). This type of opportunity is likely to lead to incremental innovations, if any innovations at all. Second, opportunities can be based on new technical knowledge but existing market knowledge (NT-EM). This type of opportunity leverages new technology to existing markets, possibly adding new features and improving the performance of previous products. Third, opportunities can be based on existing technical knowledge but new market knowledge (ET-NM). This type of opportunity uses existing technical knowledge to address a new set of customer requirements. It may be related to the emergence of new industries or changes in existing ones. Fourth, opportunities can be based on new technical knowledge and new market knowledge (NT-NM). This type of opportunity addresses a new set of customer requirements by using new technical knowledge, and may lead to radical innovation if successful.

So far, four different types of opportunities have been identified. The novelty of these types ranges from low, when opportunities are only based on existing knowledge, to high, when opportunities are only based on new knowledge. The next step is to investigate how these different types of opportunities at start-up may constrain young technology-based firms from attaining substantial growth. A useful point of departure is Penrose's (1959) theory of the growth of the firm. Her objective was to analyse the limits to growth by creating a theory of the process of firm growth.

Business opportunities and substantial growth

Firm growth is a process of development leading to an increase in size (Penrose (1959, p. 1). The pattern of development, as well as the growth rate, can vary greatly across time periods for individual firms and across firm size, age and industry affiliation (Delmar, Davidsson and Gartner 2002, Audretsch 1995).

Many studies of growth in young and small firms seek to explain differences in growth rates (Delmar 1997). Instead, this study aims at explaining what constrains new firms from attaining substantial growth. To attain substantial growth is to make the transition from being a small founder-managed firm focused on innovation into being a professionally managed firm where internal pressures are exerted for further growth (Hofer and Charan 1984, Garnsey 1998).

Growth in any single time period, according to Penrose (1959), is made possible by opportunities identified by the firms' entrepreneurs. In order to accomplish growth, the firms' managers need to be willing to act upon these opportunities, to plan for their exploitation, and to obtain the necessary resources to carry out the plans. After a period of expansion, increased resources and knowledge will provide incentives, as well as opportunities, for further expansion. The development of knowledge is cumulative and new opportunities for growth are therefore likely to be related to previous opportunities.

Based on assumptions about the general availability of resources and of profitable opportunities, Penrose (1959, pp. 43-49) argued that the limit to how fast a firm can grow in any time period is set by the capacity of the firm's managerial resources. She argued that new management capacity could only be developed within the firm by using current managerial resources. Only by being a member of the management team could new managers learn what is needed for creating and executing expansion plans for a particular firm. Hence, the capacity of the current management team will constrain both the degree of expansion possible during the current period and the increase in new management capacity during the next period.

The capacity of management in each firm is dependent on the amount of managerial resources and the knowledge that these human resources possess. This collection of knowledge is the foundation for identifying business opportunities and pursuing them in a profitable manner leading to growth (Penrose 1959, Shane 2000).

At start-up, managerial resources tend to be scarce and limited to the founding team. The management capacity in the new firm is therefore built upon the knowledge of the founders – the same knowledge that is the foundation of the opportunity they have selected to exploit. As the novelty of that knowledge is likely to affect the difficulty of finding a way to pursue the opportunity in a profitable manner, the type of opportunity is likely to affect the time it takes to build up the management capacity that is needed for growth. The more time it takes to build up the management capacity, the more growth-constrained the firm becomes, and the less likely to attain substantial growth.

Various researchers have observed how different 'lead times' may affect the growth of YTBFs. Oakey and Cooper (1991) observe that firms in different high-tech industries, such as biotechnology and software, differ greatly in how long it takes them to get a new product to the market, and these differences affect the firms' ability to attain fast growth. Roberts (1991) also observes that success in MIT spin-offs is related to the amount of technology transfer from earlier employers. He argues that the technology is more mature and will take less time to develop into products when the technology transfer is high.

Other researchers have used business similarity of parent organization (previous employer) as a measure of lead times. Feeser and Willard (1990) found that new technology-based firms which obtained high growth were similar to their parents in both the technology utilized and the markets served. Chandler (1996) also found that task environment similarity (same customers, industry, competitors, and technology) between the parent organization and the new venture positively moderated the relationship between pre-ownership experience and sales growth.

Research on small and young technology-based firms tends to emphasize the uncertainty related to development of new technical knowledge (e.g. Garnsey 1995, Oakey and Cooper 1991, Roberts 1991). But this uncertainty is likely to be further exaggerated by uncertainty related to the development of new markets and industries. In Klepper and Graddy's (1990) study, the average time from the creation of a new industry to its stability was 29 years. It takes time to spread knowledge about a new set of customer requirements and to gain legitimacy for their relevance (Aldrich and Fiol 1994). Additionally, firms may be dependent on the development of complementary technologies and institutions, which takes time and involves a number of external actors of different types (Nelson 1994, Rickne 2000, Lindmark 2002).

There is some evidence that 'lead times' are longer when opportunities are based on new market knowledge, as compared to opportunities based on new technical knowledge. Eisenhardt and Shoonhoven (1990) found that semiconductor firms were less likely to grow in emerging markets as compared to existing markets, but found no relationship between growth and the newness of technology. Autio and Lumme (1998) also found in their sample of Finnish new technology-based firms

that firms entering new markets with existing technology had obtained significantly less sales growth than firms entering existing markets with new technology. Autio and Lumme's results are not very definite as they found no significant differences in employment growth between these two types of firms, and did not control for other variables that may affect growth, such as age.

The above reasoning leads to the conclusion that young technology-based firms seeking opportunities based only on existing knowledge are less likely to be growth-constrained than firms seeking opportunities based on new knowledge. Additionally, firms seeking to exploit opportunities based on new market knowledge and existing technical knowledge are more likely to be growth-constrained than firms seeking to exploit opportunities based on new technical knowledge and existing market knowledge. Finally, firms seeking to exploit opportunities based on both new market knowledge and new technical knowledge are the most likely to be growth-constrained. These conclusions lead to the first set of hypotheses:

> Hypothesis 1: The novelty of business opportunities at start-up will affect the likelihood that an YTBF will attain substantial growth.
>
> Hypothesis 1a: YTBFs seeking to exploit opportunities based on new knowledge are less likely to attain substantial growth than YTBFs seeking to exploit opportunities based on existing knowledge.
>
> Hypothesis 1b: YTBFs seeking to exploit opportunities based on new market knowledge and existing technical knowledge are less likely to attain substantial growth than YTBFs seeking to exploit opportunities based on new technical knowledge and existing market knowledge.
>
> Hypothesis 1c: YTBFs seeking to exploit opportunities based on new market knowledge and new technical knowledge are less likely to attain substantial growth than other YTBFs.

The time it takes to pursue an opportunity in a profitable manner is highly related to the amount and the quality of available resources. The longer time it takes before firms become profitable, the more firms have to rely on external sources of resources, especially financial resources. Hence, firms seeking to exploit opportunities that have long 'lead times' may also face financial limitations that may further constrain them from attaining substantial growth. The degree of these limitations is determined by the difficulty in obtaining external financing and how sensitive firms are to such difficulties. For example, firms that need to finance extensive technological development before generating any revenues are more

growth constrained by difficulties in getting access to financing than are firms that are able to quickly generate revenues.

In young technology-based firms, differences in opportunities are likely to influence both the difficulty in obtaining external financing, and how growth constraining this difficulty is for the firm. Previous research has found that YTBFs are especially prone to financial constraints (Garnsey 1995, Murray and Lott 1995, Lockett, Murray and Wright 2002) and that the degree of those constraints is related to their technical sophistication (Westhead and Storey 1997). The main argument is that the constraints experienced by YTBFs are due to the lack of willingness, competence, or both, of existing financial markets to provide financial capital to firms facing technological uncertainty. This results in a failure of borrowers and lenders to reach an agreement on the price and conditions for financial support.

If the knowledge on which firms base their opportunity is widely known, it may be easier to get access to financial resources on favourable terms. Financiers may be more confident in estimating risks when opportunities are based on existing knowledge, and founders may be more proficient in convincing the financier about the viability of the opportunity. The opposite is true for opportunities based on new knowledge, especially new market knowledge. When markets are emerging, or do not even exist, it is likely to be more difficult to convince financiers about the viability of an opportunity, as compared to opportunities were the size of the potential market might be known.

The type of opportunity is unlikely to be the only factor explaining the difficulties facing the young technology-based firms when trying to access external sources of financing. There may be individual differences in the ability and willingness to seek external financing (Penrose 1959), and environments differ in their capacity of providing financial support (Aldrich 1979). For whatever reasons firms have difficulties in accessing external financing, the type of opportunity is likely to influence how growth constraining these difficulties are. Firms that seek to exploit opportunities based on new knowledge are likely to be more dependent on external financing than firms seeking to exploit opportunities based on existing knowledge. It is likely to take more time for them to generate own revenues and to

obtain the management competence needed to attain substantial growth. As above, one can expect firms that seek to exploit opportunities based on new market knowledge to be more dependent on external financing than firms depending on new technical knowledge.

Thus, it can be argued that firms seeking opportunities based only on existing knowledge are less likely to be growth-constrained due to difficulties in getting access to external financing than firms seeking opportunities based on new knowledge. Additionally, firms seeking to exploit opportunities based on new market knowledge and existing technical knowledge are more likely to be growth-constrained due to such difficulties than firms seeking to exploit opportunities based on new technical knowledge and existing market knowledge. Finally, firms seeking to exploit opportunities based on both new market knowledge and new technical knowledge are the most likely to be growth-constrained due to such difficulties. These conclusions lead to the second set of hypotheses:

> Hypothesis 2: The novelty of business opportunities at start-up will moderate how difficulties in getting access to external financing influence the likelihood that a YTBF will attain substantial growth.
>
> Hypothesis 2a: Difficulties in getting access to external financing are more likely to constrain YTBFs seeking to exploit opportunities based on new knowledge from attaining substantial growth than YTBFs seeking to exploit opportunities based on existing knowledge.
>
> Hypothesis 2b: Difficulties in getting access to external financing are more likely to constrain YTBFs seeking to exploit opportunities based on new market knowledge and existing technical knowledge than YTBFs seeking to exploit opportunities based on new technical knowledge and existing market knowledge.
>
> Hypothesis 2c: Difficulties in getting access to financing are more likely to constrain YTBFs seeking to exploit opportunities based on both new market knowledge and new technical knowledge from attaining substantial growth than other YTBFs.

Figure 2 summarizes the proposed relationships between differences in the type of opportunity, difficulty in getting access to external financing, and the probability of attaining substantial growth.

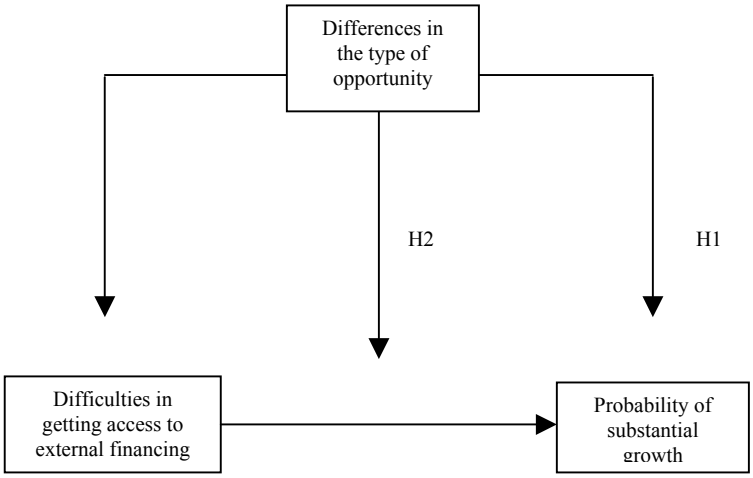

Figure 2. Summary of the proposed relationships between differences in the type of opportunities, difficulties in getting access to external financing, and the probability of attaining substantial growth.

The type of opportunity is hypothesized to influence the probability that firms attain substantial growth in two ways. First, differences in the type of opportunity is hypothesized to influence this probability directly due to differences in the time it takes to build up sufficient management capacity to exploit the opportunity in a profitable manner (H1). Second, the type of opportunity is hypothesized to influence the probability of attaining substantial growth indirectly through its moderating influence on the effects of difficulties in getting access to external financing (H2).

It was also argued that the type of opportunities would influence the difficulty in getting access to financing. Hence, it could be expected that differences in the type of opportunities could also influence the probability that firms attain substantial growth through influences on these difficulties. Do reduce the complexity of the logit regression model this relationship was not included in the model. Instead, complementary data on external financing of the firms in sample is analysed to investigate the assumptions made about differences in the need for external financing and difficulties in obtaining such financing.

In the next section the methods and sample used to test the two sets of hypotheses are described.

Method and Sample

To test the hypotheses, a logit regression model is estimated for a sample of YTBFs[1)] in Sweden. In this section the identification of the sample is described, as are the variables and measures included in the model.

Sample

Based on information from the Swedish Bureau of Statistics (SCB) all firms fulfilling the following criteria were included in a population of Swedish YTBFs:

- The firms should be founded between 1975 and 1993.
- In 1993 the firms should have at least three employees, of whom at least one should have a university degree in engineering, natural science or medicine.
- The firms should not have been established as a foreign direct investment or as a diversification from a larger firm.
- The firms should belong to industries, both manufacturing and industry-related services, that can be termed knowledge-intensive[2)].

In 1998 a postal questionnaire was sent to all surviving firms (1190) belonging to the population. After a single reminder, 400 firms had responded to the survey, of which 344 had answered the questionnaire. Additionally 20 firms answered it after a telephone reminder. These answers were used to test response bias. Since no significant difference was found between respondents and non-respondents regarding age and size distribution, the 20 firms were added to the sample. Thus, the total sample of firms having answered the postal questionnaire consists of 364 firms.

Of these 364 firms, only 262 provided complete answers that could be used for model estimation, while 102 answers had missing values for at least one of the variables used in the model. Since the size and age distribution of the 102 firms having missing values did not differ significantly from the distribution of the total sample of 364, it was considered unlikely that removing the answers with the missing values from the sample would bias the results. Hence, the final sample of

YTBFs used for model estimation consists of 262 firms, or 22% of the identified population. Of these, 36 were medium-sized or larger[3)].

Variables and measures

Substantial growth: The hypotheses proposed in the previous section are concerned with how differences in the types of business opportunities at start-up may constrain young technology-based firms from obtaining substantial growth. To attain substantial growth is to make the transition from being a small founder-managed firm focused on innovation into being a professionally managed firm where internal pressures are exerted for further growth (Hofer and Charan 1984, Garnsey 1998).

This transition is related to changes in organizational structure, which are related to the number of employees. The number of employees is therefore an appropriate measure for estimating when firms have attained substantial growth. While it is impossible to determine the exact point of transition that fits all firms, the EU definition of medium-sized firms (50-249 employees) was used in this study. Firms that had become medium-sized or larger were therefore considered to have attained substantial growth.

The dependent variable of substantial growth in the model is therefore a categorical variable having the value of 1 for those firms having 50 employees or more, and 0 for those having less than 50 employees.

Difficulties in getting access to external financing: In the postal questionnaire, the respondents were asked to report the difficulty they had experienced in obtaining external financing, both at start-up and later. Difficulty was reported on a scale from 1 to 5, ranging from very easy to very difficult, for different financial sources. The different sources included self-financing, business angels, venture capital, various sorts of loans, government support, and 'other' sources of financing.

The variable used in the model was constructed by calculating a single average from all the reported external sources, both at start-up and later. For those firms which reported that they were wholly self-financed, which can be considered as

the lowest degree of difficulty in getting access to external financing, the variable was set to zero.

Opportunities: Two measures were used to quantify the newness of market and technical knowledge.

First, if the new firm had any business relations at start-up with former employers, the business opportunity was considered to be based on existing market knowledge. If there were no business relations at start-up, or if the founders did not have any previous employment, the business opportunity was considered to be based on new market knowledge. Founders coming directly from the university belong to the latter category.

This measure of market knowledge captures well whether opportunities are based on knowledge of existing markets and industries. The measure may nevertheless overestimate the newness of market knowledge in some of the cases where founders had no business relationships with previous employers, or had no previous employer. It is therefore possible that the results are biased towards less difference between new and existing knowledge.

Second, if the respondent reported that universities or research institutes had been important at start-up, the business opportunity was considered to be based on new technical knowledge. If the respondent did not report this, the business opportunity was considered to be based on existing technical knowledge.

The measure of technical knowledge captures well those cases where the technical knowledge is new due to strong links to science. The measure may nevertheless underestimate the newness of technical knowledge in some of the cases where there is no relationship with universities or research institutes at start-up. Firms, especially large firms, may develop new technology that can be used by independent spin-offs without any links with universities or research institutes at start-up. It is therefore possible that the results are biased towards less difference between new and existing knowledge.

Based on the above two measures of market knowledge and technical knowledge at start-up, the four categories of opportunities were created:

1) ET-EM: Existing technical knowledge and existing market knowledge

2) NT-EM: New technical knowledge and existing market knowledge

3) ET-NM: Existing technical knowledge and new market knowledge

4) NT-NM: New technical knowledge and new market knowledge

Control variables: Three variables were included in the model as control variables: growth intentions, age and industry.

The lack of growth intentions has been found to constrain the growth of many small firms (Davidsson 1989), including technology-based firms (Oakey 1994). Growth intentions were measured as self-reported intentions about future growth. The growth intentions were reported on a scale of 1-4, ranging from reducing the number of employees to greatly increasing the number of employees.

As the process of growth takes time, older firms should be more likely to have obtained substantial growth, all other things equal. Age in years is therefore included as a control variable.

Previous research has shown that growth rates of new firms vary between industries. In his study of manufacturing industries, Audretsch (1995) found relationships between growth rates of firms on one hand, and industry innovation rate, industry growth rate, and minimum efficient scale in an industry, on the other. Differences in innovation rates were not controlled for here, as the whole sample in this study belongs to industries with relatively high rates of innovation. A control variable measuring differences in industry growth in Sweden at the two-digit level was constructed and tested, but was found to have no effect, either on the coefficients in the model or on the model fit. It was therefore not included in the final model. A variable that classifies firms as belonging to either manufacturing industries or industry-related services was used to control for differences in minimum efficient scale between these two types of activities. This variable has the value of one for service firms, and the value of zero for manufacturing firms.

Descriptive statistics and correlation: The descriptive statistics and correlations for the non-categorical independent variables are presented in Table 1. There is little correlation between the variables, reducing the risk of disturbing effects due to multi-colinearity.

		Descriptive Statistics		Correlations		
	Variable	Mean	S.D.	1.	2.	3.
1.	Difficulties in accessing external financing	2.24	1.44	1.00		
2.	Growth intentions	3.12	0.71	0.10	1.00	
3.	Age	11.66	4.85	-0.07	-0.12	1.00

Table 1. The descriptive statistics and correlations for the non-categorical independent variables.

In Table 2 the descriptive statistics and frequencies for the independent variables in the logit model are displayed for YTBFs that have attained substantial growth (growth firms) and YTBFs that have not (constrained firms).

Variables	Constrained firms N=224	Growth firms N=36
Difficulties in accessing ext. financing	2.2 (1.4)	2.4 (1.5)
Growth intentions	3.1 (0.70)	3.5 (0.69)
Age	11.3 (4.0)	13.3 (8.0)
Industry		
Manufacturing	25%	42%
Service	75%	58%
Opportunities		
ET-EM	50%	50%
NT-EM	17%	21%
ET-NM	15%	18%
NT-NM	18%	11%

ET=Existing Technical Knowledge, EM=Existing Market Knowledge, NT=New Technical Knowledge, NM=New Market Knowledge.

Table 2. Descriptive statistics (means and SDs) and frequencies of the variables in the logit model for YTBFs that have attained substantial growth (growth firms) and those YTBFs that have not attained substantial growth (constrained firms).

Analysis and model estimation

The four categories of opportunities were included in the model by using three dummy variables. The interaction effects between types of opportunities and difficulty in getting access to external financing (the opportunity and difficulty variables) were modelled by adding three variables, each a multiplication of the

difficulty variable and the corresponding opportunity variable. In effect, a logit model including the difficulty variable and the control variables was simultaneously estimated for the four different types of opportunities, allowing for differences between groups in both the coefficient of difficulty variable and the constant term. In that way it could be tested whether the relationship between difficulties in accessing external financing and attaining substantial growth is different depending on the type of opportunity, and whether there is a direct relationship between the type of opportunity and attaining substantial growth.

A logit regression model with eleven parameters was estimated by using the STATA software package. First, a baseline model, including only the control variables, was estimated for comparison with the full model. Second, three configurations of the full model were estimated, each including different sets of opportunity variables. The presentation of three different configurations makes the comparison between the relative effects of different opportunities easier. Each configuration represents the same model, but the opportunity that is the point of reference when interpreting the coefficients is different in each configuration.

In addition to estimating the model, complementary data on external financing in the selected sample were analysed. The purpose of this additional analysis was to increase the robustness of the conclusions of the study. Investigating the assumptions made about external financing when deriving the hypotheses provides a better understanding of the results from the model.

