Dynamic capabilities and the growth of technology-based new ventures

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SUMMARY

The growth of entrepreneurial firms is a complex and dynamic process under conditions of disruptive change and pervasive uncertainty. This dissertation builds on a dynamic capabilities framework to shed light on the development of technology-based new ventures over time. Dynamic capabilities are learned patterns enabling firms to configure its organisational setup including processes, routines, and resources. The applied framework is based on the resource-based view of the firm but it also incorporates elements from organisational learning, organisational development, and control theory. Contrary to the traditional market-based approach frequently deployed in strategic management research, this approach takes an inside-out perspective on the subject under study. By applying a longitudinal, multi-method, multi-case field research design, the study acknowledges the complexity and the dynamic character of the entrepreneurial growth process. Adopting a constructivist epistemological position, this research effort comprises hypotheses as well as explorative elements. The former are derived from theory but also from field research. Leveraging a sample of 44 venture capital-backed technology-based new ventures in the Munich region the hypotheses and explorative questions are empirically tested, elaborated, and corresponding conclusions are drawn.

The results of this study are manifold. First, drivers for the emergence of dynamic capabilities in general as well as for different functional capabilities within entrepreneurial organisations are identified. The study also provides insights on the linkage between early venture performance and the development of capabilities in various functional areas. In addition, different functional skills are compared with respect to the timing of their emergence. Internationalisation and the replacement of the founder as two important events within the lifecycle of an entrepreneurial firm are discussed with respect to their influence on performance and capability evolution. Another element of this research effort focuses on the endogeneity problem regarding organisational growth and the emergence of dynamic capabilities. The study offers insights on this classical "chicken-and-egg" problem. Finally, this research covers the sequence of dynamic capability development in technology-based new ventures and the corresponding influence on early venture performance.

This dissertation contributes to theory in different ways. The longitudinal, multi-method, multi-case field research design enables triangulation and allows for a number of descriptive and interpretative statistics explicitly incorporating the time dimension as important element of the entrepreneurial growth process. In addition, a new operationalisation for the dynamic capabilities framework is offered in the course of this research effort. This approach explains the sources of capability evolution within growing organisations and enables tracking the emergence of different functional capabilities in entrepreneurial firms over time. By applying a representative sample of technology-based new ventures, the statistical analyses carried out in this study have predictive power and could serve as a basis for future research.

Practitioners such as business founders or serial entrepreneurs also benefit from this research effort. However, the insights are relevant for other stakeholders engaged in the process of new venture development as well. This may comprise venture capitalists, angel investors, venture coaches, incubators, consultants, or advisors. By considering the importance of dynamic capabilities in their business development activities, entrepreneurial firms may put more emphasis on the development of specific capabilities and acknowledge the basic sources of these skills together with the corresponding drivers identified in this study. The provided list of capabilities may be applied as a "checklist" in this respect. The initial development of functional capabilities that were identified as being beneficial for early venture performance enables management teams to allocate their limited resources in a more effective way. Finally, practitioners could benefit from this research by leveraging the performance implications of the different paths of capability evolution offered in this study.

SAMENVATTING

De groei van ondernemende bedrijven is een complex en dynamisch proces dat zich voltrekt onder omstandigheden van onderbroken verandering en aanhoudende onzekerheid. Deze dissertatie bouwt voort op een dynamic capabilities' kader, met het doel om meer licht te werpen op de ontwikkeling van technologische bedrijven. Dynamic capabilities zijn geleerde patronen die een organisatie in staat stelt om de organisatorische set-up, inclusief de processen, routines en resources, te configureren. Het toegepaste kader is gebaseerd op de resource-based view op de onderneming, maar neemt ook elementen mee van organisational learning, organisational development en control theory. In tegenstelling tot de traditionele markgerichte benadering die vaak wordt toegepast in strategisch management onderzoek, geeft deze aanpak een "binnenstebuiten" perspectief op het bestudeerde onderwerp. Door het toepassen van een lange termijn, multi-case onderzoeksopzet erkent deze studie de complexiteit en het dynamische karakter van het groeiproces van ondernemingen. Door gebruik te maken van een constructivistisch epistemologisch uitgangspunt, bestaat het onderzoek zowel uit hypothesen als uit meer exploratieve elementen. De hypothesen zijn zowel afgeleid uit de theorie als uit het uitgevoerde veldonderzoek. De hypotheses en de exploratieve vragen zijn empirisch getest en geëxtrapoleerd op basis van een sample van 44 technologische bedrijven die worden ondersteund door venture capital in de regio München, waaruit vervolgens conclusies zijn gegenereerd.