A limitation of the study that is important to keep in mind when interpreting the results is the survivor bias inherent in the data. Because the data only include survivors, they can only answer questions about the characteristics of the surviving firms, not questions related to the characteristics of all firms belonging to the original population. Hence, we can only make inferences from our data about what constrains the surviving firms from attaining substantial growth, not what constrains firms in general from doing so.

Empirical results

The empirical results will be presented in two parts. The first part will present the estimated model. The second part will present complementary data on differences

in external financing for young technology-based firms seeking different types of opportunities.

Estimation of logit regression model

The estimated logit regression model is presented in Table 3, including both the baseline model and the three configurations of the full model (Models A, B, and C).

Variables	**Baseline Model**	**Model A**	**Model B**	**Model C**
Intercept	-6.52***	-6.36***	-6.36***	-6.36***
Age (A)	0.103**	0.104***	0.104***	.0104***
Industry (I)	-0.703	-1.04**	-1.04**	-1.04**
Growth intentions (GI)	1.20***	1.43***	1.43***	1.43***
Difficulty in access to financing (DAF)		-0.330	-0.163	1.08*
ET-EM (O1)		-	-0.0491	3.90*
NT-EM (O2)		0.0491	-	3.95*
ET-NM (O3)		-3.90**	-3.95*	-
NT-NM (O4)		-7.19**	-7.24*	-3.29
O1*DAF		-	-0.167	-1.42*
O2*DAF		0.167	-	-1.25*
O3*DAF		1.42**	1.24*	-
O4*DAF		2.07**	1.90*	0.655
Log likelihood	-95.3	-85.7	-85.7	-85.7
Model χ^2	26.3***	45.50***	45.50***	45.50***
Pseudo R^2	0.121	0.210	0.210	0.210

N=262, *=p<0.05, **=p<0.01,***=p<0.001.
H_1(using Model A): O2 = O3 = O 4 = 0, p<0.05
H_2 (using Model A): O2*FC = O3*FC = O4*FC = 0, p<0.05
O1: Opportunities based on existing technical knowledge and existing market knowledge (ET-EM).
O2: Opportunities based on new technical knowledge and existing market knowledge (NT-EM).
O3: Opportunities based on existing technical knowledge and new market knowledge (ET-NM).
O4: Opportunities based on new technical knowledge and new market knowledge (NT-NM).

Table 3. The estimated logit regression model. The baseline model is a model including only the control variables. Models A, B, and C are the same full model with different dummy variables left out of the model to facilitate comparisons between different types of opportunities.

The baseline model including age, industry affiliation (manufacturing or service) and growth intentions is highly significant, and age and growth intentions have significant influence on the probability of becoming medium-sized. This is consistent with previous research which predicts that younger firms, and firms with lower growth orientation, are less likely to have become medium-sized than older firms and firms with higher growth orientation.

The addition of the investigated variables doubles the explanatory power of the model, supporting the idea that the investigated variables have a significant influence on the likelihood of becoming medium-sized. In the full model the industry control variable is significant, indicating that service firms are less likely than manufacturing firms to grow into medium-sized firms. This is consistent with previous research which predicts that the minimum efficient scale is higher in manufacturing industries than in service industries.

Hypothesis 1: Direct influence of different types of opportunities

Using post-estimation statistical tests, it was found that the coefficients of the dummy variables representing the different types of opportunities (O2-O4 in Model A) were, as a group, significantly different from zero ($p<0.05$). This supports Hypothesis 1, which stated that differences in the type of opportunities at start-up influence the probability of attaining substantial growth.

According to Hypothesis 1a, firms seeking to exploit opportunities based on existing technical knowledge and existing market knowledge (O1) should be less constrained than firms seeking other types of opportunities (O2-O4). This is supported for O3 and O4, i.e. opportunities that are based on new market knowledge, but not for O2, which is based on new technical knowledge and existing market knowledge.

According to Hypothesis 1b, firms seeking to exploit opportunities based on new technical knowledge and existing market knowledge (O2) should be more likely to attain substantial growth than firms seeking to exploit opportunities based on existing technical knowledge and new market knowledge (O3). The model supports this hypothesis.

According to Hypothesis 1c, firms seeking to exploit opportunities based on new technical knowledge and new market knowledge (O4) should be less likely to attain substantial growth than firms seeking other opportunities (O1-O3). This is only partially supported by the model. Firms seeking to exploit O4 were found to be significantly less likely to become medium-sized than firms seeking to exploit existing knowledge (O1) or new technical knowledge and existing market knowledge (O2) as predicted, but were not found to be significantly less likely to

become medium-sized than firms seeking to exploit opportunities based on existing technical knowledge and new market knowledge (O3).

Hypothesis 2: Indirect influence of different types of opportunities

Using post-estimation statistical tests, it was found that the coefficients of the variables representing the interaction between types of opportunities and difficulty in accessing external financing (O2*DAF, O3*DAF, and O3*DAF in Model A) were, as a group, significantly different from zero ($p<0.05$). This supports Hypothesis 2, which stated that differences in the type of opportunities at start-up moderate how the difficulty in getting access to external financing influences the probability of attaining substantial growth.

According to Hypothesis 2a, firms having difficulties in getting access to external finance should be more likely to attain substantial growth if they seek to exploit opportunities based on existing knowledge (O1) compared to other types of opportunities (O2-O4). This hypothesis is not supported. There is no difference found between firms seeking to exploit O1 and firms seeking to exploit opportunities based on new technical knowledge and existing market knowledge (O2). For both types of opportunities, the degree of difficulties in getting access to external financing has no significant effects on the probability of becoming medium-sized, even if it has a negative sign (see the coefficients for DAF in models A and B). There is a significant difference between firms seeking to exploit O1 and firms seeking to exploit opportunities based on existing technical knowledge and new market knowledge (O3) as well as firms seeking to exploit opportunities based on new technical knowledge and new market knowledge (O4). But instead of the expected negative relationship between difficulties of getting access to external financing and the probability of becoming medium-sized, the relationship is significantly positive for both O3 and O4. Hence, for firms seeking to exploit O3 and O4, those firms that report less difficulty in getting access to external financing are more likely to stay small.

Because of the positive relationship between the difficulty of getting access to external financing and the probability of attaining substantial growth for firms seeking to exploit O3 and O4, Hypothesis 2b and Hypothesis 2c are not

supported. While firms seeking to exploit O3 differ significantly from firms seeking to exploit O2, the relationship between financial constraints and growth is positive instead of negative. As for Hypothesis 1, there is no significant difference between O3 and O4.

External financing

Investigating differences in external financing across different types of opportunities may help to understand the reasons for the lack of support for Hypotheses 2a-2c. In this section complementary data are provided on the sources of financing obtained by the firms in sample (Table 4), the importance of each source (Table 5), and the difficulties in accessing them (Table 6).

Table 4 shows that the average number of sources of external financing increases with increased novelty of the opportunity, with the exception of opportunities based on new technical knowledge and existing market knowledge. These results are in line with the argument made earlier that firms seeking to exploit opportunities based on new knowledge are more dependent on external financing than firms seeking to exploit opportunities based on existing knowledge. This is especially true for firms seeking opportunities based on new market knowledge.

	Opportunities			
External sources of financing	ET-EM N=130	NT-EM N=47	ET-NM N=40	NT-NM N=45
Private persons	6%	11%	8%	20%
Prepayments or loans from customers	22%	13%	18%	24%
Government grants or loans	27%	34%	28%	42%
Bank loans	62%	57%	60%	67%
Venture capital	18%	23%	33%	44%
Other	32%	26%	33%	47%
Average number of sources per firm	1.66	1.64	1.78	2.44

ET-EM: Opportunities based on existing technical knowledge and existing market knowledge
NT-EM: Opportunities based on new technical knowledge and existing market knowledge.
ET-NM: Opportunities based on existing technical knowledge and new market knowledge.
NT-NM: Opportunities based on new technical knowledge and new market knowledge.

Table 4. Sources of external financing in young technology-based firms seeking different types of opportunities.

Table 4 also shows that the degree of bank financing is similar for all types of opportunities, where around 60% of the firms have obtained bank financing. The degree of prepayment or loans from customers is also similar across different types of opportunities, even for the firms that seek to exploit new market knowledge.

Financing from private persons is three times as common in firms seeking to exploit opportunities based on both new technical knowledge and new market knowledge as for firms that seek to exploit opportunities based on existing knowledge. Financing by private persons includes investment by business angels.

Table 4 also shows the importance of the 'other' types of financing, especially for firms seeking to exploit opportunities based on both new technical knowledge and new market knowledge. Almost half of the firms have obtained financing from other sources than those that are considered traditional sources of venture financing. Table 5 also shows that this source of financing is of high importance for these firms.

Table 5 show the relative importance of government support and venture capital for firms seeking to exploit opportunities based on new knowledge. Interestingly, government support seems to be especially important for firms seeking to exploit opportunities based on new technology, while venture capital firms are especially important for firms seeking to exploit new market knowledge.

	Opportunities			
External sources of financing	ET-EM N=130	NT-EM N=47	ET-NM N=40	NT-NM N=45
Private persons	3.00 (0.93)	2.60 (1.82)	2.83 (1.89)	3.67 (1.41)
Prepayments or loans from customers	3.73 (1.16)	3.44 (1.19)	4.19 (0.90)	3.95 (1.42)
Government grants or loans	2.78 (1.56)	2.97 (1.19)	2.45 (1.06)	3.60 (1.45)
Bank loans	3.63 (1.19)	4.02 (1.01)	4.03 (1.14)	3.76 (1.20)
Venture capital	4.02 (1.12)	3.03 (1.57)	4.09 (1.26)	4.22 (1.15)
Other	3.68 (1.22)	3.60 (1.32)	3.68 (1.19)	4.19 (1.10)
Total	3.63 (1.14)	3.80 (1.03)	3.74 (1.05)	3.99 (1.08)

ET-EM: Opportunities based on existing technical knowledge and existing market knowledge
NT-EM: Opportunities based on new technical knowledge and existing market knowledge.
ET-NM: Opportunities based on existing technical knowledge and new market knowledge.
NT-NM: Opportunities based on new technical knowledge and new market knowledge.
Importance is measured on a scale 1 to 5, where 1 is very little importance and 5 is very high importance.

Table 5. Importance of different external sources of financing for young technology-based firms seeking different types of opportunities (average and standard deviation).

Table 5 shows that the importance of external financing is higher for firms that seek opportunities based on new knowledge than for firms that seek opportunities based on existing knowledge. The importance of external financing is also highest for firms that seek to exploit opportunities based on both new technical knowledge and new market knowledge.

Table 5 also shows the relative importance of loans and prepayments of customers for firms that seek to exploit opportunities based on new market knowledge. This finding indicates not only that the customers provide financial assistance, but that contacts with potential customers are important in order to learn about customer needs and requirements.

Table 6 provides data about the difficulties in getting access to different sources of external financing. It shows that firms which seek to exploit opportunities based on new knowledge report more difficulties in getting access to external sources of financing than firms seeking to exploit opportunities based on existing knowledge. Interestingly, the firms that seek to exploit opportunities based on both new technical knowledge and new market knowledge report the least difficulty among firms that seek to exploit opportunities based on new knowledge.

	Opportunities			
External sources of financing	ET-EM N=130	NT-EM N=47	ET-NM N=40	NT-NM N=45
Private persons	3.06 (0.42)	4.33 (0.62)	3.00 (2.00)	2.91 (1.26)
Prepayments or loans from customers	2.29 (1.08)	2.69 (0.91)	3.14 (1.57)	2.88 (1.20)
Government grants or loans	2.85 (1.46)	3.62 (1.05)	3.05 (1.11)	3.30 (1.23)
Bank loans	2.43 (1.27)	2.85 (1.26)	2.63 (1.07)	2.68 (1.22)
Venture capital	3.26 (1.20)	4.03 (1.03)	3.40 (1.23)	3.13 (0.95)
Other	2.12 (1.58)	2.42 (0.96)	3.00 (1.41)	2.63 (1.41)
Total	2.47 (1.17)	3.18 (1.12)	2.87 (0.98)	2.74 (1.04)

ET-EM: Opportunities based on existing technical knowledge and existing market knowledge
NT-EM: Opportunities based on new technical knowledge and existing market knowledge.
ET-NM: Opportunities based on existing technical knowledge and new market knowledge.
NT-NM: Opportunities based on new technical knowledge and new market knowledge.
Difficulty is measured on a scale 1-5, where 1 is very easy and 5 is very difficult.

Table 6. Difficulties in getting access to external sources of financing for young technology-based firms seeking different types of opportunities (average and standard deviation).

Table 6 also shows that firms seeking to exploit opportunities based on new technical knowledge and existing market knowledge report the highest difficulty in getting access to external financing. This finding is interesting because it contradicts the relative difference between new market knowledge and new technical knowledge found in the regression model. It is also interesting to note that these firms have great difficulties in obtaining financing from venture capital investors, private investors and government, while at the same time financing

from venture capital investors and private investors is of relatively low importance for those who get it. It is difficult to interpret this finding, but it might indicate the lack of commitment of these investors to this particular class of firms.

The results of the analysis of complementary data on the degree, importance and difficulty of external financing in young technology-based firms seem to support the results from previous research about the role of external financing for different types of opportunities. Firms that seek to exploit opportunities based on new knowledge need more external financing than firms that seek to exploit opportunities based on existing knowledge, and also experience more difficulty in getting access to external sources of financing. The high number of different sources that these firms are able to access indicated that the difficulty in accessing financing might be more due to greater needs than to the impossibility of accessing a particular source of financing. For example, banks do not seem to be sensitive to different types of opportunities. This might though not be true for firms that seek to exploit opportunities based on new technical knowledge and existing market knowledge. These firms seem to have difficulties getting access to, and taking advantage of, certain sources of financing, most notably private investors and venture capitalists.

It is nevertheless interesting to note the importance of venture capital financing, government support, support from customers, and other unspecified sources of financing. These types of financing seem to have a special role for particular types of opportunities, especially for opportunities based on new knowledge. This role could be related to complementary resources that these actors provide, which could be important for attaining substantial growth.

Discussion and conclusions

The aim of this paper was to investigate how business opportunities at start-up constrain young technology-based firms from attaining substantial growth. The results of the empirical analysis support the basic hypothesis of the paper that the type of business opportunities at start-up significantly influences the probability of attaining substantial growth, both directly and by moderating the effects of difficulties in getting access to external financing. The support for the hypothesis about the specific direction of this influence was more mixed.

The results confirmed that firms seeking to exploit opportunities based on existing knowledge are least likely to stay small. The results also confirmed that firms seeking to exploit opportunities based on new market knowledge are less likely to attain substantial growth than firms seeking to exploit opportunities based on new technical knowledge.

The results did not confirm that firms seeking opportunities based on new technical knowledge, irrespective of the newness of market knowledge, were less likely to attain substantial growth than firms seeking to exploit opportunities based on existing technical knowledge. This finding is unexpected because previous studies of young technology-based firms (e.g. Oakey and Cooper 1991, Roberts 1991) have emphasized the importance of low technological uncertainty for success and growth.

A possible explanation of this discrepancy is that studies emphasizing the importance of low technological uncertainty were only studying firms that were operating in new markets as well. Then the uncertainty about the user problem is a part of the technological uncertainty.

Another possible explanation has to do with measurement problems. The measure used in this study might underestimate the difference between new and existing knowledge. This study is nevertheless not the only study to report a weak, or no, relationship between newness of technology and growth. Eisenhardt and Schoonhoven (1990) found no relationship between innovativeness of firms' technology and growth, and Autio and Lumme (1998) found no difference in growth between market innovators and paradigm innovators. Hence, it seems reasonable to argue that the difference between existing and new market knowledge has much stronger constraining influence on growth than does the difference between existing and new technical knowledge. It is simply more difficult to learn how to profitably exploit opportunities based on new market knowledge, probably because this will always involve learning about both markets and technology.

While the results confirmed the basic hypothesis that the type of opportunities at start-up moderates the relationship between difficulties in accessing external

financing and the probability of attaining substantial growth, the results did not confirm the expected interaction as stated in the hypotheses. In a similar fashion as for the direct effects of differences in the novelty of opportunities, no effects were found for new technical knowledge. For opportunities based on existing market knowledge, irrespective of the newness of technical knowledge, there was no significant relationship between difficulties in getting access to external financing and the probability of becoming medium-sized. For opportunities based on new market knowledge, irrespective of the newness of technical knowledge, there was a significant relationship between difficulties in getting access to external financing and the probability of becoming medium-sized. But instead of this relationship being negative, i.e. that difficulties in getting access to finance would be more constraining for firms seeking opportunities based on new market knowledge, the relationship is positive. Thus, for firms seeking to exploit opportunities based on new market knowledge, the firms that have more difficulty in getting access to finance are more likely to attain substantial growth.

One possible explanation for this positive relationship may be due to measurement problems. There might be a confounding effect of how actively the owner-managers seek external financing in the variable that measures the degree of difficulty in getting access to external financing. Hence, growth-constrained firms, i.e. firms that do not attain substantial growth, may not actively seek external financing even if they need to do so in order to grow. This could be due to the lack of growth intentions, or because owner-managers have a particular reason to avoid seeking external financing. The latter is more probable, as differences in growth intentions are controlled for in the model. The reasons to avoid seeking external financing could be reluctance to give up control or ownership to equity investors, or reluctance to use debt financing.

Another possible explanation for the lack of support for the proposed hypothesis, about the moderating effects of the type of opportunity on the relationship between the difficulties in getting access to external financing and the probability of attaining substantial growth, is the survivor bias inherent in the data. Firms that experience severe financial limitations due to lack of access to external financing are more likely to fail and disappear from the sample. Hence, firms that experience difficulties in accessing external financing may be underrepresented in

a sample of survivors. The effects of the resulting survivor bias might differ for different types of opportunities, being strongest for firms seeking opportunities of highest novelty which are, as shown in the previous section, likely to be most dependent on external financing.

Taken together, the results of this study point to the important distinction between young technology-based firms that seek to exploit opportunities based on new market knowledge and firms that seek to exploit opportunities based on existing market knowledge. Firms that seek to exploit opportunities based on new market knowledge are less likely to attain substantial growth than firms that seek to exploit opportunities based on existing market knowledge. Furthermore, the results from the model, combined with the analysis of complementary data, suggest that firms seeking to exploit opportunities based on new market knowledge are more likely to attain substantial growth if they actively seek external financing. Seeking external financing from multiple sources, including e.g. customers and venture capitalists, not only ensures the financial resources needed for survival, but also may help to obtain other complementary resources and knowledge needed to build up the necessary management competence for attaining substantial growth.

In this paper it has been argued, based on previous theory, that different types of opportunities represent different degrees of learning challenges which face the firm. Further research is needed in order to understand these different challenges and how firms respond to them. Do firms refine their original product idea, concentrating on building up the complementary resources needed for successful commercialization? Or do firms "innovate away" from their problems, pursuing new product ideas that they judge to be more likely to be accepted in the market? While the acquisition of complementary resources is important for early growth (Garnsey 1998), the ability to identify new opportunities is crucial for continued growth (Penrose 1959). Balancing the two is a critical question for management. Without the former, the firm might never enter on the path of growth – and without the latter, the firm is not likely to get very far.

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Notes

1. The concept of the young technology-based firm refers to a recently established firm whose competitive strength comes from the knowledge and skills of the employees within the fields of the natural sciences, engineering and medicine, and the subsequent transformation of this knowledge into products and services that can be sold on a market (Klofsten 1992, Rickne and Jacobsson 1999). This includes manufacturing firms as well as firms providing industry-related services.
2. These industries were ISIC 341, 35, 37, 38, 6112, 72002, 8323, 83249, 83292, 83299 and 932. Special rules were applied in ISIC 61120 and in ISIC 83292 and ISIC 83299 for selecting the relevant firms. See Rickne and Jacobsson (1999) for further details.
3. The relatively low number of medium-sized firms raises two questions. First, are the medium-sized firms underrepresented in the sample? A follow-up study on the size distribution of the original population in 1999 found that 14% of the firms that still existed were medium-sized or larger. This is the same percentage as obtained in the final sample used for estimating the model. Second, how will this relatively low number of medium-sized firms affect the maximum number of parameters in the model? Hosmer and Lemeshow (2000, pp. 346-347) argue that the issue of sample size in logistic regression models is complex and dependent on the characteristics of the data. They suggest as a rule of thumb, which may be too stringent, that 10 events of the least frequent outcome are needed for each parameter. In our case this would mean that the model in this study is constrained to 3-4 parameters. The full model presented in this paper includes 11 parameters, which is 3-4 times larger than recommended by the rule of thumb. To test the robustness of the model, a model with seven parameters (only two categories of opportunities) was tested. The results were stable, suggesting that the problem of underestimation or overestimation due to large model size is not serious.

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Paper IV

Saemundsson, R. J. “On the Interaction between Growth Intentions, Access to Resources, and Growth in New Technology-Based Firms”. Accepted for publication in *The International Journal of Entrepreneurship and Innovation*.