De resultaten van de studie zijn veelzijdig. Ten eerste zijn er drijfveren geïdentificeerd voor het ontstaan van dynamic capabilities, evenals voor andersoortige functionele vaardigheden binnen ondernemingen. De studie verschaft ook inzicht in de verbanden tussen de prestatie van startende ondernemingen en het ontwikkelen van vaardigheden binnen verscheidene functionele gebieden. In aanvulling hierop zijn verschillende functionele vaardigheden vergeleken met het oog op het moment in het proces waarop ze ontstaan. Internationalisering en het vervangen van de bedrijfsoprichter zijn specifiek behandeld als twee relevante gebeurtenissen in de ontwikkeling van een bedrijf. Hierbij is specifiek aandacht besteed aan de invloed op prestatie en de evolutie van het ontwikkelen van vaardigheden. Een ander element van dit onderzoek is de focus op het probleem van

endogeniteit, met betrekking tot organisationele groei en het ontstaan van dynamic capabilities. De studie geeft inzicht in dit klassieke "kip en ei" probleem. Tenslotte omvat het onderzoek de volgorde waarin dynamic capabilities tot stand komen binnen technostarters en de invloed hiervan op de prestatie van dergelijke starters.

Deze dissertatie draagt op verschillende manieren bij aan theorievorming. De lange termijn, multi-case aanpak van veldonderzoek maakt triangulatie mogelijk, evenals het ontwikkelen van een aantal beschrijvende en interpreterende statistieken die de tijdsdimensie meewegen als een belangrijk onderdeel van het ondernemende groeiproces. In aanvulling hierop wordt een nieuwe operationalisering aangeboden voor het dynamic capabilities kader. Deze aanpak verklaart de oorzaken van de evolutie van het ontwikkelen van vaardigheden binnen groeiende organisaties en maakt het mogelijk om het ontstaan van verscheidene van deze functionele vaardigheden te traceren in het groeiproces van ondernemende bedrijven. Door het bieden van een representatief sample van technostarters geeft de studie voorspellende kracht, zodat deze zou kunnen dienen als basis voor verder onderzoek.

Praktijkgerichte mensen, zoals de oprichters van bedrijven of meervoudige ondernemers, kunnen profiteren van het onderzoek. Daarnaast zijn de gepresenteerde inzichten van belang voor andere partijen die zich bezighouden met het starten van nieuwe bedrijven. Hierbij kan worden gedacht aan venture capitalists, angel investors, venture coaches, incubators, consultants of adviseurs. Door het belang van dynamic capabilities te onderkennen in hun zakelijke leven, zouden ondernemende bedrijven meer nadruk kunnen leggen op het ontwikkelen van specifieke vaardigheden. Bovendien zouden ze de voornaamste bronnen van deze vaardigheden en de bijbehorende drijfveren kunnen erkennen die in deze studie zijn gepresenteerd. De lijst van vaardigheden zou in dit verband als "checklist" kunnen worden toegepast. De initiële ontwikkeling van functionele vaardigheden die in deze studie als belangrijk voor starters zijn bevonden geeft management teams de kans om hun beperkte middelen op meer effectieve wijze te alloceren. Tenslotte, mensen uit de praktijk zouden voordeel van het onderzoek kunnen hebben door het onderkennen van de implicaties van de verschillende processen van het ontwikkelen van vaardigheden die in deze studie zijn onderscheiden.