On the Interaction between Growth Intentions, Access to Resources, and Growth in New Technology-Based Firms

Rögnvaldur J. Saemundsson

Industrial Dynamics
Chalmers University of Technology
Göteborg, Sweden

Tel:
+46 31 772 5121
Fax:
+46 31 772 12 37
Email:
rjs@mot.chalmers.se

On the Interaction Between Growth Intentions, Access to Resources, and Growth in New Technology-Based Firms

Abstract

This paper explores the interaction between growth intentions, access to resources and growth in new technology-based firms. Based on a combination of a cross-sectional survey study and case studies of individual firms, it is shown that growth orientation of new technology-based firms may be mediated, or determined jointly, by the firms' need for external resources. New technology-based firms that have low growth orientation at start-up may obtain actual growth through the influences of new owners that allow access to critical resources. These results have important implications for understanding the growth process in new technology-based firms.

Keywords

New technology-based firms, small firm growth, growth intentions, resources

Introduction

New technology-based firms (NTBFs) have attracted growing interest in recent years. Some researchers stress the large growth potential of NTBFs (e.g. Bollinger, Hope and Utterback 1983), while others emphasize the collective role of NTBFs as agents of change in the techno-economic system as a whole (e.g. Autio 1997). In any case, the suggested importance of NTBFs for economic growth and development has challenged researchers to investigate the nature of NTBFs and the conditions for their successful establishment and growth.

Previous research on the growth of NTBFs displays a dichotomy that is common in entrepreneurship research. On the one hand, researchers examine various conditions for growth, given high growth intentions of firms' owner-managers (see Autio 2000 for a review). On the other hand, researchers acknowledge that the degree of owner-managers' growth intentions may differ, and argue that lack of growth intention constrains the growth of many firms (Utterback and Reitberger 1982, Oakey 1994).

The dichotomy has led to a situation where growth intentions are studied separately from other conditions facing firms. If the owner-managers have intentions for growth, other

conditions are important for understanding growth. Otherwise they are not, because growth will not take place under any such conditions. This separation is implicitly based on two assumptions. First, the growth orientation of firms is assumed to be determined by a single individual or by the shared intentions of many individuals. Second, it is assumed that individual growth intention, or the growth orientation of firms, is stable and not influenced by conditions facing the firms.

The purpose of this paper is to demonstrate that this separation is unfortunate, at least when studying the relationship between access to resources and growth in NTBFs. It is argued that the above assumptions are likely to be violated in this particular case and that the growth orientation of NTBFs may be mediated, or determined jointly, by the firms' need for external resources. Due to their specific nature, and unrelated to their growth orientation, NTBFs may have to add new owners in order to get access to resources. New owners may provide resources necessary for survival and growth, but their growth intentions may differ from those of the founders. Understanding the interaction between access to resources, ownership changes and growth intentions may thereby greatly enhance our understanding of the growth process in NTBFs.

The paper will be structured as follows. First, the frame of reference will be developed, leading to the research questions guiding the empirical part of the study. Following a description of the methods used for data collection and analysis, the empirical data will be presented and analyzed. Finally, conclusions will be drawn and some suggestions made for further research.

Frame of Reference

The concept of the NTBF, or of the technology-based venture, has been used in a number of different ways (Bollinger et al. 1983, Storey and Tether 1998). In this study the concept refers to a recently established firm whose competitive strength is based on employees' knowledge and skills within the fields of the natural sciences, engineering and medicine (Klofsten 1992, Rickne and Jacobsson 1999). The focus is therefore on the knowledge and skills of the employees, rather than the newness of the innovations, or how much the firm spends on research and development. Consequently, both manufacturing firms and firms providing industry-related services are included.

NTBFs are founded for a variety of reasons. The founders may seek independence, they may want to create personal wealth, or they may want to create a technology-oriented working environment (Jones-Evans 1996). The focus of activity is innovation based on the founders' specialized technological expertise (Oakey and Cooper 1991, Eisenhardt and Schoonhoven 1990).

Irrespective of growth orientation, the new firms are dependent on the environment for the provision of resources needed for survival and development (Pfeffer and Salancik 1978). Environments differ in their resource capacity (Aldrich 1979), the types of actors providing resources, and the available mechanisms for mobilizing actors (Freeman 1991). Environments can be rich or poor in terms of the number of actors and the amount of resources they control. Possible actors include banks, venture capital firms, business angels, suppliers, customers, corporations, and universities (Rickne 2000). These actors can be mobilized through market exchange, informal personal networks (Becattini 1990), strategic alliances (Stuart 2000) or ownership (Sapienza and De Clercq 2000, Lindholm 1996). Different actors are likely to have different requirements for resource exchange that are related to the mechanism used for mobilizing them. For example, banks deliver their services through markets but demand guaranties for payback before issuing a loan (Storey 1994). Venture capital firms demand an ownership position and the performance of an extensive due diligence process before giving access to their resources (Tyebjee and Bruno 1984).

The specific nature of NTBFs may constrain the number of actors and mechanisms available for accessing certain important resources. In many cases, the alternatives are limited to actors that demand ownership positions in exchange for access to resources. The inherent uncertainty of technical development makes it difficult for NTBFs to obtain loan financing for extensive pre-sales development (Garnsey 1995). This type of financing may thus only be available through actors that specialize in high-risk equity investments, such as venture capital firms and business angels – or through actors, such as large corporations, that are interested in the new firm as a source of new technology. In both cases the investment can range from a minority investment to a full acquisition.

Founders of NTBFs may be reluctant to give up ownership in exchange for access to resources. In such cases they may experience severe resource constraints on their operations (Garnsey 1995). These constraints can lead to either failure or reduced ambitions unless the founders are able to find alternative sources of resources.

To get access to critical resources for technical development and survival in an early phase is an important condition for growth, but not a sufficient one. Additional resources are needed for expansion and the owner-managers must be willing to execute the expansion (Penrose 1959, Garnsey 1998). Without intentions to expand, firms are unlikely to grow.

Psychological theories of motivation have been used by scholars of entrepreneurship to empirically investigate the relationship between growth intentions and actual growth (Kolvereid and Bullvåg 1996, Delmar 1999, Wiklund and Sheperd (ath. rithátt sbr. heimildaskrá) 2001). While the strength of this relationship has differed between the studies, they all find a positive relationship between growth intentions and actual growth.

While pointing to the importance of, and the variation in, growth intentions, the psychological-motivation approach has serious limitations that are relevant to this study. First, the basic theories of motivation are individual-level theories. While helpful for investigating the impacts of individual entrepreneurs, they are problematic when many individuals are involved in deciding on intentions and goals of the firm. Most NTBFs are established by a team of founders (Cooper 1986, Utterback and Reitberger 1982), i.e. there is no single entrepreneur. Second, when these theories are applied to small-firm growth, it is assumed that growth intentions are stable over time, and already established at founding. This is somewhat at odds with psychological-motivation theories where concepts, such as goals and intentions that are proximal to behaviour, are much more dynamic and changing than concepts that are more distal to behaviour, such as needs and values (Kanfer 1990). Empirical evidence also points to changes in growth intentions through time. Fleck and Garnsey (1988) describe how growth becomes a prime objective at Acorn Computers, and Kolvereid (1992) found strong relationship between past growth and the desire for future growth.

Another theoretical concept, which allows for differences in motivational aspects, resolves both of these problems and is more appropriate on a firm level. Cyert and March (1963, pp. 30-50) presented the concept of the dominant coalition as a part of their behavioural theory of the firm. According to their theory, the firm is viewed as a coalition of individuals where each individual may have substantially different intentions or goals. As a result there will take place a continuous goal-bargaining process that may or may not produce consistent goals. Some participants will be “external” (such as stockholders) and others “internal” (such as employees). Even if the bargaining process is more or less continuous, the coalition members are motivated, because of limited time and capacity, to reach an agreement

on the goals, or the orientation of the firm. Such an agreement is based on side payments to those who do not share the agreed goals. The coalition agreements provide much more stability than would typify a pure bargaining situation, but are nevertheless subject to change. They are likely to change in the early phase of the organization, in crisis, or because of changes in the coalition structure. Such changes have been confirmed by empirical studies related to increased influence of management in growing firms (Scott 1998, pp. 295-296).

While Cyert and March had large firms in mind when they constructed their theory, the concept of the dominant coalition could be helpful for exploring the link between access to resources, growth intentions and actual growth in small firms. In order to get access to resources, the entrepreneur(s) will have to connect with actors in the environment. These actors then become "external" participants in the firm and change the coalition structure. Such a change may affect the growth orientation of the firm.

The degree of influence on growth orientation by an external actor is likely to be related to how dependent the firm is on that particular actor for access to critical resources. Pfeffer and Salancik (1978, pp. 45-51) argue that the degree of resource dependence is determined by three factors: first, the importance of the resource for continued operation and survival; second, the discretion which the external actor has over the allocation and use of the resource; third, the general availability of the resource.

External actors demanding ownership position in exchange for access to resources are likely to have a high degree of influence on the growth orientation of NTBFs. They tend to provide critical resources, they are likely to obtain a sufficient equity position to influence the operations of the firm as members of the board of directors, and they usually provide resources not available through other means.

The direction of the influence on the growth orientation is likely to be related to the motives of the new owner. New owners interested in obtaining high return on their investment in the firm through later exit are likely to bring with them high growth intentions, thereby possibly increasing the growth orientation of the firm. Venture capitalist firms are a typical example of such owners. New owners with other motives, e.g. interested primarily in the acquisition and transfer of the firms' technology, may have negative effects on the firms' growth orientation. Large industrial corporations are a typical example of such owners.

The purpose of this paper is to demonstrate that the separation of growth intentions from other conditions for growth is unfortunate, at least when studying the relationship between

access to resources and growth in NTBFs. Previous research has shown that NTBFs are likely to add new owners in order to get access to critical resources. Previous research has also shown that NTBFs are often established by teams, where at least some members of the team may have low growth intentions. Less known is whether the growth orientation of NTBFs is subject to change, and whether adding new owners may lead to such a change. In particular, we do not know if actual growth is dependent on high growth orientation at the start, or if firms having low growth orientation at the start may obtain actual growth after adding new owners. In order to increase our knowledge of these issues, the following empirical analysis tries to answer three questions:

1. Is the growth orientation of NTBFs subject to change?
2. If the growth orientation of NTBFs is subject to change, how are the changes related to the addition of new owners?
3. Is it possible that firms having low growth orientation at the start may obtain actual growth after adding new owners?

Before going through the empirical analysis, the methods and sample used for the analysis are presented in the next section.

Methods and Sample

The empirical analysis is based on a combination of a cross-sectional survey study of a population of Swedish NTBFs and a number of case studies of individual firms within that population. This combination makes it possible to formulate some generalizations for a population of firms, as well as to capture the dynamics of the growth process within an individual firm, i.e. how it has unfolded over time.

It is difficult to determine the point at which a small firm has obtained actual, or substantial, growth. Absolute and relative increases in sales or the number of employees are problematic. Intuitively, the change from 20 employees to 60 employees is a more fundamental change than the change from two employees to six, even though it is the same relative change. Changing from two employees to twelve is also a more fundamental change than changing from 80 employees to 90, although the absolute change is the same.

Other, more qualitative measures of substantial growth have been proposed. Garnsey (1998) uses the concept of reinforced growth when growth is under way and internal pressures are exerted for further growth. Hofer and Charan (1984) have emphasized a

transition from being a small founder-managed firm into being a professionally managed and growth-focused firm. This transition is related to changes in organizational structure, from being informal and focused on innovation, into a considerably more formalized and functional structure focused on operation (Hanks and Chandler 1994). For the purpose of this study, the transition to reinforced growth seems to be the most appropriate.

One implicit condition of reinforced growth is growth focus, matching the transition in organizational structure mentioned above. While this transition is difficult to establish, it was decided to use the EU definition of medium-sized firms (50-249 employees) as a breakpoint. This decision was based on two arguments. First, it was assumed that all firms having become medium-sized or larger had reached the stage of reinforced growth. Selecting a lower level would have increased the risk of including firms that had not reached reinforced growth. The validity of this assumption was confirmed by observing the structure and growth orientation of the investigated case firms, and by measures of growth orientation within the sample of medium-sized firms. Second, the use of an EU definition makes comparison between other studies easier.

The survey study

The survey study is based on a sample of Swedish NTBFs. Based on information from the Swedish Bureau of Statistics (SCB) all firms fulfilling the following criteria were included in the NTBF sample:

- The firms should be founded between 1975 and 1993.
- In 1993 the firms should have at least three employees, where at least one should have a university degree in engineering, one of the natural sciences or medicine.
- The firms should not have been established as a foreign direct investment or as a diversification from a larger firm.
- The firms should belong to industries, both manufacturing and industry-related services, that can be termed knowledge-intensive.[1]

In 1998 a postal questionnaire was sent to all surviving firms (1190) belonging to the sample. After a single reminder, 400 firms had responded to the survey, of which 344 had returned a completed questionnaire that could be used for analysis. A further 20 completed questionnaires were received through telephone interviews. These answers were used for analysis of non-respondents. Since no significant difference was found between respondents

and non-respondents in terms of the size and the age of the firms, these 20 answers were added to the sample. The total sample thus consisted of 364 firms.

Of the 364 firms in the sample, 44 had become medium-sized, i.e. had more than 50 employees. As the medium-sized firms were of special interest in the study, it was decided to increase the response for this group of firms. A further 17 medium-sized firms were therefore interviewed by telephone, using the original survey, and added to the sample. In total, this resulted in 61 medium-sized firms.

While the postal survey was designed to obtain information on the background, turnover and employment, internationalisation, financing, cooperation, acquisitions and spin-offs of the NTBF sample, some of the questions were related to growth intentions and ownership changes.

In the statistical analysis of the survey data, the group of medium-sized firms (the MTBF sample) was compared to those firms which are small, i.e. have fewer than 50 employees (the STBF sample).

The survey data have important limitations that are common to such types of data. First, the data only include survivors. Depending on the characteristics of the disappearing firms, this may lead to biased comparisons between growers and non-growers. Second, the information in the survey is based on a single informant whose tenure with the firm is unknown. This makes it impossible to capture individual growth intentions of the participants of the firm. Finally, it is impossible to know the growth orientation of the medium-sized firms before they became medium-sized, in the event that they have changed.

The case studies

The case-study firms were selected from the NTBF sample described earlier. In order to obtain as much breadth as possible, the case firms belonged to different industries, were based on different technologies, and offered different types of products and services. Industrial classification available in the sample data, as well as information from the Internet, was used for selection.

Seven case firms were selected, all of them medium-sized or larger.[2] While it would have been most appropriate to obtain longitudinal data in real time, this was not possible considering the time frame of the study. The analysis is therefore based on retrospective data with all its limitations.

Selecting an appropriate number of case firms is a balance between effort and results. It was decided to start out with seven firms and see if there would be a need for adding more cases later on for exploring certain aspects in more detail. After completing the studies it was judged that the information was sufficient in order to give the qualitative understanding needed for this investigation.

All case firms were visited by the interviewer. In total 11 people were interviewed, in seven firms, each for 2-4 hours. In all but one case the interviewees included the CEO of the firm. The questions, which were open-ended, concerned the growth process, products, markets, technology, financing and ownership. The interviews were complemented by secondary information, such as the firm's web pages, written material from the firm (financial statements and product descriptions) and articles from the business press.

Case histories were written on the basis of interview protocols and secondary data. Extracts from these histories are used to illustrate certain points in the analysis and to fill gaps in the survey data. To avoid repetition and because the case histories only serve as examples, only four case histories are used in the following text. No attempts are made to generalize from the results of the case studies.

Analysis

The survey data and case data are combined in the analysis. Results of the survey data will be presented first, investigating differences between the firms that have grown into medium-sized and those that have not. Then results from the case studies will be added to give a better understanding of how the medium-sized firms may develop over time.

Empirical Analysis

In this section the results from the empirical analysis will be presented in two subsections. The first subsection presents the analysis of growth orientation and its changes (research question 1), and the second subsection presents the analysis of the influence of new owners on the firms' growth orientation (research questions 2 and 3).

Changes in Growth Orientation

As growth intentions have been found to be positively related to actual growth (Kolvereid and Bullvåg 1996, Delmar 1999, Wiklund and Shepherd 2001) as well as to previous growth (Kolvereid 1992), one would expect the managers of the medium-sized firms to report higher growth intentions than the managers in the small firms. This is also the case (Table 1).

Table 1 Growth orientation in terms of the reported intentions to increase the number of employees in small (STBF) and medium-sized technology-based firms (MTBF).

	Number of firms (Share of firms)	
	STBF	MTBF
Do not want to grow	56 (18%)	3 (5%)
Want slow growth	180 (58%)	23 (39%)
Want fast growth	73 (24%)	33 (56%)
Total	309 (100%)	59 (100%)

Chi-square test gives a significant difference between the two groups ($p<0.001$).

Of the medium-sized firms 56% report that they intend to grow fast compared with 24% of the small firms. Only 5% of the medium-sized firms report that they do not intend to grow at all, compared to 18% for the small firms. The difference in growth orientation is significant between the two groups of firms. These results show that firms which have grown to medium size are likely to have developed a strong growth orientation. But they do not tell us whether this high growth orientation was present at the start, or how changes in growth orientation relate to actual growth. Using the data from the case studies gives an opportunity to investigate such issues (see Box 1).

Box 1 Growth intentions in IFS AB and Karabio AB.

Example 1: IFS AB was established by five engineering graduates directly after their graduation from the local university. The foundation was not based on any business idea in particular, the main motive for foundation being their shared unwillingness to work in a large organization. At the time of founding, the founders did not have any aspiration for future growth. During its first years the firm was involved in diverse consulting work, and developed, among other things, a computer software for a specific application. This computer software had a narrow application focus and needed a specific type of computer hardware to run. Shortly afterwards the founders became aware of development software for portable development, which made it possible to develop software simultaneously for multiple hardware- and operating-system platforms. They decided to develop their application software in this way and sell it to Swedish customers. At that time there were 30 persons employed by the firm. As the firm started to sell the software to new customers, its functionality was extended and it gradually developed into a general application software for industrial firms. At the same time the firm added employees to handle sales and customer support. Only at that point, with around 100 employees, did the firm formulate an aggressive growth strategy aiming at global presence. This was a collective decision that was taken despite different opinions among the founders about the future of the firm. Today, when the firm has over 1,500 employees worldwide, all five founders still work for the firm. The CEO is one of the founders, but not all of the founders hold management positions.

Example 2: Karobio AB was established by two researchers, active within the field of biomedicine/biotechnology. There was no particular product idea behind the establishment of the firm. The founders saw firms based on biotechnology as a coming trend and wanted to exploit their knowledge by developing pharmaceuticals. They contacted a group of institutional investors who raised 250 million SEK in start-up capital. The investors appointed a management group to run the firm. From the beginning there were three groups related to the firm that had different views of the world and different interests. First, there was a group of scientists, led by the founders, who wanted to concentrate on activities that were of scientific interest. Second, there was the management group, led by the CEO. The management group, with experience from industry, concentrated on obtaining rights to products that could be sold, as well as on distribution channels (through an acquisition) for those products. These products were not in line with the research activity of the scientific group. Third, there was the group of investors who were patient, but increasingly worried about the unfocused and expensive strategy of the firm. After two years it was obvious that the firm was in trouble. The company had 100 employees, unfocused strategy, little money left and no sales. The management team was changed, bringing in a CEO with experience from the pharmaceutical industry. The strategy was focused on the research activities of the founders, unrelated activities sold, more capital provided by the investor group and the number of employees reduced to 30. After that, the investor group lost interest in the venture and sold their shares to the management team and the personnel. Following a number of research contracts with larger pharmaceutical firms and subsequent rounds of financing, the firm employs around 60 persons.

Box 1 shows that the relation between growth intentions and growth is not straightforward. In both cases the firms were established by a team of founders. In IFS AB the founders had low growth intentions at start-up. In fact the main reason for them to establish the firm was to avoid working for a large organization. The demand for their services nevertheless encouraged them to employ more people as a solution to their work situation. As they broadened their focus they experienced still more demand. At some point growth became a matter of strategic importance. After that, the growth intentions became an important driver of growth.

In IFS AB the founders seemed to accept growth, even if they did not strive for growth from the start. One could suspect that they did not consider an organization with 30 people a large organization. When the number of employees was around 100, the founders had to decide whether to proceed on the path that they had entered or to continue to be a small firm. Although there were different growth intentions among the founders at this point, a collective decision was made to choose an aggressive growth strategy. The founders with low growth intentions accepted growth and continued working for the firm, focusing on technical work rather than on management. Founders with high growth intentions took management positions, e.g. the CEO position.

The case of IFS demonstrates one problem with the concept of growth intentions as used in this paper. While growth intentions clearly can differ from low to high, what the individuals judge as low or high is subjective. Although not striving for high growth, the IFS founders had nothing against expanding their operations, i.e. doing more of what they were doing. They therefore grew substantially before they considered growth as a separate goal. Their acceptance of growth is a form of low growth orientation with indifference to whether growth happens or not.

In the example of Karobio AB it is difficult to identify the entrepreneur. Right from the start there were three groups represented in the founding team. It is likely that the scientific founders were motivated by the prospect of personal wealth and/or the opportunity to finance interesting research. It is unlikely that they were interested in the growth of the firm as such. The investors and the management team clearly had high growth intentions, but in this case these intentions did not lead to sustained growth.

Karabio AB clearly shows the limitations of the psychological-motivation approach and the need for a more organizational approach such as the dominant-coalition concept. Even in small firms the members of the organizational coalition may not share the same growth intentions, leading to a continuous negotiating process and a conflict of intentions. In Karobio AB, the scientists accepted the growth intentions of other members of the coalition and got resources to pursue their scientific interests. In IFS AB the founders who lacked growth intentions accepted the growth orientation of the firm and were given opportunities and resources to pursue their technical interests.

To summarize, the managers of the medium-sized firms are more likely to report higher growth intentions than the managers of the small firms, yet the link between growth intentions and actual growth may not be as straightforward and stable as modelled by psychological-motivation approaches to entrepreneurship. The examples from the case studies describe situations that are better understood in terms of the dominant-coalition model. The members of the organizational coalition differ in growth intentions and some members simply accept growth. As predicted by the dominant-coalition concept, this acceptance has demanded resources from the firm in the form of side payments. These side payments involve job assignments and/or resources for pursuing personal technical or scientific interests.

The link between ownership changes and growth intentions

The next step in the analysis is to investigate the relation between ownership changes and growth intentions.

Adding new owners can be a prerequisite for obtaining external financing and may in some cases give access to resources and knowledge needed for growth, such as management and market experience, distribution channels, contacts, etc. (Garnsey 1998). It is evident from Table 2 that adding new owners is important for growth.

Table 2 Ownership changes in small and medium-sized new technology-based firms.

	Share of firms[b)]		Difference
	STBF	MTBF	p-value [a)]
Have added new owners (either minority or majority of shares)	47.2%	70.7%	<0.01
Have sold minority shares	33.8%	50.0%	<0.05
Have been acquired	18.1%	32.8%	<0.01

a) Chi-square test. b) Percentages are related to the number of answers to each question.

While roughly 70% of the medium-sized firms have added new owners, either by selling minority shares or by being acquired, this has happened in only 47% of the small

firms. About 50% of the medium-sized firms have sold minority shares while almost 33% have been acquired. A significantly lower share of the small firms have sold minority shares (34%) or been acquired (18%). It is interesting to note that it is more common that acquisitions by other industrial firms have a positive, rather than negative or neutral, association with growth. This is in line with Lindholm's (1996) results and indicates that most new owners, even acquirers, are interested in the growth of the NTBF. For venture capitalists this interest in growth is obvious, but other industrial firms might have different motives for their investments, such as getting access to the technical knowledge residing in the NTBF.

While it is not possible, using the survey data, to measure the direct influence from new owners on the growth orientation of the firms, one can measure it indirectly by comparing the growth orientations of the firms that have added new owners and those that have not (Table 3).

Table 3 The relationship between growth orientation and ownership changes (selling minority shares or being acquired).

	No new owners N=144	New owners N=146
Do not want to grow	18%	9.0%
Want to grow slowly	67%	47%
Want to grow fast	15%	45%

Chi-square test gives a significant difference at the 95% level ($p<0.001$) in the willingness to grow, between the firms that have added new owners and those that have not.

There is a significant difference between the two groups, the firms that have added new owners displaying stronger growth orientation than the firms that have not. Only 9% of the firms that have added new owners do not intend to grow and 45% of them have high growth orientation. This is to be compared to 18% and 15% of the firms that have not added new owners. While it indicates that new owners have positive effects on the growth orientation of the firm, there are inherent limitations in the data. As pointed out before, the growth orientation at an earlier point in time, i.e. before the ownership changes, is not known. Those firms that are growth-oriented might therefore be the ones that have added new owners in the first place. In order to investigate this relation in more detail, examples from the case studies are useful (Box 2).

Box 2 Growth orientation and new owners in MyData AB, Mecel AB and IFS AB.

Example 1: In MyData AB the main idea at start-up was to develop and commercialize a technical idea (electromechanical device) that would be licensed to others. Originally, the firm was funded by grants provided by government agencies. The two founders searched for more capital but were reluctant to sell equity in the company. When the government money dried up, they were forced to sell a majority of the shares to an investment company in order to continue the development. The new owners hired new management. The development was completed; production facilities were built up as well as sales and distribution networks, and the firm entered a growth path. Both founders left the firm after completing the original development – one for personal reasons, the other after disagreement with the new owners about technical and contractual issues.
Example 2: In Mecel AB the idea at start-up was to develop a technical idea of one of the founders. The development was financed by a large Swedish firm that was interested in using the invention in its products. Once the development proved successful, the large firm acquired the start-up firm in order to control the technology. When a part of the large Swedish firm using the invention was sold to an even larger US firm, the start-up firm was jointly owned by the Swedish and the US firm. While the new owners supplied resources for early growth, the firms' technology was considered proprietary and to be available only for its owners. Neither owner was particularly interested in further growth of the firm and it was unclear which one should be the driving force in the development of the firm. In order to obtain more freedom and to realize opportunities for growth, the CEO (one of the original founders) suggested a scheme where the firm would be wholly owned by the US firm and not be constrained by selling its services only to its owner. Since then, the firm has continued on its growth path.
Example 3: IFS AB, mentioned in the previous section, operated in a very expansive industry and there was a high demand for its types of products and services. The firm did not add new owners before it adopted an explicit growth strategy. Only when the firm went public were new owners added. While the founders came to have different growth intentions, new owners did not directly influence the growth orientation of the firm.

In the examples in Box 2 all the firms had low growth orientation at start-up, which developed into high growth orientation later on. The effects of new owners on the growth orientation of the firm ranged from non-existent in IFS AB, and negative in Mecel AB, to positive in MyData AB. Table 4 gives a schematic overview of the changes in growth orientation in each firm, the type of equity financing, and actual growth.

Table 4 Overview of changes in growth orientation, type of equity financing and actual growth in MyData AB, Mecel AB and IFS AB.

Firm	Growth orientation at start-up	Equity financing prior to becoming medium-sized	Growth orientation after equity financing	Changes in growth orientation	Actual Growth
Mecel AB	Low	Corporate acquisition	Low/Medium	Low->High	Medium
MyData AB	Low	Investment company	High	Low->High	High
IFS AB	Low	None	-	Low->High	High

IFS AB is an example where new owners were not added until the firm had reached considerable size and had high growth intentions. It seems that IFS AB was not dependent on external actors, apart from its customers, for providing the complementary resources needed for survival and growth. The expansive nature of the industry helped the firm to quickly create own revenues that enabled it to develop new products and services. Later on, it was believed that growth had a strategic value, which fuelled further growth. One could say that there were external pressures for growth at an early stage and that these were superseded by internal pressures later on.

Mecel AB and MyData AB display different effects of new owners on growth orientation. The difference might be explained by different motives of the new owners. While the investment firm invested in MyData AB in order to reap later returns, the large Swedish firm was concerned about the technology rather than the growth of Mecel AB. In both cases the new owner changed the dominant coalition of the firm. In MyData AB the dominance of technology-related motives was replaced by growth-related motives. This led to a conflict between the new owners and the founders, which eventually made the founders leave the firm. In Mecel AB the new owners shared the technology-related motives of the founders, but the activities of the firm were increased in order to serve the operations of the new owners. The growth intentions of the new owners were limited by the requirement of keeping the firms' technology proprietary. At the same time, the growth intentions of one of the founders grew stronger, leading him to propose changes in the firms' ownership in order to enable further growth.

In summary, the empirical evidence indicates a relationship between ownership changes and growth orientation. Ownership changes have been found to affect the growth orientation in NTBFs through changes in the dominant coalition within the firm. New owners, by increasing the growth orientation of firms, may make it possible for firms with low growth orientation at start-up to grow considerably. Nonetheless, new owners may instead reduce the growth orientation of the firm. Finally, growth orientation in NTBFs has also been found to change without changes in ownership.

Conclusions and Implications for Further Research

The study presented in this paper was aimed at demonstrating that it is unfortunate to separate growth intentions from other conditions of growth, especially when considering the relationship between access to resources and growth in NTBFs. Based upon previous research and theoretical reasoning, it has been argued that NTBFs are likely to add new owners in order to obtain critical resources for survival and growth, and that these new owners are likely to affect the growth orientation of the firms. The empirical analysis has confirmed that growth orientation in NTBFs can be subject to change and that new owners can have an important role in bringing about this change through their own intentions. Hence, NTBFs that have low growth orientation at start-up may obtain reinforced growth through the influences of new owners. Participants holding goals that are in conflict with the goal of growth may either stay

or leave the firm. These results have interesting implications for understanding the process of growth in NTBFs as well as for further research.

First, it is important to take multiple growth intentions and changes in growth orientation into account in models explaining firm growth. Even if there are cases where decisions about growth are due to a single individual, in many cases they are not. This is especially true in NTBFs that tend to be established by multiple founders (Cooper 1986, Utterback and Reitberger 1982). With multiple founders the decision to plan for, or accept, growth is not an individual decision, but an agreement of a group of individuals having different goals and intentions. In those cases the psychological theories of motivation are inappropriate insofar as they are only applicable on the individual level. The concept of dominant coalition becomes more reasonable as it assumes the possibility of changing or conflicting goals, taking into account changes influenced by new members, such as new owners. The use of this concept seems to be essential in further research on the dynamics of growth intentions and how they interact with other conditions for growth in NTBFs.

Second, while changes from low to high growth orientation may have positive effects on further growth, little is known about the long-term effects of such changes and the associated conflicts with and within the original founding team. According to Cyert and March (1963) the firm can survive with a set of conflicting goals by attending to them sequentially and by affording resources to pay the coalition members adequately. Because of various imperfections, there is usually a disparity between the resources available to the firm and the payments required to maintain the coalition. This leads the firm to pay the coalition members in excess of what is required to maintain them in the organization. The result is an organizational slack which functions as a stabilizing mechanism by absorbing excess resources and by providing a pool of emergency resources. Conflicting goals therefore may turn out to have a stabilizing long-term effect on the firm. Put differently, these conflicting goals can have important consequences for the balancing between effectiveness and renewal in the firm. Without growth-related goals, the firm would not attend to issues related to effectiveness of operations. Without technology-related goals, the firm might be unable to attract and keep competent technical employees, lessening its innovative capability. Further research is needed on how NTBFs attend to these different goals in practice, and what types of payments are adequate for retaining key technical personnel who may not share the goal of growth.

Third, since new owners may increase the growth orientation of NTBFs, policy-makers interested in the growth of NTBFs may be tempted to argue that stimulating equity-based financing will greatly enhance the number of growing NTBFs. While such stimulation may have an effect, the situation is not that simple. Founders of NTBFs may be reluctant to give up ownership of their firms, irrespective of their own growth intentions. They may distrust the competence of new owners and the influence these owners may have on the operation of their firms, or they may just want to stay independent (Garnsey 1995). Hence, the lack of alternative ways of financing may constrain firms that might grow given sufficient access to resources, but not where the owners are reluctant to give up control. Even if founders start with high growth orientation, resource constraints may lower their ambitions. More research is therefore needed on the interaction between access to resources, growth intentions and growth, before effective policies can be constructed for stimulating growth in NTBFs.

There is one limitation of this study that may seriously affect the validity of its results, namely the limitations in the empirical data. Due to time constraints it was not possible to gather longitudinal data tracking changes in growth intentions of the coalition members in real time. Cross-sectional data taken at a single point in time have deficiencies that are only partially offset by retrospective case studies. Memories fade and myths are created. Hopefully, the data are sufficient for creating interest in further research on the important subject of the dynamics of growth intentions and access to resources, using more suitable data-collection methods.

To use the dominant-coalition model for studying growth intentions is a continuation of the path laid out by Davidsson (1989) related to the need for more abstract concepts in entrepreneurship research. It is also a logical step when moving from personal traits, through individual intentions, to the intentions or orientation of a social group. Entrepreneurship, at least in NTBFs, is seldom a heroic individual activity dependent on superior personal qualities, but a social process involving different actors with distinctive goals.

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Notes

[1] These industries were ISIC 341, 35, 37, 38, 6112, 72002, 8323, 83249, 83292, 83299 and 932. Special rules were applied in ISIC 61120 and in ISIC 83292 and ISIC 83299 for selecting the relevant firms. See Rickne and Jacobsson (1999) for further details.

[2] These firms were involved in medical software (Helax AB), ERP software (IFS AB), biotechnology (Karobio AB), industrial printers (Markpoint AB), automotive electronics (Mecel AB), SMT assembly machines (MyData AB) and technical consulting (Semcon AB).

Paper V

Saemundsson, R. J. "On the Interaction between the Growth Process and the Development of Technical Knowledge in Young and Growing Technology-Based Firms". Submitted to an international journal for review.

On the Interaction between the Growth Process and the Development of Technical Knowledge in Young and Growing Technology-Based Firms

Rögnvaldur J. Saemundsson

Industrial Dynamics
Chalmers University of Technology
rjs@mot.chalmers.se
Tel: +46 31 7725121

On the Interaction between the Growth Process and the Development of Technical Knowledge in Young and Growing Technology-Based Firms

Abstract

The purpose of this paper is to investigate the tensions in young and growing technology-based firms between (1) increasing technological opportunities for further growth by increasing the number of separate fields of technical knowledge developed within the firm, and (2) the cost of developing and integrating knowledge from multiple fields. Data from 70 medium-sized, young technology-based firms were used to test two hypotheses related to changes in the number of separate fields of technical knowledge during growth. The results imply that tensions between technological opportunities and costs of technological development in young technology-based firms are created not only through the progress of science and technology but also through the growth process itself.

Introduction

The successful establishment and growth of new technology-based firms have been widely studied within the field of entrepreneurship research (e.g. Bollinger, Hope and Utterback 1983, Cooper 1986, Roberts 1991, Kazanjian and Drazin 1990, Oakey 1995). Despite considerable interest in the growth of new technology-based firms, few researchers have investigated what may be the most specific nature of technology-based firms as compared to other business firms, namely their dependence on technical knowledge. In a recent review Autio (2000) observes that few models have been developed specifically for explaining the growth of new technology-based firms and argues that, if the growth of new technology-based firms is a phenomenon that warrants a separate study, more research should be aimed at investigating the link between technology and growth in these firms.

The research reported in this paper is an attempt to answer Autio's call for more research on the interaction between technology and growth in new, or young, technology-based firms. The selected approach is inspired by the competence-based and evolutionary views of the firm (Foss and Knudsen 1996, Montgomery 1995) and Penrose's (1959) theory of growth of the firm. According to these views, firms are creative entities, the outcomes of ongoing processes of organizational design that provide a framework for creating and combining different kinds of productive knowledge. Understanding knowledge, organization

of knowledge, and its subsequent changes, therefore becomes the main explanatory challenge (Metcalfe 2001) in explaining both firms' competitiveness and their opportunities for further growth.

The purpose of this paper is to investigate the interaction between growth and the development of technical knowledge in young technology-based firms. More specifically the paper will investigate the tensions in young and growing technology-based firms between (1) increasing technological opportunities for further growth by increasing the number of separate fields of technical knowledge developed within the firm, and (2) the cost of developing and integrating knowledge from multiple fields.

Previous studies have identified tensions between technological diversification and increasing R&D costs in large technology-based firms (Granstrand and Sjölander 1990, Granstrand 1998). Empirical evidence (Kodama 1986, Oskarsson 1993, Patel and Pavitt 1998) shows that large industrial firms are accumulating competencies in an increasing number of technological fields. This process is driven by progress and increased differentiation of scientific and technological activities. The increase in the number of technological fields increases R&D costs, but it also increases technological opportunities that can be utilized to cover these costs. The challenge of management is to balance this tension between costs and opportunities in favour of growth and profits (Granstrand 1998).

In this paper it is argued that similar tensions exist in young and growing technology-based firms. But rather than being driven by exogenous changes in science and technology, it is argued that these tensions are inherent in the growth process of young technology-based firms and amplified through exogenous changes.

The paper is structured in the following way. First, a frame of reference will be developed on how the growth process and the development of technical knowledge jointly influence changes in the number of technical knowledge fields. Two hypotheses will be derived, whose testing will help us understand the role of the growth process in creating tensions between the costs of technological development and future opportunities for growth. Second, the method and sample

used for testing the hypothesis are described. Third, the results of the statistical analysis are presented, followed by conclusions and discussion.

Frame of Reference

The concept of the new technology-based firm has been used in a number of different ways (Bollinger et al. 1983, Storey and Tether 1998, Autio 2000). Most definitions stress the newness of the firm and the intensity of internal research and development.

This study refers to young and growing technology-based firms. These are recently established technology-based firms that have achieved reinforced growth, i.e. internal pressures are exerted for further growth (Garnsey 1998). As technology-based firms they rely on the technical knowledge of employees for the creation, detection, and exploitation of business opportunities (Granstrand 1998). They are likely to contain a specialized collection of technical knowledge related to their focus of activity. This collection of technical knowledge is extended and refined by a group of employees specialized in such activities. This group of employees will be referred to as technical employees, and it is the development of their knowledge that this paper focuses on.

In the following three sections the proposed interaction between the growth process and the development of technical knowledge will be developed. In the first two sections it will be investigated how the number of separate knowledge fields changes, on one hand during growth, and on the other hand through the development of technical knowledge in firms. Finally, the different strings will be pulled together investigating how the two processes interact in young and growing technology-based firms leading to the proposed hypothesis.

The process of firm growth

Penrose (1959) describes the process of firm growth as recurrent periods of expansion of the firms' resource base and administrative structure. This expansion is based on productive opportunities identified by the firm's entrepreneurs and the managerial capacity to plan and carry out the exploitation of these opportunities.

The ability to identify new productive opportunities is dependent on the knowledge of the firm's entrepreneurs. Penrose (1959) argues that this knowledge will increase during expansion and that firms will always have new possibilities and inducements for further expansion, even if external conditions are unchanged. For technology-based firms this means that technical knowledge available to the firms' entrepreneurs will increase during growth, making it possible to identify opportunities for further growth.

Further growth may be within existing areas of specialization (technology and markets) or through diversification into new areas with different combinations of new and existing technologies and markets. While diversification may make firms less vulnerable to abrupt changes in their environments, it puts strain on the firms' resources, especially in competitive and technologically progressive environments. This restricts the number of fields that a firm can support at any given time (Penrose 1959, pp. 104-152).

As firms grow larger, the number of formal structural components, such as levels and divisions, are likely to increase within existing areas of specialization (Penrose 1959, Blau 1970). This increases the division of labour, which is linked to knowledge development. Not only is increased division of labour conducive to the development of knowledge, but more knowledge will also increase the possibility of further, or different, division of labour (Loasby 1998). There is therefore a possibility of positive feedback between division of labour and knowledge.

Parallel to increased division of labour, knowledge becomes increasingly specialized and differentiated within each structural component. The attainment of feedback between division of labour and knowledge, and its value for the firm, is therefore dependent on the administrative structures used to coordinate the development and use of knowledge across multiple structural components (Fransman 1994, Grant 1996, Kogut and Zander 1996, Loasby 1998).

Thus, growth is likely to increase the number of separate knowledge fields in two ways. First, firms may add new knowledge fields related to diversification into new areas of specialization. Second, firms may increase the division of labour within existing areas of specialization leading to the creation of separate and

differentiated fields of knowledge. While both will increase the knowledge available to the firm, and enhance its ability to identify new opportunities, increased resources and managerial competence are needed to coordinate the development and use of knowledge within multiple fields.

Despite paying attention to the importance of industrial research for diversification, Penrose (1959) was not specifically concerned with the development of technical knowledge. In the next section, previous research on the development of technical knowledge in firms will be reviewed with a focus on the relationship between the development of technical knowledge and the increase in the number of separate knowledge fields.

Development of technical knowledge in firms

The most basic factor directing firms to develop new technical knowledge for use in their products and services is competitive pressure from other firms (Pavitt and Steinmueller 2002). Failure to develop new technical knowledge may render products and services uncompetitive and make firms vulnerable to the process of creative destruction (Schumpeter 1942). Such competitive pressures are different in different industries (Pavitt and Steinmueller 2002) and are likely to be most pressing in dynamic environments (Eisenhardt and Martin 2000) and in technology-based firms (Granstrand 1998).

A number of researchers have observed that large industrial firms are increasingly becoming multi-technology, i.e. they actively develop technical knowledge within a number of separate fields (Kodama 1986, Pavitt, Robson and Townsend 1989, Granstrand and Sjölander 1990, Oskarsson 1993, Granstrand 1998, Patel and Pavitt 1998). The main argument of these authors is that this increase in the number of technological fields is due to the progress of science and technology as well as the increased differentiation of scientific and technological fields and customer requirement. In order to sustain a competitive position in their product markets, firms need to be able to respond to the competitive pressures of new technological opportunities, and at the same time integrate new technologies with existing ones.

Even if there are external pressures for adding new fields of technical knowledge, there are internal pressures for stability of the number of fields that a firm is active in. Due to uncertainty, bounded rationality and reliance on historical experience, firms tend to search for new technical knowledge in areas that enable them to build upon their established knowledge and resource base (Nelson and Winter 1982). This makes the technological profile of firms stable over time, and differentiated from most other firms, except those that compete in the same product markets (Patel and Pavitt 1998).