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LIST OF ABBREVIATIONS

CEO	Chief executive officer
CFO	Chief financial officer
CRM	Customer relationship management
FDA	United States Food and Drug Administration
HRM	Human resource management
IPO	Initial public offering
Max	Maximum
MCS	Management control system
Min	Minimum
Q1	First quartile
Q3	Third quartile
SD	Standard deviation
VC	Venture capital
VCs	Venture capitalists

1 INTRODUCTION

1.1 MOTIVATION AND PROBLEM STATEMENT

In today's economies, the foundation and growth of innovation-based businesses is more important than it has ever been before. A major reason for this requirement is the ongoing globalisation that has altered the rules of the game substantially. Germany as Europe's largest economy has encountered these changes as well. A few decades ago, large corporations like Siemens, Volkswagen, Mercedes-Benz, or Mannesmann provided major benefits to the economic growth in Germany. Nowadays, these corporations follow the paths of global competition and transfer large parts of their value creation to regions that allow substantial labour cost reduction. In addition, German mid-sized companies, the so-called "Mittelstand", which had been very successful over many decades has slowed down in its development and is driven into mergers or is acquired by larger international players. This trend leads to a stagnation of the German economy and results in increasing unemployment.

In Germany, the source of growth has shifted away from large corporations during the 1980s to entrepreneurial start-up firms (Audretsch and Fritsch 2003). In fact, the foundation and development of new businesses is generally expected to create new jobs and wealth for society (Amit, Glosten, and Muller 1993; Kao 1995; Lee, Lee, and Pennings 2001). While in the US a growth-oriented technology industry has evolved over the past decades, Germany has more or less neglected this trend for a long time (Lehrer 2000). A possibility to impede the current trend could be the systematic development of a technology-based growth industry (Wedell, Winnen, Harhoff et al. 2004). Innovation-based businesses can justify higher labour costs and provide the country with a competitive edge on the global market that leads to higher employment rates and economic growth and wealth.

The development of such an industry is a difficult task and requires different important boundary conditions (Brettel 2002). These conditions comprise the technical and environmental infrastructure, highly skilled employees, as well as committed university

institutes performing the necessary fundamental research and providing excellent education. In most of these areas, Germany plays a leading role (Kluge, Meffert, and Stein 2000). The country has a long and fruitful scientific history accounting for 84 Nobel Prize winners. Especially in the field of technology development and advanced engineering, Germany still holds a leading position in the world (Gill, Minshall, and Rigby 2003).

Although these conditions are all promising, the country has experienced some critical roadblocks as well. Technology-based industries need considerable financial support in order to realise the targeted growth rates (Brettel 2002; Davila, Foster, and Gupta 2003). For the foundation of technology-based innovative companies, private investors such as venture capitalist or business angels are highly important (Sternberg and Lückgen 2005)[1]. However, the German venture capital market is rather small compared to other industrial countries (Schefczyk and Gerpott 2000) and suffered a reasonable downturn in the years 2001 to 2003 (BVK 2004). The country has always had a traditional bank-based financial system (Hellmann 2000), which is not ideally suited for the financing of high-technology start-ups and usually leads to lower performance (Audretsch and Lehmann 2004). However, recent fundraising news from German venture capital firms indicates the possibility of an improvement in the national risk capital market (Red Herring 2005; Schuermann 2005). In addition, four out of ten European early stage investments in the first quarter of 2005 were closed in Germany (Incisive Media 2005).

A problem that is much more severe than the relatively small venture capital market is the lack of entrepreneurial spirit (Kluge, Meffert, and Stein 2000; Lehrer 2000). Regarding the number of new businesses with reasonable growth potential, Germany misses the European average by far. This is also because the country encounters a lack of expertise regarding the ability to found, develop, and nurture new businesses. In fact, Germany has a substantial shortage of capable and experienced managers who are able to grow entrepreneurial firms to a substantial size within a short period.