Internal pressures for stability in the development of technical knowledge are overcome in two ways. First, employees may develop technical knowledge by themselves, independently of the firm. There are various studies that report how technical knowledge that has been developed by groups of individuals, so-called skunk-works, have had major effects on the strategic direction and the technological profile of firms (e.g. Burgelman 1994). Second, firms may have explicit exploration strategies (Rosenkopf and Nerkar 2001), which aim to increase the absorptive capacity of the firm (Cohen and Levinthal 1990) – i.e. its ability to detect and respond to technological change – or which are responses to competitive threats.

Explicit exploration strategies are related to the strategic management of technology. The increased need to include multiple technologies in products and services has escalated R&D costs in firms (e.g. Granstrand 1998). These increased costs and the inherent uncertainty of technological development have challenged managers to strategically align the pursuit of technological development with other business objectives (Coombs 1994). This includes various methods for technology sourcing and exploitation (Granstrand and Sjölander 1990).

Cognitive aspects of technical knowledge are likely to influence the challenges faced by management when trying to balance the costs of development and the uncertainty of its successful exploitation. Stankiewicz (2000, 2002) uses the concept of design space to describe these differences. A design space is a combinatorial search space generated by a set of operants. Operants are units of technical knowledge, or artefacts, that link structures and processes with functions and use. Combinations of these operants are utilized when designing and assembling artefacts. Design spaces evolve through time in two basic ways: by the

introduction of new operants, and by becoming increasingly structured and articulated. Problem-solving, or design, within a well-structured design space is less uncertain and costly than problem-solving within a poorly structured design space.

While the properties of design spaces can vary on a continuum, two extremes are identified by Stankiewicz (2002):

> *Discovery-driven technologies* are characterized by poorly articulated and weakly structured design spaces. Solutions to problems have to be discovered rather than designed, and innovation is driven by opportunity rather than demand. Technologies near the scientific frontier are an example of discovery-driven technologies. Technical development processes are characterized by long duration, high costs and high uncertainty.
>
> *Design-driven technologies* are characterized by structured and well-articulated design spaces with known boundaries. Search processes are sequential and iterative rather than parallel, and innovation is demand-driven. Technologies that are based on scientific knowledge, but are far away from the scientific frontier, are largely design-driven. Technical development cycles are relatively short and costs and uncertainty are relatively low.

The development of technical knowledge at the two extremes not only differs in terms of the cost of development and the uncertainty of the viability of the resulting technological opportunities, but is also likely to differ in terms of increases in the number of distinct fields of technical knowledge. Technical development within design-driven technologies is likely to be incremental and related to the refinement of the existing design space. This refinement may be due to development outside the firm, but is unlikely to lead to changes in the number of technological fields where the firm is active. Technical development within discovery-driven technologies is likely to be more fragmented and unpredictable. While much of the development consists of refining an existing design space, the design space is also likely to be extended through new operants that are discovered. The extension of the design space may lead to its restructuring, e.g.

through the process of technological fusion (Kodama 1986), which may increase the number of technological fields that firms need to master.

There are thus three reasons why technical development within discovery-driven technologies is more challenging for managers, as compared to design-driven technologies. First, their business value is more uncertain. Second, they take longer time, and are more costly, to develop. Third, they are more likely to develop into multiple fields that need to be integrated.

In this and the previous section, two processes have been identified that create tensions between (1) increasing technological opportunities by increasing the number of technical knowledge fields developed within the firm, and (2) the cost of developing and integrating knowledge from multiple fields. One is the process of growth, where the number of separate knowledge fields is likely to increase due to increased differentiation within existing areas of specialization or diversification into new areas of specialization. The other is the development of technical knowledge in firms, where progress in science and technology requires firms, for competitive reasons, to increase the number of technological fields that firms need to master. Both processes will influence the tension during growth between increased opportunities for growth and the cost of the development and integration of multiple fields of technical knowledge. The next section will seek to explain how these two processes interact in young and growing technology-based firms.

The interaction between growth and the development of technical knowledge in young and growing technology-based firms

In this section two hypotheses will be proposed. The first concerns the expected changes in the number of separate fields of technical knowledge during growth in young technology-based firms. The second concerns the expected moderating effect of differences in the properties of the firms' design spaces on these expected changes. The former predicts the combined effects of the growth process and technological development on increasing opportunities for growth. The latter makes it possible to infer the role that each of the two process of growth and the

development of technical knowledge plays in creating and resolving the tensions between opportunities and costs.

The processes of growth and technological development can be seen to interact in basically two ways to influence the changes in the number of separate fields of technical knowledge during growth. First, firms may add new fields of technical knowledge for competitive reasons. Usually this happens due to external changes in science and technology and the degree of inertia in the firm will determine whether the external changes are identified and acted upon. The new fields of technical knowledge will provide new opportunities for growth. Second, an increase in size will increase the division of labour in the firm leading to an increased number of specialized and differentiated knowledge fields. This is not only true of functional specialization between, for example, research and development, production and sales, but also within each area of functional specialization. This includes activities related to the development of technical knowledge within the firm. Increased specialization and differentiation will also provide new opportunities for growth.

Responding to changes in science and technology involve the addition of new fields of technical knowledge that the firm did not master before[1]. Increased specialization and differentiation of activities related to the development of technical knowledge leads to the 'splitting up' of technical knowledge fields that the firm has previously mastered. Both type of changes lead to an increase in the number of separate fields of technical knowledge that have to be coordinated and managed.

Based on the above, the interaction between growth and the development of technical knowledge is likely to result in an increase in the number of technological fields during growth. This is especially true for young and growing technology-based firms for three reasons. First, at start-up the focus of activity in technology-based firms is usually on innovation based on the founders' specialized technological expertise (Oakey and Cooper 1991, Eisenhardt and

[1] The relatedness between the new fields and the existing ones can vary greatly, which will affect the ease of integration.

Schoonhoven 1990). Before the innovation becomes successful and reinforced growth is attained, this specialized expertise needs to be complemented by other fields of technical knowledge (Teece 1986, Garnsey 1998). Second, because small firms tend to have few organizational rigidities (Dodgson and Rothwell 1991), they are likely to adapt to external changes in science and technology. This adaptability is increased by inflow of new employees during growth (March 1991). Finally, the increased specialization and differentiation of activities related to the development of technical knowledge increase the number of separate fields of knowledge development. Thus, the first hypothesis of this paper becomes:

H1: The number of separate fields of technical knowledge is likely to have increased in young and growing technology-based firms since start-up.

While the number of separate fields of technical knowledge is likely to increase as young technology-based firms attain reinforced growth, this does not tell us much about the tensions between the increase of opportunities for further growth by increasing the number of technological fields and the associated costs. In order to learn more, it is instructive to investigate how the characteristics of design spaces moderate the increase in the number of technological fields.

Differences in the characteristics of design-driven and discovery-driven technologies polarize the influences of the two processes of growth and technological development. Due to the higher costs of development and coordination, firms depending on discovery-driven technologies ('discovery-driven firms') are less likely to add new fields of technical knowledge than firms depending on design-driven technologies ('design-driven firm'). For the same reasons, and due to the unpredictability of development, activities related to the development of technical knowledge are likely to be less specialized and differentiated in discovery-driven firms than in design-driven firms for a given size. Thus, the increase in the number of technological fields is expected to be less for discovery-driven firms than for design-driven firms according to the logic of the growth process. But the contrary is implied by the logic of the technological development process. External changes in discovery-driven technologies are expected to be more common and discovery-driven firms are likely to be more open to external changes, i.e. they have less inertia against identifying external

changes. This is especially true for science-based firms. Hence the external, competitive pressure to add new technological fields is higher for discovery-driven firms than for design-driven firms.

The above polarization indicates three possible scenarios that are mutually exclusive. In the first scenario, the growth process constrains the number of technological fields that can be managed. Failure to take this into account will constrain growth or reduce the probability of survival. If this is the case, the increase in the number of technological fields during growth is likely to be less for discovery-driven firms than for design-driven firms. In the second scenario, external changes in science and technology require firms to increase the number of technological fields in order to survive competitive pressures. This means that adding technological fields and managing the associated costs is a precondition for attaining growth. In this case the increase in the number of technological fields is likely to be higher for discovery-driven firms than for design-driven firms. In the forth scenario, there is no predominant effect of either the process of growth or the development of technical knowledge. In this case there would be no significant difference between changes in the number of technological fields during growth for discovery-driven and design-driven firms.

The first scenario is partly supported in recent empirical research by Cantwell and Santangelo (2000), who found that firms belonging to science-based industries show a greater focus of technological specialization than firms in other industries. In order to test whether the growth process sets important constraints on the development of technical knowledge, allowing for a continuum between design-driven and discovery-driven firms, the following hypothesis is proposed:

H2: The increase in the number of technological fields in young and growing technology-based firms is likely to be negatively moderated by the degree to which the firms develop discovery-driven technologies.

H2 suggests that the more discovery-driven a firm is, the less the number of separate fields of technical knowledge will increase during growth, all else being equal. If the hypothesis is confirmed, it suggests that the growth process itself can

constrain the number of technological fields developed by firms, even if there are competitive pressures, or opportunities, to increase them.

In the next section the methods and sample used for testing the two hypotheses are presented.

Methods and Sample

In order to empirically test the hypotheses presented in the previous section, a web-based survey study of young, medium-sized, technology-based firms in Sweden was performed. A cross-sectional study was selected in order to enable statistical testing of the hypotheses.

This study uses process logic to explain relationships between independent and dependent variables through deductive reasoning. The processes of firm growth and technological development are therefore not directly observed. This approach is one of the three ways identified by Van de Ven (1992) for empirically studying processes. While Van de Ven stresses the importance of investigating processes in real time, such an approach is both costly and time-consuming when studying growth processes. Due to the uncertainty about whether and how quickly firms will attain reinforced growth, large samples of firms need to be studied for a considerable time. Such an approach was not feasible for this study.

This study is concerned with changes in number of technological fields since start-up. Since the study is cross-sectional and retrospective, it is important to study firms that have attained sufficient size for observing possible changes in the number of technological fields. While the degree of complementary technologies needed to ensure reinforced growth depends on the number of technological fields available at start-up, division of labour and the expected increase in the number of knowledge fields is related to the number of employees. Empirical studies of firm growth that have used a life-cycle perspective have emphasized the transition from an informal, more entrepreneurial organization to a more formal, more growth-oriented, professional organization (e.g. Hofer and Charan 1984, Hanks and Chandler 1994, Garnsey 1998). One of the characteristics of the latter is increased division of labour among employees. While each firm is likely to enter this transition at a different size, it is preferable to choose a lower limit on the

number of employees for firms included in the study. In a study using the same population of Swedish firms as used in this study, Semundsson and Lindholm Dahlstrand (1999) argued that firms having become medium-sized or larger (≥50 employees) had gone through that transition. Only firms that had become medium-sized and larger, therefore, were included in this study.

Sample

The sample of firms used in this study was extracted from a population of technology-based firms in Sweden established between 1975 and 1993. The identification of the population was based on educational data from the Swedish Bureau of Statistics (SCB). Firms whose competitive strength was based on employees' knowledge and skills within the fields of engineering, natural sciences or medicine, and which belonged to industries that can be termed knowledge-intensive, were included in the sample. This included firms in both manufacturing and industry-related services (see Rickne and Jacobsson (1999) for a more detailed description of how the population was identified). In 1993 around 1350 firms were included in the population. Of these, 1027 were still registered at the end of year 2001.

Using data from the Affärsdata database, which holds accounting information from all limited liability companies in Sweden, 145 firms of the 1027 firms mentioned above were identified as medium-sized or larger. Closer inspection revealed that 51 of these 145 firms were different from the firms originally found in the database. Due to mergers and integration with acquiring firms, the original firms had lost their identity. These 51 firms were therefore excluded, leading to a population of 94 firms that were medium-sized and larger.

Due to its small size, the whole population of medium-sized firms was used for data collection. Technical directors of the 94 firms were contacted by email and asked to answer a short web-based questionnaire. If the firm had no such position, e.g. in many consulting firms, the CEO was contacted. The questionnaire included questions on the degree of the science-technology interaction as well as questions on changes in the technical knowledge base from start-up. Apart from the original

email, two additional emails were sent as reminders to those that had not yet answered.

Of the 94 firms asked, 72 responded and answered the survey. Of these, 70 answers were useful for analysis, resulting in a response rate of 74%. The high response rate can be attributed to two factors. First, the conciseness of the questionnaire, which could be answered in less than 10 minutes, and second, the use of email and the World Wide Web, which made it easier to reach directly to the technical directors and allowed them to respond instantly.

Variables and measures

Changes in the number of technological fields: To measure the number of technological fields, respondents were asked to estimate the current number of separate fields of technical knowledge relative to the number of fields at start-up. The respondents were asked to select an answer on a nine-point scale ranging from 'considerably fewer', through 'no change', to 'considerably larger'.

Changes in knowledge are hard to measure, even in a qualitative manner. Distinctive knowledge fields exist at different levels of abstraction with a different degree of cognitive distance between them. It may be difficult to make a distinction between a sub-field at a lower level of abstraction, and a different field at the same level of abstraction. Even finding a common level of abstraction might be problematic. Using the current measure, it is not possible to make this distinction. Measuring subjective change nevertheless enables the respondent to judge the degree of change as experienced by the firm. While more complex schemes could have been administrated for increased information, it was judged that the possible cost in lower response rate was not worth the effort considering the small sample available.

Another problem with the measure is the possibility of skewed, non-normal distribution of answers. It is hypothesized from previous theory that growth will lead to an increased number of separate knowledge fields. Therefore, it is likely that answers will be clustered in the upper half of the scale. Because a decrease in the number of fields could not be ruled out as impossible, and because of the possible disturbance from having an asymmetrical scale, 'No change' was used as

a symmetric middle point. Instead, a relatively high resolution (9 points) was used in an attempt to avoid skewed distributions.

Degree of dependence on discovery-driven technologies: The degree of interaction with science was used as a proxy for measuring the degree of dependence on discovery-driven technologies. The degree of interaction with science refers to how actively the technical employees in the firm take part in scientific activities.

Technology and science can be seen as semiautonomous streams of activity where science tends to build upon old science and technology on old technology, but with a different degree of mutual interaction (de Solla Price 1965, Faulkner 1994). The interaction is complex because it can be either direct, through knowledge flows, or indirect, through textbooks used in training and education, research skills, methods and equipment, and may vary in time and between different sectors and technologies (Pavitt 1991). For example, there is a high degree of interaction between technology and science within chemistry and biotechnology, while the degree of interaction is low in most mechanical engineering. When there is a high degree of interaction, technologists keep up with the 'research front' in science, and even contribute to it – while when there is a low degree of interaction there may be no scientific contribution at all, or the contribution may be through textbooks used in engineering education. In between, technical advance in some industries and technologies may depend upon the use of scientific research skills, but without close interaction with academic research.

The degree of science-technology interaction should be highly correlated with positions on the continuum between design-driven and discovery-driven technologies described by Stankiewicz (2002). A low degree of science-technology interaction corresponds to design-driven technologies where the scientific base of the technology is well known through textbooks. A high degree of science-technology interaction corresponds to discovery-driven technologies, where development of the technologies is driven by scientific discoveries.

Two different variables were used to measure the degree of the interaction with science. They capture two aspects of science-technology interaction: use of direct knowledge-flows and the use of employees with research skills. Use of direct

knowledge-flows was operationalized by using the degree of scientific publishing. Knowledge transfer between communities of science and technology is mainly person-embodied, involving personal contacts, movements and participation in networks (Pavitt 1991). As scientific publishing is needed in order to enter and retain a position in the scientific networks, the degree of scientific publishing is a proxy of network involvement. The degree of scientific publication of firms' research was measured by using a five-point ordinal scale (Never, has happened, seldom, often, very often). The use of employees with research skills was measured as the current number of employees working on technical development who had a PhD degree in engineering, natural sciences, or medicine. A four-point ordinal scale was used (None, 1-4, 5-9, ≥10).

Control variables: Three additional variables were used as control variables: age, the number of employees in year 2000, and sales per employee in year 2000[2]. The last two were added from a secondary data source (the Affärsdata database mentioned before).

These three controls were selected for different reasons. First, the age of the firm is likely to affect the build-up of managerial competence in the firms. If science-intensive firms are systematically younger than those that are less science-intensive, lower age might explain less increase in the number of knowledge fields. Younger firms are likely to have experienced less external change in science and technology and have less developed management competence. Second, previous studies have indicated that new technology-based firms that base their operations on university research, such as university spin-offs, grow more slowly than other new technology-based firms (Lindholm Dahlstrand 1997). If they are systematically smaller than other firms, it might explain the smaller increase in the number of separate knowledge fields. Third, from the discussion above on discovery-driven design spaces one could expect that science-intensive firms have a longer time to market than other firms. They may therefore need extensive capital financing and headcount before reaching substantial sales. In that case one would expect that the firms would be less constrained by the growth

[2] Year 2000 was selected, as full information from 2001 was not available for all the firms.

leading to larger changes in the number of knowledge fields, cancelling out the predicted effect of the science-technology interaction.

Descriptive statistics: Table 1 shows descriptive statistics and correlations for the independent variables and the control variables. As the variables measuring science-technology interaction are ordinal variables with very unequal distances between successive values, descriptive statistics are not shown for those variables. Their frequency is instead tabulated in Table 2.

		Descriptive Statistics				Correlations[a)]				
	Variables	Mean	SD	Min	Max	1	2	3	4	5
1	Scientific publications	-	-	-	-	1.000				
2	Number of PhDs	-	-	-	-	0.371**	1.000			
3	Age	16	4	10	27	-0.177	0.004	1.000		
4	Employees	161	124	31 [b)]	690	0.026	0.031	-0.037	1.000	
5	Sales/employee (SEK)	1366	1076	485	8238	-0.008	0.065	0.016	-0.069	1.000

a) Kendall's rank correlation. b) The employee data are from year 2000. All firms included in the population had become medium-sized or larger in year 2001. **p<0.01

Table 1. Descriptive statistics for independent variables and control variables.

Except for the expected correlation between scientific publications and the number of PhDs, there is no significant correlation between the independent variables and the control variables.

		Scientific Publications				
		Never	Has happened	Often	Very often	Total
Number of PhDs	None	41%	7%	4%	0%	53%
	1-4	20%	11%	3%	3%	37%
	5-9	0%	3%	0%	1%	4%
	≥10	1%	1%	0%	3%	6%
	Total	63%	23%	7%	7%	100%

Table 2. Frequencies within each category along the two indicators of the degree of interaction with science.

It is interesting to note that of the 26 firms (37%) that report scientific publishing, eight do not report any PhD as currently employed. It is also interesting to note that most of these firms are involved in electronics and software development, some serving the life sciences. Gaining access to scientific knowledge flows therefore seems, at least in some cases, not to require employees with a PhD degree.

Analysis

To test the hypotheses, non-parametric, bivariate statistical analysis was performed. Additionally, Kendall's partial rank correlation was used for analysing the effects of the control variables.

Non-parametric testing was used because most of the variables were measured on an ordinal scale and few did follow a normal distribution. Non-parametric tests require much weaker assumptions of the scale and distribution of variables than parametric tests that assume an interval scale and normal distribution of variables. Their power efficiency is relatively high for moderate size samples and they should be used in instances where there is reasonable doubt of either an interval scale or normality (Blalock 1979, pp. 265-266).

Bivariate tests were used because of the nature of the hypotheses. The goal was not to develop a model that would explain all variance in the changes in the number of separate knowledge fields during growth. Rather it was to test whether a certain variable was likely to have a certain effect on another variable. The bivariate analysis was extended by investigating the effects of three control variables. As the tests were testing for difference in only one direction, one-tailed tests were used. In all cases the significance level was set at 5%.

The effect of different degree of interaction with science was compared in two ways. First, they were compared for different groups of firms representing the endpoints of a continuum between low degree of interaction and high degree of interaction. Second, the degree of interaction was correlated with the changes in the number of technological fields.

Scientific publications and the number of employees with a PhD degree were used as two indicators of interaction with science. These two indicators not only provide different ways of measuring different degrees of interaction with science, but also themselves represent different degrees of interaction with science. While the PhD degree is a measure of scientific research qualifications, it does not imply continued research activities. The measure of the number of employees with a PhD degree therefore measures a lower degree of interaction than does the measure of scientific publishing.

The comparison of the different groups was based on two-sample comparison using the Mann-Whitney test. For each indicator the answers were divided in two groups, one of high intensity of interaction, and one of low intensity of interaction. On one hand, firms were classified into the high-intensity group if the results of their research had been published in scientific publications. Those that had not were classified into the low-intensity group. On the other hand, firms were classified into the high-intensity group if they had at least one employee holding a PhD degree, and into the low-intensity group if they had none. These high- and low-intensity groups correspond to discovery-driven firms and design-driven firms.

The comparison along each dimension was tested by correlation analysis. Kendall's rank correlation was used, and Kendall's partial rank correlation was used to control for the effects of age, size, and sales per employee. No confounding effects of age, size, and sales were found.

A limitation of the study that is important to keep in mind when interpreting the results is the survivor bias inherent in the data. Because the data only include survivors, they can only answer questions about the characteristics of the surviving firms that have attained reinforced growth, not questions related to the characteristics of all firms belonging to the population of YTBF. Hence, we can only make inferences from our data about the interaction between growth and technology in surviving firms that have attained reinforced growth, not for YTBF in general.

Empirical Results

In this section the results from the analysis of the empirical data will be presented. This will be done in two parts. First, the hypothesis about the changes in the number of separate fields of technical knowledge during growth will be tested, followed by the testing of the hypothesis on the moderating effect of the degree of dependence on discovery-driven technologies.

Changes in the number of separate fields of technical knowledge

In an earlier section it was hypothesized that the number of separate fields of technical knowledge was likely to increase as the firm attained reinforced growth. Table 3 provides descriptive statistics that support this hypothesis.

	Changes in the number of technological fields
Mean	7.6
Std. Dev	1.2
Low	4
High	9
Above 'No change'	92.9%

Table 3. Descriptive statistics for changes in the number of technological fields since start-up. Changes are measured on a 9-point scale (1-9) ranging from 'Considerably fewer', through 'No change', to 'Considerably larger'.

We see clearly that almost all firms report that the number of technological fields has increased during the process of growth. Only five firms, less than 8%, report that the number of their fields of technical knowledge has stayed the same or decreased during growth. The measurement scale, as expected, is not fully utilized, and the distribution of the answers does not follow a normal distribution. Around ¼ of the firms report considerable change (nine, or the highest value on the scale), while the lowest value is four. The mean is found in the middle between 'No change' and 'Considerable change'.

The moderating effect of the degree of dependence on discovery-driven technologies

The next step is to test the second hypothesis related to the moderating effect of the degree of dependence on discovery-driven technologies. The test will proceed in two stages.

First, it will be tested whether there is less increase in the number of separate knowledge fields in those firms that have a high degree of interaction with science (high-intensity firms) compared to those firms that have a low degree of interaction with science (low-intensity firms). This will be done for two indicators of science-technology interaction: scientific publishing and employment of PhDs.

Second, the effects of different degree of interaction along each indicator will be tested by correlation analysis.

Table 4 shows the comparison between the high-intensity firms and low-intensity firms, using two indicators of science-technology interaction.

	Mean Ranks of the number of technological fields			
	Low intensity firms	High intensity firms	Z-score	p-value[a)] (one-tailed)
Scientific publications $N_{High\ intensity} = 26$ $N_{Low\ intensity} = 44$	40.3	27.5	-2.63	0.00423
PhDs $N_{High\ intensity} = 33$ $N_{Low\ intensity} = 37$	35.3	35.7	-0.0732	0.529

a) Mann-Whitney test

Table 4. Comparison between the changes in the number of technological fields in firms having high degree of interaction with science (high-intensity firms) and firms having low degree of interaction with science (low-intensity firms).

When the interaction with science is measured using scientific publications, the change in the number of technological fields is significantly less in the high-intensity firms than in the low-intensity firms ($p<0.01$, one-tailed). This supports Hypothesis 2 that changes in the number of technological fields are negatively moderated by the degree of dependence on discovery driven technologies. When the interaction with science is measured as the employment of PhDs, there is no significant difference between the high-intensity firms and the low-intensity firms. This finding does also support Hypothesis 2 but in a different way. Scientific publications represent a higher degree of interaction with science than the employment of PhDs. Hence, that significant moderating effect is found when using scientific publications but not when using the number of PhDs supports the idea that the increase in the number of technological fields during growth is less for discovery-driven firms than for design driven firms.

In Table 5 the results of the correlation between the degree of interaction with science and changes in the number of technological fields are presented for the two indicators of science-technology interaction.

	Degree of interaction with science	
	Scientific publication	PhDs
Changes in the number of technological fields	-0.274*	0.0341ns

* = significant at p<0.01 (one-tailed). ns = not significant at p<0.05 (one-tailed).

Table 5. Kendall's τ for the correlation between changes in the number of technological fields and the degree of interaction with science.

The results in Table 5 are similar to the results in Table 4. The negative moderation of the degree of dependence on discovery-driven technologies is supported when using the scientific publication indicator. Likewise no significant effect is found along the PhD indicator. The results therefore provide further support for Hypothesis 2.

Conclusions and discussion

The purpose of this paper has been to investigate the interaction between the growth process and the development of technical knowledge in young technology-based firms. The focus has been on the tensions between increasing opportunities for further growth by increasing the separate fields of technical knowledge, and the associated costs of doing so.

Based on Penrose's (1959) theory of the growth process and previous research on the development of technical knowledge in firms, it has been argued that both processes interact to create tensions between opportunities and costs. Two hypotheses were proposed. First, it was hypothesized that the number of separate fields of technical knowledge would increase during growth. Second, it was hypothesized that this increase would be negatively moderated by the degree of dependence on discovery-driven technologies. Empirically, the degree of interaction with science was used as a proxy for the degree to which firms depended on discovery-driven technologies.

Based on the empirical support for the hypothesis, the following conclusions can be made. First, technical opportunities in young and growing technology-based firms are likely to increase through the addition of separate fields of technical knowledge. Second, cognitive aspects of technical knowledge influence the degree of the increase of separate knowledge fields during growth. The increase in

the number of technological fields is likely to be lower in firms that depend on the development discovery-driven technologies. These technologies are more uncertain in their business utility, take longer to develop, have higher costs of development, and have higher costs of integration with other technologies.

There are two possible interpretations of these conclusions. The first is to take them at face value. Technological opportunities for growth increase during growth due to the interaction between the growth process and the development of technical knowledge. How challenging it is to manage this interaction in terms of higher costs of development and integration depends on the cognitive properties of the technical knowledge, being most challenging for firms that have a high degree of science-technology interaction. Surviving firms depending on a high degree of science-technology interaction that have obtained reinforced growth have responded to these challenges by developing fewer fields of technical knowledge than other firms. The implication for managers is therefore to be aware of the higher uncertainty, higher costs of development and higher costs of integration that are related to closer interaction with science when making decisions about technological diversification, or differentiation within existing areas of specialization. While adding new fields of technical knowledge and 'splitting up' existing ones increase opportunities for growth, firms may not be able to manage the associated increase in costs that are needed to exploit these opportunities.

The second interpretation, which does not exclude the first one, is more daring and far-reaching. Due to the specific differences between discovery-driven technologies and design-driven technologies, it is possible to make inferences about the different roles that the process of growth and the development of technical knowledge play for the creation and resolution of the tensions between opportunities and costs. These differences polarize the influences of the two processes, in such a way that the increase in the number of separate fields of technical knowledge is likely to be smaller for discovery-driven technologies according to the logic of the growth process, while it is likely to be larger according to the logic of technological development. That it turns out to be smaller suggests that the logic of the growth process takes precedence over the logic of technological development.

There are two main implications of the conclusion about the precedence of the logic of the growth process over the logic of technological development. First, it implies that tensions between technological opportunities and the costs of technological development in young technology-based firms are created not only through the progress of science and technology, as suggested by e.g. Granstrand (1998), but also through the growth process itself. This may not be very surprising, considering that it can be seen as a variation of the basic Penrosian (1959) theme, but the theme has received little attention in recent research on the growth of firms.

Second, it implies that in young and growing technology-based firms it is more important to manage according to the logic of the growth process than the logic of technological development. While this seems obvious at first sight, there are hidden implications in the statement. To manage according to the logic of technological development is to manage according to the logic of technological competition (Pavitt and Steinmueller 2002). Thus, it amounts to saying that during growth it is more important to manage according to the logic of growth rather than the logic of technological competition.

But saying that it is more important to manage according to the logic of the growth process than the logic of technological development is not the same as saying that it is unimportant to manage according to the logic of technological competition. It only means that it is not sufficient to manage according to the logic of technological competition in order to attain growth. The logic of the growth process constrains how technological competition can be managed, increasing the challenge for management. This implies that young technology-based firms may have to be selective regarding the technological fields they choose to add, in order to satisfy the requirements of growth and competition. Being forced to do so may increase the probability of failure, as these firms are not able to build a portfolio of technical knowledge in a number of fields in order to be better prepared for future competition.

It could be argued that the study does not provide sufficient evidence to make general conclusions about the role of the growth process for creating and resolving tensions between opportunities and costs. That is, the results on the role of the growth process are peculiar to firms with a high degree of interaction with

science. It is true that these general conclusions are based on the assumption that the growth process displays the same logic independently of the cognitive properties of the technical knowledge that the firms depend on. This assumes that characteristics which are displayed under one condition, e.g. for discovery-driven firms, can be understood as expressions of the general characteristics of the growth process. While this may not seem an unreasonable assumption, further research is needed on the interaction between the processes of growth and development of technical development.

Penrose's (1959) investigation has been very influential for the study of competitive advantage in firms. These studies have nevertheless not given much attention to the main Penrosian theme of the tensions inherent in the growth process (Rugman and Verbeke 2002). The present study points to some opportunities for reconnection with the current research on competitive advantage in order to better understand the interaction between technology and growth in young technology-based firms, as well as the relationship between managing according to the logic of growth and managing according to the logic of technological competition.

In this study the processes of growth and development of technical knowledge have not been observed directly. Further studies should seek to observe the interaction between these processes more directly, through either retrospective case studies or longitudinal studies in real time. While longitudinal studies are preferred due to better quality of data, they are expensive and time-consuming to conduct when studying the growth process.

Better understanding of the interaction between growth and the development of technical knowledge might be facilitated by more precise conceptualisation of technical knowledge than was used in this study. Here it was not possible to distinguish between increases in the number of fields due to diversification into new fields and differentiation within existing fields. In order to be able to do so, more attention must be given to how different fields are delineated and how this delineation evolves over time.

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Paper VI

Saemundsson, R. J. "Technical Knowledge Seeking in Young and Growing Technology-Based Firms: Incentives and Direction". Submitted to an international journal for review.

Technical Knowledge-Seeking in Young and Growing Technology-Based Firms: Incentives and Direction

Rögnvaldur J. Saemundsson

Industrial Dynamics
Chalmers University of Technology
rjs@mot.chalmers.se
Tel: +46 31 7725121

Technical Knowledge-Seeking in Young and Growing Technology-Based Firms: Incentives and Direction

Abstract

The purpose of the paper is to investigate technical knowledge-seeking activities in young and growing technology-based firms. Changes in technical knowledge-seeking activities were traced using a single illustrative case study of a young and growing technology-based firm. The results of the study show how strong commitment to the business concept of the emerging firm affects the direction of technical knowledge-seeking in a way that increases the vulnerability of the firm. New employees who are not as committed to the original business concept bring with them different incentives for knowledge-seeking, which lead to search in new directions. These directions become important for the renewal of the firm's knowledge base. It is therefore suggested that differences in individual incentives may affect the direction of technical knowledge-seeking activities, and correspondingly, that multiple incentives are an important source of diversity in technical knowledge creation.

Introduction

Growth of new technology-based firms has been widely studied within the field of entrepreneurship research. In his review on the subject, Autio (2000) notes that despite the large number of studies, few researchers have investigated the relationship between technical knowledge and growth, and how this relationship evolves over time. This is somewhat surprising considering that the dependence on technical knowledge is what may be the most specific feature of technology-based firms as compared to other business firms (Granstrand 1998).

Much attention has lately been given to the importance of knowledge for competitiveness of firms (Winter 1987, Grant 1996). Researchers have claimed that firms exist because of their superior ability to create and coordinate knowledge (Loasby 1998, Kogut and Zander 1996) or that firms' ability to learn is their most valuable competitive asset (Teece, Pisano and Shuen 1997). Much attention has also been given to the cumulative nature of such learning, i.e. how the current activities, or routines, shape the knowledge that is developed within firms (Nelson and Winter 1982, Helfat 1994). While cumulative learning enables effective operation of the firm, such knowledge dynamics may also cause firms to become rigid and vulnerable to change (Leonard-Barton 1992).

Most of this literature can be traced back to the work of Edith Penrose (1959) and her theory of the growth of the firm. Penrose argued that productive opportunities of firms

are dependent on the resources and knowledge available to the firm. She also argued that, as resources accumulate and knowledge increases during growth, there would always be new opportunities for further growth. Her argument is partly based on her assumption that firms' personnel learn not only from taking part in the operations of the firm, but also by deliberately and voluntarily searching for new knowledge. This might be done proactively through industrial research, but she also stated that "both an automatic increase in knowledge and an incentive to search for new knowledge are, as it were, 'built into' the very nature of firms possessing entrepreneurial resources of even average initiative." (Penrose 1959, p. 78).

Penrose (1959) is unspecific about how these incentives are 'built into' the firm. Because of the design of her theory one has to suspect that the administrative structure of the firm, comprising its management and organization, is involved. Penrose views the firm as composed of an administrative structure and a collection of resources. The disposal of resources, including both human and physical resources, is an administrative decision. Hence, administrative decisions specify the current operations of the firm and the context of knowledge-seeking at the firm level, and thereby firm-level incentives for seeking new knowledge. Since the administrative structure is flexible and will change as firms grow, one would also expect that the incentives to seek new knowledge change as firms grow.

But the development of firms' knowledge base is not only dependent on whether employees will seek new knowledge or not. The direction of their knowledge-seeking is also important. Employees may seek new knowledge within the firms' existing knowledge domains, or within new ones. In the former case the knowledge base of the firm becomes more refined, while in the latter case it becomes broader.

It is likely that incentives to seek new knowledge are related not only to the intensity of the knowledge-seeking but also to its direction. If there are incentives to innovate, knowledge-seeking is likely to be broader. If there are incentives to increase the effectiveness of current operations, knowledge-seeking is likely to be within the existing knowledge base.

Changes in incentives may therefore lead to changes in the direction of knowledge-seeking. Such changes may have important consequences for how well firms are able to adapt to changes in their environment (Cohen and Levinthal 1990), or how well

they are able to identify profitable opportunities for growth (Penrose 1959).

In technology-based firms, technical knowledge is an important source of productive opportunities. A study of technical knowledge-seeking activities is therefore fundamental for increasing our understanding of the relationship between technical knowledge and growth, and how this relationship evolves over time.

Most studies on knowledge development and knowledge-seeking make simple assumptions about employees' incentives to seek new knowledge, or do not consider these explicitly at all. To explore the issue, this paper traces technical knowledge-seeking activities during growth by using a single illustrative case study of a young and growing technology-based firm. More specifically we ask:

1) How do the incentives for technical knowledge-seeking change during growth?
2) How does the direction of technical knowledge-seeking change during growth?
3) What is the relationship between incentives for technical knowledge-seeking and the directions of such activities?

The results of the study show how strong commitment to the business concept of the emerging firm affects the direction of technical knowledge-seeking in a way that increases the vulnerability of the firm. New employees who are not as committed to the original business concept bring with them different incentives for knowledge-seeking, which lead to search in new directions. These directions become important for the renewal of the firm's knowledge base. It is therefore suggested that differences in individual incentives may affect the direction of technical knowledge-seeking activities, and correspondingly, that multiple incentives are an important source of diversity in technical knowledge creation.

The paper is organized into four sections. The first section provides the frame of reference for the empirical study. The second section briefly describes the methodology used. The third section provides the case description and analysis within the selected frame of reference. In the final section, the results and their implications for further research are discussed.

Frame of Reference

The concept of the new technology-based firm has been used in a number of different ways (Bollinger, Hope and Utterback 1983, Storey and Tether 1998, Autio 2000). Most definitions stress the newness of the firm and the intensity of internal research and development.

This study refers to young and growing technology-based firms. These are recently established technology-based firms which have reached, using Garnsey's (1998) terminology, a stage of reinforced growth. As technology-based firms, they depend and rely on the technical knowledge of their own employees for the creation, detection, and exploitation of business opportunities (Granstrand 1998). The firms are likely to contain a specialized collection of technical knowledge related to their focus of activity. This knowledge is extended and refined by a group of employees specialized in such activities. The education and experience of each of these technical employees are likely to be related to externally defined domains of technical knowledge, such as electrical engineering, mechanical engineering, telecommunications, etc. (Pavitt 1999).

It is the knowledge-seeking activities of technical employees that are investigated in this paper. Before discussing the knowledge-seeking activities themselves, it is in order to discuss the conceptualization of technical knowledge, i.e. what it is that technical employees seek.

Technical Knowledge

The concept of technical knowledge is closely linked to the concept of technology. While the concept of technology is widely used in everyday language, its meaning is elusive. Literally, technology means the "study of techniques", where the word 'technique' derives from the Greek word 'téchne' (Granstrand 1979, p. 4). According to Aristotle, 'téchne' is the knowledge of how to make things "whose origin is in the maker and not in the thing made" (Aristotele 1998, p. 141). Correspondingly, while the scope and emphasis may differ, researchers of technology are likely to agree that technology is somehow related to artifacts, the methods of producing artifacts and knowledge of artifacts and their production (Schon 1967, Rosenberg 1976, Vincenti 1990, Dasgupta 1996). Thus, technical knowledge has close relation with the creation of the artificial (Simon 1996). This may be contrasted with scientific knowledge that

can be seen as related to the understanding of the natural world, of which the artificial is a part (McKelvey 1996, pp. 52-53).

In order to create the artificial, knowledge within three somewhat distinct domains is needed. First, since artifacts contain a logic related to human goals, aspirations and wants (Dasgupta 1996, p. 4), knowledge is needed of human goals, aspirations and wants. Second, knowledge is needed of the artificial world and, because artifacts belong to the natural world, so is a knowledge needed of how the natural and the artificial interact. Third, knowledge is needed of methods for using the knowledge of the artificial to fulfill human goals, aspirations and wants. In all three domains, knowledge may include both knowledge that can be expressed and communicated and knowledge that is personal, or tacit (Polanyi 1962, 1983)[1].

While the knowledge within the first of the three domains could be termed *problem knowledge*, knowledge in the second two domains could be termed *solution knowledge*. There are two reasons for making this distinction. First, it explicitly acknowledges the importance of user knowledge for technical problem-solving. The context of use is often the most specific part of technological problem-solving activity, setting important criteria for how, and what, solution knowledge is of use (Vincenti 1990, von Hippel 1998, Iansiti 1998). Second, the distinction between problem knowledge and solution knowledge helps to analyze changes in the organization of technical knowledge and the direction of technical knowledge-seeking.

What is problem knowledge and what is solution knowledge is always relative to a given technical problem-solving situation. Rather as goals can be nested into a means–ends hierarchy, so can technical problems (Simon 1996). An artifact that has been created to solve one problem can be used as a solution to solve a different problem, usually at a higher level of abstraction (Vincenti 1990). In the same way, problem knowledge can become solution knowledge at a higher level of abstraction. For this to be effective and useful for a person who is solving a problem at a higher level of abstraction, the previous solution knowledge at the lower level of abstraction

[1] It also can take the form of understanding ('knowing why'), propositions ('knowing that'), and knowledge in action ('knowing how') (Ryle 1949, Rosenberg 1976). It may include scientific knowledge, or knowledge of scientific methods. While science has an important influence on technical knowledge, technical knowledge is more than knowledge related to the application of science, and does not have to rely on science at all (Rosenberg 1976, Vincenti 1990).

needs to be made accessible in some simplified way. This simplification usually takes the form of an artifact or an interface. As an example, consider the operating system of a computer. The specifications of a good operating system are related to what functions operating systems have. The problem knowledge used when designing an operating system is composed of knowledge of these functions and their interrelations. When designing application software that relies on the operating system to provide some of its functionality, the knowledge of the functional specifications of the operating system is important solution knowledge, needed in order to solve the problem of designing application software. Hence, what is problem knowledge for the designer of the operating system becomes a part of the solution knowledge of the application software designer, through the functional specifications of the operating system. But the application software designer does not need to know how this functionality is provided by the operating system.

On a firm level, the boundaries between problem knowledge and solution knowledge can change when a firm changes its focus of activity. In the preceding example, if a firm that develops operating systems becomes an application software developer, the technical problem-solving activity of the firm changes. The problem knowledge relative to the firm would then become knowledge related to the design of application software, instead of operating systems. For many individuals within the firm, their technical problem-solving activities might not have changed as they still specialize exclusively in the design of operating systems.

Direction of Technical Knowledge-Seeking

On a firm level, knowledge is increased either by repeating previous activities or performing new ones. March (1991) uses the terms ‘exploitation’ for the former and ‘exploration’ for the latter. As learning is based on previous knowledge (Cohen and Levinthal 1990), the two processes are related, even if they produce divergent results. Exploitation improves current skills and makes experimentation less attractive. Exploration improves the possibility of having many skills but does not develop them (March 1991).

Technical problem-solving is an activity that is seldom repetitive (Cohen and Levinthal 1990). Technical problems tend to be an example of ill-structured problems (Simon 1973) where the problem is vaguely specified and no existing solutions can be

used without some revision or adaptation. Even if technical employees go through many problem-solving cycles, or what Nelson and Winter (1982) would call search routines, each cycle involves exploration to some degree.

While there is always some degree of exploration related to technical problem-solving activities, the degree of exploration may differ. For example, if one is not happy with a certain solution to a problem, one might try a different approach, which could require seeking new solution knowledge that is unrelated to the previous knowledge base and is only a refinement of the existing problem knowledge. Thus, the technical knowledge-seeking can be more or less related to the existing knowledge base.