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[1] Although many new businesses are financed in other ways, most of these firms cannot be considered as high growth companies. This is due to the fact that more than 99% of all start-up firms have less than five employees (Katzy and Strehle 2004).

One reason for the lack of entrepreneurial spirit and thus the willingness to found new businesses is the lack of entrepreneurial education in schools and universities (Sternberg and Bergmann 2003). Regarding this aspect, Germany assumes a weak position compared to other economies in Europe but also on a global basis (Sternberg, Bergmann, and Lückgen 2004; Sternberg and Lückgen 2005).

Entrepreneurship education in general is difficult. This is mainly due to the interdisciplinary character of the field. While managers need to develop skills in finance, strategy, marketing and sales, and human resources in order to contribute to the economic success of the organisation, engineers have to gain deep insights in technology and product development, or production and manufacturing to add value to the firm. An entrepreneur who launches a technology-based company requires skills in both fields. This type of technology-oriented entrepreneur is also referred to as a technopreneur (Katzy 2005a). The concept of technopreneurship education should comprise elements of business administration with a focus on entrepreneurial activity as well as engineering curricula. While different research institutes in this field have recently been established, the efforts are rather rudimentary and scattered. Exceptions include areas with high entrepreneurial activity such as the Munich region (Audretsch and Fritsch 2002) where four local universities founded centres for entrepreneurial research and education[2].

Apart from the educational difficulties stemming from the interdisciplinary character of the subject, there is another reason for potential shortcomings in entrepreneurship education. For many decades, research activities in this field had been very limited. First in the 1980s, entrepreneurial research has found substantial recognition resulting in an increase of efforts and publications. The corresponding findings brought the field closer to a "position of being able to explain behaviour, predict performance, and provide normative advice, rather than merely document the entrepreneurial phenomenon" (Amit, Glosten, and Muller 1993, p. 815). However, the achievements were not sufficient to

[2] These centres comprise the Strascheg Entrepreneurial Center at the University of Applied Sciences, the Odeon Center for Entrepreneurship at the Ludwigs-Maximilians-Universität, the Center for Entrepreneurial and Financial Studies (CEFS) at the Technical University and the Center for Technology and Innovation Management (CeTIM) at the University BW.

predict ex ante whether an entrepreneurial firm will be successful or not (Amit, Glosten, and Muller 1993).

In order to increase the quality of entrepreneurship education, research has to be focused on the in-depth analysis of new venture success. Success and therefore firm performance is often related to growth and profitability (Baum and Wally 2003). However, entrepreneurship research generally deploys growth as the dominant indicator for the success of new ventures (Low and MacMillan 1988; Zahra and George 2000; Baum, Locke, and Smith 2001). In fact, growth is the primary goal of entrepreneurial firms (Mintzberg 1973). The evolution of a start-up company is a complex process over time. Thus, efforts in entrepreneurial research should address this process in order to gain insights on the determinants of new venture performance.

Entrepreneurship research can be divided into three domains (Stevenson and Jarillo 1990). Researchers from the first domain (e.g., Knight 1921; Schumpeter 1934; Leibenstein 1966; Leibenstein 1968; Kirzner 1979) mainly focus on the economic role and contribution of entrepreneurship. The second direction in entrepreneurial research addresses the reasons for individuals to become entrepreneurs. Scholars in this domain consider environmental influences as well as personal targets, values, and motivations (Fallgatter 2004). Both of these directions provide only limited insights on the growth process of a new venture. By contrast, the third direction assumes a more managerial perspective on the actions taken by the entrepreneur and the corresponding strategies, structures, and processes (e.g., Low and MacMillan 1988). Research in this direction often deploys concepts and theories from strategic management and applies them to new ventures (Shane and Venkataraman 2000). In fact, entrepreneurship and strategic management have many things in common such as the interest in growth, innovation, or organisational learning (Ireland, Hitt, Camp et al. 2001). However, strategic management research is often reduced to Porter's seminal contributions to strategic positioning (Porter 1980; Porter 1985) and Miles and Snow's typology of organisational adaptation to uncertainty and environmental change (Miles and Snow 1978). Although highly regarded in strategic management research, these concepts do not focus on the internal parts of the firm (Borch, Huse, and Senneseth 1999) and thus are not ideally suited for the

investigation of entrepreneurial growth processes. Instead, a conceptual framework should assume an inside-out perspective on start-up firms (Katzy 2005a).