It may seem natural to use the concept of exploration for what Penrose (1959) calls a voluntary search for new knowledge, i.e. knowledge-seeking, and the concept of exploitation for what she calls increase in knowledge obtained by taking part in the current operations of the firm. However, there are two problems related to the use of this terminology. First, it gives the impression that technical knowledge-seeking is always a new type of activity. This is not the case, because the seeking activity itself may be repetitive – e.g. searching the Internet, reading magazines and meeting with colleagues. Second, it does not capture differences in the degree of relatedness between the existing knowledge base and the knowledge that is sought. To solve these two problems, the concept of design spaces (Stankiewicz 2000, 2002) is used for conceptualizing technical knowledge-seeking and its directions.

A design space is a combinatorial search space generated by a set of operants. Operants are units of technical knowledge, or artifacts, that link structures and processes with functions and use. Hence, the scope of the search space is defined by available units of both solution knowledge and problem knowledge.

Design spaces evolve through time, basically in two ways: first, by the introduction of new operants and, second, by becoming increasingly structured and articulated. Technological knowledge-seeking within the search space involves a struggle to structure, and thus reduce the complexity of the search space. This occurs through the development of design languages. Problem-solving, or design, within a well-structured design space is less uncertain and costly than problem-solving within a poorly structured design space.

Stankiewicz (2000, 2002) developed the concept of design space to be used at the industry level, or at the level of technological systems. In this paper it is adapted to the firm level as well. Technical knowledge-seeking within firms can be seen in relation to their design space. The set of operands defining the scope of the firm's design space is determined by the technical knowledge of the employees. New employees, as well as knowledge-seeking by current employees, can extend this set and thereby increase the scope of the search space. Knowledge-seeking by current employees within the search space can also increase their own knowledge and refine the structure of the firm's design space.

The firm's design space will overlap with design spaces that are external to the firm. These may be the design spaces of other firms, or collective design spaces of certain technologies or industries. Technical employees may also know of external design spaces that do not overlap the design space of their firm. For example, technical employees may know that a certain method of software development has become very popular, without anybody in the firm having an ability to apply that particular method when creating software.

Using design spaces, the direction of knowledge-seeking can be characterized by two dimensions: problem/solution knowledge, and inside/outside of the existing design space. The former refers to the type of knowledge related to the firm's focus, and the latter refers to the similarity of that knowledge to knowledge already found within the firm. These two dimensions combine into four analytically distinct knowledge-seeking activities, which have different effects on the design space (Fig 1).

	Within design space	**Outside design space**
Solution knowledge	Refining existing solution knowledge	Adding new solution knowledge
Problem knowledge	Refining existing problem knowledge	Adding new problem knowledge

Figure 1. Different directions of technical knowledge-seeking.

First, technical employees may seek knowledge within the firm's design space about solutions. This will result in the refinement of the firm's solution knowledge, and increase the structure of the existing design space. Firms will be able to apply their solution knowledge more efficiently to existing problems.

Second, technical employees may seek knowledge within the firm's design space about problems. This will result in the refinement of the firm's problem knowledge, and increase the structure of the design space. The firm will have more detailed knowledge of known problems, and will be able to solve them more effectively.

Third, technical employees may seek solution knowledge outside the firm's design space. This will result in new solution knowledge, and the expansion of the design space. This expansion will make the design space on the whole less structured, although older, more structured parts of it may stay the same. After the expansion, the firm may be able to solve known problems in new ways.

Fourth, technical employees may seek problem knowledge outside the firm's design space. This will result in new problem knowledge, and the expansion of the design space. The effects on the structure of the design space will be similar to those for solution knowledge. After the expansion, the firm may be able to solve new problems by using existing solution knowledge.

In reality, technical knowledge-seeking is usually a complex mixture of all these different directions. The analytical distinction nevertheless provides a simplified picture of how differences in directions affect the knowledge base of the firm. We now turn to incentives for technical knowledge-seeking.

Incentives for Technical Knowledge-Seeking

Incentives that can affect the intensity and direction of technical knowledge-seeking activities are found at two different levels of analysis. First, there are incentives at the firm level that relate to the survival and performance of the firm. Second, there are incentives at the individual level that relate to the motivation of individual technical employees.

At the firm level there are two main incentives for seeking new technical knowledge: *competitive pressures*, and *goals of profitability and growth*.[2]

Failure to develop new technical knowledge may render firms' products and services uncompetitive (Pavitt and Steinmüller 2002) and make firms vulnerable to the process of creative destruction "which strikes not at the margins of the profits and the output

[2] We might add institutional pressures from authorities (Garud and Karnoe 2001) as a separate incentive; but since it is not important for the argument of the paper to discuss it separately, it is seen as a competitive pressure.

of the existing firms but at their foundations and their very lives" (Schumpeter 1942, p. 84). The pressures are different in different industries (Pavitt and Steinmüller 2002), and are likely to be strongest in dynamic environments (Eisenhardt and Martin 2000) and in technology-based firms (Granstrand 1998).

But firms do not seek new technology only as a response to threats. Many firms view new technology as a source of opportunities for profits and growth (Maidique and Patch 1978, Prahalad and Hamel 1990). New technical knowledge can create previously unknown economic opportunities, or make it possible for the firm to exploit already known opportunities (Itami and Numagani 1992).

The firm-level incentives for seeking new technical knowledge are offset by the cost of knowledge-seeking and the uncertainty of the outcomes (Nelson and Winter 1982). Hence, the strength of the incentives is related to the amount of resources available, and to the competitive situation. Firms have incentives to act reactively when faced with a problematic event if the competitive situation demands it, or to act proactively to avoid problematic events if they have resources available.

The individual incentives for seeking new technical knowledge are more complex. To simplify, we assume there are three types of such incentives: *self-interest*, *commitment to the organization*, and *commitment to an external group of peers*. These three types are derived from Deci (1975), who argues that individuals are motivated in two different ways – either intrinsically or extrinsically.

An intrinsically motivated person is motivated to perform an activity for its inherent satisfaction rather than for some separable consequences. An extrinsically motivated person, on the other hand, is motivated to perform an activity in order to attain an outcome that is separable from the activity itself (Deci 1975, Ryan and Deci 2000).

Intrinsic motivation is highly personal. There are no activities that are more intrinsically motivating than others for all people. Different people are intrinsically motivated to do different things. Technical employees may be intrinsically motivated to seek new technical knowledge. As the direction of such knowledge-seeking is either highly personal or unpredictable, intrinsic motivation was not included in this study as an incentive for knowledge-seeking.

Extrinsic motivation of different people can be based on the same outcome that is separate from the activity itself. Ryan and Deci (2000) describe how extrinsic

motivation may vary in its autonomy, ranging from unwillingness, through passive compliance, to active personal commitment.

This study is only concerned with voluntary knowledge-seeking. It is therefore only concerned with autonomous extrinsic motivation. Ryan and Deci (2000) describe two stages of autonomous extrinsic motivation: regulation through identification, and integrated regulation.

Regulation through identification means that one has identified the personal importance of the activity and accepted its regulation as one's own. Hence, even though one may not identify oneself with the reasons for doing the activity, one considers it of personal interest to perform the activity. Integrated regulation means that the reasons for an action become congruent with one's values and needs. Thus, one is committed to performing the activity because one has identified oneself with the reasons for doing so. The activity is nevertheless performed for its instrumental value rather than for its own sake.

A precondition for facilitating integrated regulation is to provide a sense of relatedness, e.g. to belong to a group or culture (Ryan and Deci 2000). Two groups are likely to have a strong effect on the motives of technical employees: first, the firm they work for and, second, the group of peers, or profession, they belong to.[3] Hence, technical employees may be committed to the firm that they work for, or to an external group of peers, e.g. their profession.

Research has shown that there may be conflicts between commitments to organizations and professions (Reichers 1985). But there are indications that motivation and performance of technical employees are greatly enhanced if the two can be aligned with each other (von Glinow 1988) or if the employee is highly committed to both (Baugh and Roberts 1994). Some have pointed to the difference between engineers and scientists in this respect (see von Glinow 1988), i.e. that scientists are less likely to be committed to the organization and more likely to be committed to a group of peers.

To summarize, five analytically different incentives for technological knowledge-seeking have been identified, at two levels of analysis (Figure 2). Two of them are at

[3] In a large firm an individual might be related more strongly to a particular group, or a division within the firm, than to the firm as a whole. As this study is considered only with relatively small firms, and for analytical simplicity, only relations to the firm are considered.

the firm level (competitive pressures, and goals of profitability and growth), and three are at the individual level (self-interest, commitment to the firm, and commitment to an external group of peers).

Firm-level incentives	Individual incentives
Competitive pressures	Self-interest
Goals of profitability and growth	Commitment to the firm
	Commitment to an external group of peers

Figure 2. Incentives for technical knowledge-seeking.

There is a relation between incentives at firm level and incentives at individual level. For those individuals who seek new knowledge because they are committed to the firm, the individual incentives are aligned with the firm incentives. This may also be true for individuals motivated by self-interest, if they judge this alignment to be in their own interest. If they see their employment with the firm as temporary, however, their incentives for knowledge-seeking may differ from that of the firm. Incentives for individuals who are committed to a group of peers are most likely to be independent of the incentives at firm level, although there may be some overlap.

The purpose of this study was to trace incentives for technical knowledge-seeking and the direction of these activities in a young and growing technology-based firm, and to learn whether incentives and directions are related. The focus will be on the directions of knowledge-seeking presented in Figure 1, and on the five different types of incentives presented in Figure 2.

Method

Technical knowledge-seeking activities in young and growing technology-based firms were traced by using a single illustrative case study. In doing so we seek preliminary answers and hope to encourage further research.

The case study was selected from eight case studies on the effects of growth upon the development of technical knowledge in young and growing technology-based firms. It was selected to illustrate certain aspects of the interaction between technology and growth that were seen in all the case studies. As this paper is more an attempt to describe this particular development than a comparison of different patterns of

development, only one of the case studies is described and analyzed in this paper. Such analysis is a first step in creating a framework that can be used for comparison and further studies.

The firm was visited for two time periods with three years in between. In 1998 the CEO, who was one of the founders, was interviewed. In 2001, the same person was interviewed twice. Additionally, in 2001, four more people were interviewed. These included the technical director, the director of research, and two technical employees. The directors had been with the firm from the start-up phase, as had one of the technical employees. The other technical employee had only been employed for one year. In total, there were seven interviews, each lasting 1-2 hours. Additional secondary information was obtained from the firm and gathered from the firm's website and from articles in the popular press.

Each interview was semi-structured. In the first interview with the CEO the focus was on the growth process and its critical moments. All the other interviews focused on the effects of the growth process upon the technical development within the firm.

An important criterion for selecting a case study approach was the need, at least at this stage, for the flexibility of the personal interview. As the focus is on the development of technical knowledge, it is difficult to obtain, without personal interaction, an understanding of both the specific knowledge domains mastered by the firm and how these have developed. There is also a need for interviewing different actors in the process.

There are several weaknesses and risks in using a single case study (Yin 1991, Eisenhardt 1991). First, the phenomenon that is under study might not express itself in the selected case. Second, the ability to generalize the findings, or to build a theory, is likely to be hampered by the idiosyncrasy of the selected case. Both of these weaknesses are offset by the other seven case studies done on similar issues, not reported here.

The retrospective nature of the case study is also a weakness. Reconstruction of history, failed memory and the establishing of myths can bias retrospective information. This weakness was somewhat offset by interviewing individuals in different positions in the firm, both managers and technical employees.

The Case Study

In this section we will provide a description of the growth process of Helax AB, using the framework developed in a previous section. We start with some background information.

Background

Helax AB was founded in 1986 by three persons previously working at the Uppsala University Data Centre (UDAC). The founders had university degrees in physics, mathematics and computer science, and working experience of the use of computers in medicine. Since the early 1970s they had mainly done work within radiotherapy for cancer patients. UDAC was highly regarded in this area and cooperated closely with the University Hospital in Uppsala and other Swedish hospitals. UDAC also cooperated with Siemens, one of the largest manufacturers of radiotherapy devices, on the development of a computerized dose planning system.

In the early 1980s UDAC initiated a Nordic project, the Computer Aided Radio Therapy (CART) project, for specifying an information management system for cancer patients treated with high-energy radiation. At that time alternative methods for treating cancers, such as chemotherapy, had emerged and were believed to be a more effective substitute for radiotherapy. The CART project was initiated because it was believed that the quality of radiotherapy could be greatly improved by better information management in the therapy process. The project considered all stages of the therapy process. These included the diagnosis performed by various scans and examinations, the localization of a tumor, the dose planning, and several rounds of radiation. Multiple rounds of radiation take advantage of the fact that sick cells recover more slowly than healthy cells, making them more vulnerable to repeated radiation. The information management system should keep track of information gathered during the process, and provide health care professionals with appropriate information whenever needed.

The results of the CART project were very promising. They showed that the quality of the therapy process could be greatly improved by controlling the information in the process and providing the right information at the right moment. More patients could be cured and less damage done to healthy cells.

The founders of Helax AB were interested in bringing the vision and the results of the CART project further. Because of the uncertain future of radiotherapy, no established firm was willing to finance the implementation of that vision. Hence, the foundation of Helax was based on the vision of providing an integrated information system for radiotherapy before year 2000. The founders managed to raise 23 MSEK in venture capital from government sources and a private venture capital firm. The initial financing was estimated to secure three years of operations without any revenues. Helax became wholly owned by the venture capital firm.

At the time of the founding, the CART project had provided the user requirements of an integrated information system. It had also specified individual subsystems and sub-processes within the total radiotherapy process. While many of the subsystems existed, e.g. dose planning modules and radiation devices, they did not live up to the vision of the CART project, or they lacked interconnections. One of the important bottlenecks was the dose planning system. This system calculates the appropriate pattern of radiation for eliminating cancer cells while minimizing side effects on healthy cells. An important prerequisite for a good dose planning system is knowledge about the relationship between the radiation patterns from the radiation devices and the biological effect in tissues and cells. In the mid-1980s this knowledge was limited. Around the same time as Helax was founded, a physicist who had earlier contacts with UDAC, together with the founders of Helax, initiated his PhD research project on developing better methods of dose planning. The project was half-financed by Helax and half-financed by a government grant. Since the completion of the PhD project this research has been continued within Helax.

Thus, at start-up the founders had both problem knowledge and solution knowledge related to the firm's selected focus of activity, i.e. within the domain of radiotherapy for cancer patients. The founders had knowledge of the user problem of radiotherapy in terms of a decade of previous experience at UDAC and the CART project. They also had solution knowledge within computer science, mathematics and physics, both of basic principles and of using them in problem-solving related to their application in radiotherapy. For further analysis, it is useful to split the solution knowledge in two parts. One concerns the overall system and the components concerned with information management, and the other concerns methods for dose planning. The

developments of these two domains of solution knowledge were organizationally separate and followed different logic.

We will now proceed by describing technical knowledge-seeking activities as Helax grows, including directions and incentives. For clarity, and to emphasize differences during different periods of growth, the description is in five parts. Each part, or period of development, is selected on the basis of critical moments in the development of Helax. The first part describes early development before the system is sold and installed. The second part describes the period of early sales that is terminated by a partnership with Siemens. The third part describes the period when the firm has to deal with a dramatic increase in demand following the partnership with Siemens. The fourth part describes a period of reorientation and refocusing, leading to an acquisition by a much larger Canadian firm. Finally, the current status of the firm is briefly described. For each period the knowledge-seeking activities are described, followed by analysis using the concepts of the selected frame of reference.

Early Development (1986-1990)

During the first four years, the focus was on the development of a product based on the vision of the CART project. In 1988 the product was installed in two hospitals in Sweden for clinical evaluation. In 1989, when the original financing had dried out, there was a conflict between the management of the venture capital firm and Helax on the future direction of the firm. True to their original CART vision, the founders bought back all shares in the company. In a tight financial situation, an important sale to Radiumhemmet in Stockholm started the early sales period in 1990. This sale followed positive results from the clinical evaluation.

Based on the results from the CART project, the first step in the new company was to create a process map of the clinical process without any mention of a possible system design. This process map was sent to 25-30 international cancer centers for feedback. Those who answered were positive and became potential future customers.

The process map described the whole radiotherapy process. It was never intended that Helax would provide all the components needed in the process. Helax would have the role of a system integrator partnering with other manufacturers of components and devices. At the heart of the system integration of the process is the dose planning system. The development of the dose planning system, later to be called the TMS

(Treatment Management System), became the main focus of early development. In a way it was a new generation of the system that the UDAC group had developed earlier.

The development was along three lines. First, there was the development of system architecture – including, among other things, the computer hardware, the operating system, the data management system, and connections to other systems. Second, there was the development of the software that interacted with users and provided the functionality of the system. Much of this work concerned the practical complexity of preparing data for the dose planning algorithms, such as locating the tumor, forming the radiation beam, and controlling that everything was right. Finally, there was the development of algorithms for calculating the doses. In order to develop the algorithms, research was needed on the biological effects that different radiation patterns have upon tissue. This research was done very much in relation to a scientific community, and independent of other developmental activities.

Within one year the whole group of thirteen people from UDAC was working at Helax. The group was very knowledgeable about the radiotherapy problem and had a state-of-the-art knowledge of computer science, although few had any formal computer science education.[4] It was a research-oriented group with experience from support and research in a clinical setting. The group had little knowledge of building commercial products. Engineers with product-development experience and background in applied physics and computer science were recruited to help with the product design. At the end of the period Helax employed 20 people, almost all with a university degree.

The core of the knowledge base of the firm was applied physics. It was decided early not to employ medical professionals. It was argued that it would be better to access their knowledge through networks and alliances. There existed different approaches within the medical profession on radiotherapy. Instead of selecting a particular approach, Helax intended to create something that all could use. To ensure that the technical product would be useful in its medical application, a scientific board was established. The scientific board included medical doctors with a large network of

[4] Computer science as a university education was not widely available in the 1970s when most members of the group had completed their university studies.

international contacts. Additionally, there were close contacts with the two reference clinics in Uppsala and Malmö.

The problem that Helax as a company was trying to solve during the early development period was a particular sub-process of the radiotherapy process. The group in the company was very knowledgeable about the basic problem and tried to make sure, by continuous feedback from the medical community, that they got it right. Additionally, the group had state-of-the-art solution knowledge within physics and computer science. The knowledge-seeking activities in this period were mostly concerned with three things. First, refinement of the existing problem knowledge by creating a detailed process map used for getting feedback from potential customers. Second, the extension of the firm's design space to include knowledge on product-related issues, knowledge on how to solve practical problems related to the location of tumors, etc. This knowledge was complementary to existing solution knowledge. Third, the extension of the firm's design space with solution knowledge about the relationship between radiation patterns and their biological effect on tissue, in order to be able to create better dose planning algorithms.

At the firm level there were incentives, made possible by the three-year financing, to proactively seek new technical knowledge for implementing the CART vision. Due to the tight financial situation at the end of the period, there were strong incentives to refine the structure of the existing design space in order to be able to deliver a validated product and to create the first sale.

At the individual level, the incentive for knowledge-seeking in this period was almost exclusively a commitment to the business concept based on the CART vision. An especially close group of people, with a strong identity related to the original business concept, was built up during this period that was to become the core of the firm. This identity was amplified by the conflict with the venture capital firm at the end of the period, and by the tight financial situation that followed.

The incentives to seek new knowledge related to the dose planning algorithms were an important exception. Although sharing the part of the design space related to the problems of radiotherapy, and relied on for providing inputs into the product development process, the knowledge-seeking activities clearly had a different logic. They were performed in a larger perspective, within a research community that was

independent of the firm. This community, rather than the operations of the firm, directed the knowledge-seeking activities.

Early Sales (1990-1994)

During the next four years, the focus was on selling the product to the first customers and creating a production process to be able to adapt the product to differences in customer requirements. The period was also characterized by increasing depth and by high interest rates. At a critical moment, the period started with an important sale to Radiumhemmet in Stockholm. This sale was quickly followed by further sales in Sweden and the rest of the Nordic countries. In 1994 Helax had its system installed in 11 of Sweden's 15 radiotherapy clinics. The first international sales were in Scotland and Germany in 1992. That was the first time Helax competed directly with the large companies in the industry, like Siemens and General Electric. In 1994 Helax established a partnership with Siemens. Siemens decided to discontinue the development of its own dose planning system and promote the Helax system instead. Overnight, the demand for the system increased tremendously.

Even though sales had started, the group continued to develop the product along the lines mentioned above. Many solutions, such as the dose planning algorithms, still had room for improvement. The first phase of dose planning research had only helped in understanding the relationship between the radiation patterns and absorbed energy in the tissue, and still more work was needed in relation to optimization of parameters. Some hardware changes were made to the system in order to increase performance, but the effects on the software were minimal. Product maintenance started to emerge in the form of updating. Release cycles were relatively short, resulting in four to five releases per year.

In parallel, the firm built up a production process in order to be able to reproduce the system. In the beginning the systems were adapted to each customer. To assemble a whole system of both hardware and software demanded much competence due to the specialization required for each customer. Some new personnel with engineering background were employed for producing the system, but the development team also took part in these activities. The number of employees in the firm nevertheless stayed much the same as in the earlier period.