Technology-based new ventures usually compete in high-velocity environments (Bourgeois III and Eisenhardt 1987; Bourgeois III and Eisenhardt 1988; Eisenhardt 1989). These conditions are characterised by rapid and disruptive changes with respect to competitors, demand, technology, and regulation (Bourgeois III and Eisenhardt 1988) and thus are highly dynamic. Facing these environments, entrepreneurial ventures are subject to high levels of uncertainty (Amit, Glosten, and Muller 1993; Alvarez and Busenitz 2001). A conceptual framework to be applied for research on entrepreneurial growth processes has to acknowledge the characteristics of high-velocity environments. Consequently, concepts and theories in this field should be dynamic instead of static.

1.2 RESEARCH OBJECTIVES

The main objective of this dissertation is to shed light on the growth processes of technology-based new ventures and link these processes to performance. The previous section revealed that a conceptual framework for research in this direction has to meet two fundamental requirements. First, it has to assume an inside-out perspective on the organisation and second, it has to be dynamic. The concept of dynamic capabilities (Teece and Pisano 1994; Teece, Pisano, and Shuen 1997; Zollo and Winter 1999; Eisenhardt and Martin 2000; Zollo and Winter 2002; Winter 2003) has attracted growing attention from strategic management scholars during the past years. The main purpose of this framework is to explain how firms gain a competitive advantage under conditions of rapid and unpredictable change. This dynamic concept is especially relevant in Schumpeterian worlds dominated by innovation-based competition, creative destruction of established competencies, and increasing returns (Teece, Pisano, and Shuen 1997). In fact, entrepreneurial firms mostly compete on innovation (Cooper and Bruno 1977; Miller and Garnsey 2000; Gompers and Sahlman 2002; Löfsten and Lindelöf 2002). Consequently, the concept can be considered to analyse performance differences and thus differences in growth rates of technology-based new ventures.

According to Teece, Pisano, and Shuen (1997) dynamic capabilities are an organisation's "ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (p. 516), and thus are a source of competitive advantage under conditions of rapid change (Eisenhardt and Martin 2000). The concept of dynamic capabilities builds on the resource-based view of the firm (Wernerfelt 1984; Barney 1991; Amit and Schoemaker 1993; Peteraf 1993), which argues that the competitive advantage of organisations is contingent upon their resource base. When firms grow in high-velocity environments, they need to alter this resource base and consequently have to deploy certain capabilities. However, these capabilities need to be developed as well. Just as firms do not have a large resource base from the beginning (Stinchcombe 1965; Romanelli 1989; Brush, Greene, and Hart 2001; Stuart and Sorenson 2003; Ravasi and Turati 2005), new organisations do not possess dynamic capabilities in their early days (Helfat and Peteraf 2003).

Given this theoretical excurse, I am able to specify the initial research objective. In order to describe the growth processes of technology-based new ventures and link them to performance, I apply the concept of dynamic capabilities. The approach can be separated into two specific tasks: the operationalisation of the concept, and the process description including the linkage to performance. Regarding the first task, I use the emerging dynamic capabilities in the entrepreneurial firm as contrast agents to describe the process of organisational development. Therefore, the capabilities themselves need to be specified at an operational level. In addition, the evolution of dynamic capabilities in the growing firm has to be made visible, i.e. an observer must be able to track the emergence of certain capabilities over time.