During this period the knowledge-seeking activities were more within the existing design space, as compared to the previous period. Knowledge-seeking related to new requirements from new customers helped to refine the structure of the existing design space, rather than to extend it. Knowledge-seeking related to the reproduction of the system, even if it was still under development, also led more to increased structure of the design space than to its extension. An exception was, again, the knowledge-seeking activities related to the dose planning system. They were still focused on adding new solution knowledge to the firm's design space as well as refining its structure.

The firm-level incentives were similar to those at the end of the previous period. In order to obtain early sales, there were incentives to react to customer requirements. This included the adaptation of the product to each customer and improving the operation of the system, e.g. by fixing 'bugs' in the software system.

At the individual level, the incentives for knowledge-seeking stayed much the same as in the earlier period.

Scaling up the Operations (1994-1998)

The partnership with Siemens marked the start of a period of fast growth. During that period similar partnerships were made with General Electric and Philips. Before the partnership with Siemens, Helax had the capacity of assembling and installing 12 systems per year. At the start of the partnership Siemens ordered 60 systems that should be delivered within the next six months. This put great pressure on simplifying the production and installation process. But the increased sales also solved the financial problems and made the firm attractive for further investment. New product development work was started on other components within the CART framework. At the same time, the firm made a failed attempt to update the software platform of the TMS system. At the end of the period the firm had 90 employees, headquarters in Uppsala, and six subsidiaries in Europe and the US. While successful in Europe, especially in Northern Europe, the company experienced some difficulties on the US market.

The large increase in demand for the TMS product was a great challenge for the firm. Previously, much time was spent on putting components together, both hardware and software. By defining modules whose production and testing could be outsourced to

other manufacturers, Helax was able to cut the installation time to three days in one month. But it changed the firm.

> *"But at the same time we learned a new part of our life. That is, about production capacity, product maintenance and service, and everything else that we had not needed to think of before. And we became a new firm."*

Increased numbers of customers increased the load on product maintenance, customer service and further development. More 'bugs' were identified and the pressure increased on fixing them. In the beginning, only the developers could do that and they had to provide all the support. Although most of the developers liked the intensity of the situation, they quickly became tired of it. Conflicts emerged because little time was available for concentrating on the development of the next generation of products. The development work was also to a large degree unplanned. Changes were made to the system on an ad-hoc basis in order to respond to new customer requirements. While flexibility had to some degree been built into the system from the start, it became older and more difficult to maintain on this basis. There were many discussions about how to solve these conflicts, and some employees quit because of them.

A strongly related issue concerned the development of the skills of each employee. Shortage of time and resources constrained the possibility for employees to keep up with the development within their fields of expertise.

> *"This was the dilemma we had...Fortran programmers. You program in Fortran but then you realize that other programming languages are becoming more popular. But you don't need them in order to keep on programming [in the company]. But if I continue to program only in Fortran and [it becomes obsolete], not in the company, I will not be valuable [on the job market] because nobody wants to employ a Fortran programmer...either I leave the company in order to get into the new world or get help from the company to develop myself... And we had a lot of discussions... Do we have time and money for this?...despite what we said and decided it was always broken by the amount of work. There was so much work that we never had any time for education."*

Gradually, these problems were solved. New personnel with experience of more structured development processes and having formal education in software engineering were recruited. Development processes became more structured as an ISO 9001 quality system was put in place in 1995-96. A special service department was formed that included technical employees who specialized in service and maintenance rather than development. The development team nevertheless supported the service department when needed.

Despite the strains, the increased sales provided resources and opportunities to start the development of new products. Two new products were introduced in the period. The Helax-Visir product is an information system that provides a core database for the radiotherapy clinic, holding information about the patients. This database includes information about the planned and the actual treatment, making possible the verification of the treatment. The Helax-IMCON is a tool for helping in the planning process. It simulates the planned radiotherapy by using special X-ray simulators in order to verify the location of the tumor and the treatment fields. The Helax-Visir was originally a Norwegian research project which became a part of Helax through its Norwegian subsidiary. The Helax-IMCON is based on results from research within Helax.

The research on dose planning continued during the period. While the amount of resources available for research varied, and some research personnel had been involved in development work, the research group was consciously isolated from the scaling-up pressures. The focus of the research group had not changed, as there was still work to do related to the original problem of dose planning. Nevertheless, the group was becoming more involved in optimization of parameters, rather than in basic investigations on the effects of radiation upon biological tissues.

In the middle of the 1990s new requirements emerged from customers. They started to question the value of using special-purpose computers for radiotherapy that had a non-standard user interface. Instead they expected the system to be able to run on a standard PC machine and to have a Windows interface. Helax tried to respond to these pressures by updating the TMS product to a PC platform and the NT operating system. Much of the work was outsourced to specialists in that particular platform. The project was a failure. It became too expensive and had to be abandoned.

> *"We have argued that we could outsource the development process and only provide the specifications of what is to be developed. But it does not work."*

The firm continued using the old product, and has spent more time on preparing for an update of the software platform. New employees with education in software engineering were recruited for further in-house development of the software platform.

At the end of the period Helax employed 90 people. Much of the increase in employment during the period was due to recruiting at subsidiaries abroad and the increasing number of personnel needed to run daily operations. Still, there was an

influx of new technical employees who did not have as strong a Helax identity as did the original group of 20 people that is mostly intact in the firm.

> *"We have always said that at Helax nobody leaves the company. In our organization nobody leaves. Then we took a look at our employment records...this company has had a turnover of new people that is one and a half times its size in the last five years. But we say that in this company nobody leaves. Why do we say that? Because the 20 core people, they never leave. These are the people that express the mission, these are the people that express the identity, these are the people that ARE Helax... All those that come and go, they don't count. And if you look, there are a lot of people that have been here for one, two, three years. But these are the people that want to develop their careers, to become better."*

Hence in this period the turnover of employees increased. There were difficulties in recruiting software developers, mainly because of the high demand for such services at the time, and because the firm was not in the forefront of computer technology as it once had been.

During this period the direction of the knowledge-seeking activities became more complex than before. A large part of the technical learning was related to ongoing activities and incremental improvements of the existing product. This learning led to the refinement of the existing design space. There was little time for the extension of the design space, at least in the beginning of the period. At the end of the period new products were introduced. Although knowledge-seeking related to their development – mostly for new solution knowledge – extended the firm's design space to some degree, they were very much based on the firm's existing knowledge base.

The research on dose planning continues as before, not much influenced by the pressures of growth. While there are some extensions to the design space, the emphasis is moving towards refinement, i.e. optimization of parameters.

During this period it became evident that the firm was lacking basic solution knowledge of computers and software development, which the customers were asking for. This was hurting the firm. After a failed attempt to outsource this knowledge development, knowledge-seeking activities were initiated that aimed at extending the design space to include this knowledge. The updating of the products took time because the new part of the design space was still unstructured.

During the period there were strong firm-level incentives to deal reactively with the pressures and problems of growth. The difference from earlier periods was that, in addition to pressures from customers, there were also pressures from new employees.

New technical employees played an important part in the firm's technical knowledge development at this point. They were not a part of the original Helax team and did not identify themselves as strongly with the original business concept of the company. For them it was important to be up to date in their professional fields. They therefore had other incentives for knowledge-seeking than commitment to the firm, and these incentives were closer to self-interest than commitment to a group of peers. They questioned the viability of updating only the expertise within the process of radiotherapy, which was so closely related to the identity of Helax. They also argued for more slack in the system for proactive knowledge-seeking activity related to the basic solution knowledge of the firm, especially software knowledge.

The original group of employees played down the importance of new software technology for the quality of the radiotherapy process. They may be fundamentally right in their judgments that the new technology will not improve the quality of the process, but the customer wants it anyway and the company needs to respond to this wish. Finally, it had become very difficult to recruit and retain qualified software developers without updating the basic software knowledge.

It seems that the management of the firm did not respond fully to this until it became apparent that the lack of internal development of software knowledge was hurting the company in the market. The response led to changes in how development work was organized, e.g. with the introduction of a quality system. Incentives for more structured development work were built into the quality system, giving the individual employees opportunities to extend the design space of the firm at the same time as its structure was refined. This resulted in a compromise between short-term and long-term firm incentives for technical knowledge-seeking.

Reorientation (1998-1999)

This period, shorter than the previous ones, was characterized by a strategic refocus from radiotherapy to oncology. Instead of only providing an integrated computerized system for radiotherapy alone, a strategic vision is created that broadens the scope of the firm to build an information system that can cover all methods of cancer therapy. The new concept is called HOME (Helax Oncology Management Environment). This refocus was a part of a restructuring which aimed at building up a more professional

firm with financial stability. The former CFO became the CEO, and the former CEO (one of the founders) focused on business development.

At the beginning of the period, the company had built up a strong position in Northern Europe with 70-80% of new sales within radiotherapy, compared to 20% of new sales worldwide. After a failure to establish Helax firmly on the US market, the management team realized that the firm did not have enough resources to build up a global presence in the broader field of oncology. It therefore looked for a strategic partner with a global presence and capital that could help in the process. A match was found in the Canadian firm MDS Nordion, which needed a partner with a strong presence in Europe and a strategic focus on radiotherapy. A condition for the partnership was that MDS Nordion would acquire Helax. Despite disliking the idea of selling the firm, the founders sold their shares in order to take their vision further.

Despite the changes in the strategic vision, it did not affect the daily operations of Helax. The idea of broadening the scope of the company was not completely new. Such ideas had been discussed once in a while, but the firm had never obtained specific knowledge of other fields, such as chemotherapy, surgery etc. While the latter had much in common – e.g. most were based on cell biology – they used different methods to discern between sick and healthy cells and to disturb the sick ones. Even though these ideas had been around for some time, they did not affect product development. The firm continued instead to deepen its competence within the field of radiotherapy.

The period was characterized by ideas of a new direction in problem knowledge. By moving to a higher level of abstraction, the problem knowledge relative to the company was redefined. An attempt was made to extend the design space of the firm by adding new problem knowledge. The former problem became a means of solving a new problem. For the firm, radiotherapy should become just one solution for curing cancer.

Despite the extension of the design space to include new problem knowledge, the structuring of the new part of the space did not start during this period. Radiotherapy was still the problem and employees were solving it in much the same way as they did in earlier periods. The effort on updating the software knowledge continued along the

same line as in the previous period. So did the further development of existing products and the research on dose calculations.

At the firm level there were changes in incentives. There emerged incentives to increase the scope of the firm in order to obtain further growth. Resources were set aside to seek new opportunities and for finding a way to implement them. Because the implementation was such a large step, in terms of both financing needs and the required extension and structuring of the firm's design space, it was believed to be impossible without a strong partner firm.

The original vision, however, continued to thrive and dominate the activities of the firm. On an operational level there was no visible commitment to these new ideas, or any active knowledge-seeking based on such commitment. There were no signs that those who were committed to the firm had developed a commitment to the 'new' firm.

Post-Acquisition Epilogue (1999-2001)

Helax is currently a division in MDS Nordion which is a large and global firm. As agreed, Helax in Uppsala became a center of excellence for the development of the HOME concept, and MDS Nordion was committed to take the vision further. But things have changed in the process and Helax has lost much of the control it had in the beginning. This is partly because of management changes in Canada.

While MDS Nordion may bring the vision further, it is unclear both what form it will take and what role Helax will play. The firm continues its efforts within radiotherapy, working on a new generation of products. That generation will be based on a new software platform. The research activity related to dose planning continues to be state-of-the-art, holding its status within the scientific community. There are still some unsolved research problems from the original CART vision.

Looking back, the firm has been driven by the strong commitment of the early employees to create an information system for radiotherapy. This commitment has been strongly related to the identity of Helax as the venue for such creation.

> *"The 20 first employees have become, and still are, the core of the company. [But they have not] broadened their core function since they started, but have become stable mentors in the company's main process, i.e. development of a system for radiotherapy."*

As a part of MDS Nordion, Helax does not have a separate identity any more. But the strong identity of the original group is still there and has taken on a rock-like formation during the years.

> *"The 'rock' is there...but I don't think it is possible to break it up and get the individuals to work together in a different perspective. The only way is to open up [possibilities] for it to grow by using the same identity as before. Or take it away as a whole."*

Hence, the identity still exists but has been separated from the firm Helax. At present it is uncertain whether this identity will continue, change, or disappear within the new firm.

Discussion

The purpose of this paper was to trace technical knowledge-seeking activity in young and growing technology-based firms. Technical knowledge-seeking activities have been conceptualized as activities that seek new problem or solution knowledge within, or outside, the firm's design space. We have traced the technical knowledge-seeking activities through time in a single illustrative case study, focusing on the direction of the activities and the incentives for performing them. We have done this in order to provide some preliminary answers on how direction and incentives change during growth, and about the relationship between the two.

In this section we discuss the findings in relation to our research questions and their implications for future research. First, we will discuss the development through time of both directions and incentives along three lines: research on dose planning, development of the knowledge within radiotherapy, and the development of software knowledge. We select these three lines because they represent the main domain of technical knowledge in the firm and their development follows different logic. Second, we draw conclusions related to each of the three research questions. Finally, we discuss the implications for further research.

The research on the dose planning method has always been considered a separate activity at Helax. With varying amounts of resources, the research has been mostly independent of other development activities within the firm. It has mostly been pursued in relation to the design space of an external community of international researchers within the same field. It has both extended and refined the structure of that particular design space, mainly through new solution knowledge. As the knowledge-

seeking activities are parts of the operations of Helax, it has extended and structured the design space of Helax as well.

The research on dose planning has focused on new solution knowledge related to the problem of using high-energy radiation for eliminating cancer cells. The research has not expanded into related areas, such as chemotherapy, or changed its focus to the more general problem of cancer treatment.

A partial reason for the lack of diversification is that the practical problems which were put forward in the CART vision have still not been fully solved, and there has always been a strong commitment to solve those problems. But within the research part of the company, this commitment has not been equated with a commitment to the company, but devoted to the general problem that the company happened to be focused on. The incentives to search for solutions have not been so much for the sake of the company, but rather to do well in the community of research. In the long run, because of the strong focus on radiotherapy, this commitment to research peers has been beneficial to the firm, as it has made it possible for the firm to continue to embody a state-of-the-arts knowledge of dose planning methods in its products. As such it has expanded, and structured, an important part of the company's design space.

The part of the design space of Helax related to the knowledge of radiotherapy, which has been the problem knowledge of the company most of the time, has not been extended very much. The basic process of radiotherapy has not changed since the making of the CART process map. What has changed is that increasing cost awareness and the myriad of different incompatible computer systems in hospitals have made the managers of the health care system more aware of the importance of the integration and management of information.

The basic dimensions of the design space related to the problem knowledge of radiotherapy had been acquired before the founding of the firm. Through the development of the firm, the structure of this part of the design space has been refined by the particulars of different user situations and practical problem-solving.

The knowledge on the radiotherapy process, combined with the specific knowledge on dose planning, has been an important part of the identity of the firm. In fact, the firm has attempted to outsource other parts of the design space needed for creating the

firm's products. On a firm level, there have been incentives to respond to signals indicating that this core part of the firm's design space needs to be refined and expanded. Individuals committed to the firm have internalized these incentives and have been very responsive. New employees who do not share the same commitment have not been as responsive, as they have other incentives for seeking new technical knowledge.

When attempts were made to shift the problem knowledge of the firm to a higher level of abstraction, it seems that incentives for refining and expanding the design space to accommodate this change were lacking. Apparently the employees have difficulties in adjusting to the new identity of the firm. As the firm becomes a part of a larger organization, or perhaps because of that, the core group of the firm continued to identify themselves on the basis of their knowledge within the field of radiotherapy.

The software knowledge has not been closely related to the identity of the firm. The software knowledge is also a general-solution knowledge that can be used for solving many different problems. In the early phase there were some knowledge-seeking activities for extending and updating the software knowledge that was used earlier at the hospital. The changes were related not only to the solving of the radiotherapy problems, but also to the specific problems of creating a commercial product. This involved the knowledge related to both system architecture and software functionality. During the development of the firm, there were few knowledge-seeking activities directed towards further expanding the design space of the software knowledge.

Because software knowledge has not been seen as a part of the firm's identity, there have been fewer firm-level incentives to extend it. Even when customers start to ask for renewal of software and hardware components, the employees of the firm – perhaps somewhat correctly – argue that the renewal of these components will not affect the quality of the radiotherapy process, nor the ability to interact with other information systems. At the same time, conflicts within the firm, and problems related to the recruitment of new employees with software knowledge, indicate that personal incentives to expand the design space with new software solution knowledge could not be responded to because of a lack of slack in the firm's operations. Gradually, after a failed attempt to outsource this development, the firm provided the slack for expansion of this particular part of the design space.

The first research question of this paper was concerned with changes in incentives for technical knowledge-seeking during growth. On an individual level there existed two different types of incentives at start-up. First, there was a group of employees that became committed to the original CART vision. These employees had incentives to seek new technical knowledge related to the implementation of that vision. Second, there was a small group of employees who were more committed to a research community than to the firm. They had incentives to seek new technical knowledge according to the logic of this community. Both types of incentives were consistent throughout the whole period observed in this study.

As the firm grew larger, new employees were added who brought with them different incentives for seeking new technical knowledge. These incentives suited their own interest besides working for the firm, i.e. their future careers. Combined with the two different incentives already present at start-up, the individual incentives became more diverse as the firm added new employees.

The second research question was concerned with changes in the direction of technical knowledge-seeking during growth. At start-up, the knowledge-seeking activities extended the firm's design space by adding mostly new solution knowledge. During growth, the knowledge-seeking activities were aimed at refining the firm's design space, through both new problem knowledge and new solution knowledge. After a period of growth, knowledge-seeking activities have extended the design space in two ways: by updating a specific part of the firm's solution knowledge, and in order to shift the firm's problem knowledge to a higher level of abstraction. In the former case, the extension has been followed by gradual refinement in order to be able to use this knowledge for updating the firm's products. In the latter case, a refinement of the extended design space had not yet started in any significant degree at the end of the observed period.

The third research question was concerned with the relationship between incentives for knowledge-seeking and the direction of such activities. On a firm level, the direction of the knowledge-seeking was closely related to the incentives. At start-up, the firm had strong incentives to extend the design space in order to find solutions that fitted the known problem it was trying to solve. To solve the problem was technically demanding and needed solutions that were state-of-the-art. As the financial situation became more pressing, there were strong incentives for the firm to refine the design

space in order to be able to create a product that could be sold. During growth there were still strong incentives to refine the design space in order to accommodate all customers and manage the production process. Due to pressures from customers and its own employees, as well as from failures related to outsourcing, the firm had strong incentives to extend a specific part of the design space. Finally, in order to pursue further growth, there were incentives to extend the design space by adding new problem knowledge at a higher level of abstraction.

At the individual level, the direction of the knowledge-seeking was also related to incentives. The strong incentives provided by the commitment to the original vision directed the knowledge activities of the core group of technical employees along the directions provided by firm-level incentives. The incentives provided by a commitment to a research community also oriented the direction of knowledge-seeking. The direction of knowledge-seeking followed the logic of the research community and had very little relation to firm-level incentives, even during times of strong growth pressure. While affecting the resources available for the research, the growth pressure did not affect the direction of the knowledge-seeking. Similarly, individual self-interest affected the preferred direction of knowledge-seeking by new employees. While at times responding to firm-level incentives, the new employees protested, and even left the firm, when the directions of knowledge-seeking, as guided by firm-level interests, were against their own interests.

From the above one could suggest that individual incentives based on self-interest and commitment to a group of peers were likely to lead to knowledge-seeking activities outside the firm's design space. Individual incentives based on commitment to the firm are likely to be aligned with the incentives of the firm, which during growth were mostly related to the refinement of the existing design space. This refining was crucial in order for the firm to be able to produce its products for a larger group of customers. On this basis, one could argue with Kogut and Zander (1996) that the common identity within the firm is an important prerequisite for knowledge development, but the identity may limit the direction of this development. In order to obtain a balance between refining and extending the knowledge base of the firm, it is important to provide other incentives for knowledge-seeking that are created by such an identity.

The results of this study are preliminary and more an attempt to raise interest in the question than providing some definitive answers. The results show how tensions are

created during growth, which are threatening to the future development of the firm. These issues clearly have important implications for management and further research is needed in order to understand how managers can respond to them.

It would be interesting to move closer to the individual level of analysis so as to better understand why technical people seek new technical knowledge. This study included only a simple view of incentives and motivation of individuals, and was mostly concerned with the firm level. Individual differences in incentives can be seen as an important generation of variety, having valuable implications for the evolutionary development of the firm (Nelson and Winter 1982) and its absorptive capacity (Cohen and Levinthal 1990).

Additionally, it would be interesting to better understand the evolution of identity and its role in shaping the incentives for knowledge-seeking within the firm. It would especially be interesting to understand better what happens as the scope of the activities of the firm is changed, e.g. by moving to a higher level of abstraction, and to know more about the associated processes of reorienting the knowledge domains within the firm. A particular aspect of this reorientation is the conversion of former solution knowledge to problem knowledge.

The above-mentioned further research would not only be interesting in its own right. It may also increase our knowledge of the relationship between technical knowledge and growth. Penrose (1959) viewed the growth process as a recurrent process of opportunity identification and exploitation, which was fueled by the growth of knowledge. A better understanding of the relationship between incentives for knowledge-seeking and the direction of such activities adds to our understanding how firm growth is sustained.

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