The second task comprises the representation of the entrepreneurial growth process, which is described by the evolution of certain dynamic capabilities over time. In order to understand this process I address three different aspects. The first aspect covers external and internal drivers for the emergence of dynamic capabilities in technology-based new ventures. The second aspect addresses the linkage between certain characteristics of the growth process and new venture performance, i.e. growth of the firm. The last aspect focuses on the specific paths of entrepreneurial growth.

This thesis is another result of a dedicated research programme at the Centre for Technology and Innovation Management (CeTIM) at Leiden University and University BW Munich, which focuses on the concept of dynamic capabilities. Previous work at this institute prepared the ground for this dissertation. Examples of successful research in this field include the measurement of dynamic capabilities under conditions of high uncertainty in new technology-based ventures (Dissel 2003) or the dynamic capabilities of product development (Blum 2004). Due to the promising results, additional work is expected to provide further insights in this direction.

1.3 RESEARCH QUESTION

As laid out in the previous sections, I intend to understand the growth processes of technology-based new ventures and link them to performance. Therefore, I apply the concept of dynamic capabilities in order to observe growth in the entrepreneurial firm over time. To realise the objective of this dissertation I seek an answer to the following research question:

> *How is the evolution of dynamic capabilities linked to the growth processes and the performance of technology-based new ventures?*

1.4 RESEARCH EPISTEMOLOGY

To derive an appropriate research methodology for this study, I define the corresponding epistemological position. According to Webster's "New world dictionary", epistemology is the "study or theory of nature, sources, and limits of knowledge". A similar definition can be found in the French "Vocabulaire technique et critique de la philosophie" which denotes epistemology as the "theory of knowledge" (Calori 1998, p. 288).

Research into the nature of knowledge and inquiry has a long history with its roots in the work of the Greek philosophers Aristotle and Plato. However, from the very beginning, the two famous scholars contemplated very different beliefs of how reality can be appreciated. Aristotle advocated empirical investigations to acquire knowledge and thus

constituted the empiricist belief. Empiricists generally see observations, experiences, or sense data as the most important or even the only form of knowledge acquisition. Classical empiricists include John Locke, George Berkeley, David Hume, and John Stuart Mill. In modern philosophy, influences of empiricism can be found in logical empiricism, the most recent form of positivism (Lyddon 1995; Tacconi 1998; Hjorland 2005).

Contrary to Aristotle's point of view, Plato emphasised logical intuition instead of empirical investigations. This perspective is referred to as rationalism. In its extreme form, rationalism does not consider any experience. According to the rationalist's belief, all observations require clear concepts as a basis. However, those concepts cannot be derived from empirical investigations. Consequently, the most important concepts are given a priori. These concepts are evident statements that cannot be questioned. In this context, new knowledge can only be derived by combining these statements. Important rationalists comprise René Descartes[3], Benedict de Spinoza, and Gottfried Wilhelm Leibniz (Hjorland 2005).

Empiricism and rationalism constituted the two main epistemological directions in the time between scholasticism and enlightenment. However, during the latter period, Immanuel Kant developed a critical view that advocates the coexistence of rational and empirical beliefs (Calori 1998). According to Kant's transcendental epistemology (Politis 1997), knowledge can be divided into absolute and empirical parts. The former comprises a priori categories such as space, time, and causality, which are rooted in the human consciousness. The latter part addresses the objects under study and can only be known a posteriori by empirical investigation (Kant 1781). With his work, Kant set the basis for modern constructivism.

Today's research is mostly dominated by two philosophical paradigms; positivism and constructivism. The positivist view dominated scientific research throughout most of the twentieth century. Positivism is closely related to empiricism; however, the positivist view allows for theoretical statements in theories of science (Tacconi 1998). The observer does not interact with the subject of study. Thus, values and other forms of bias are

[3] René Descartes used to explain his notion of science and philosophy based on geometry. Geometry as a whole science was built solely by means of pure logic and intuition without any empirical investigations.

excluded. The methodology for positivist research is mainly experimental. Hypotheses or questions are stated in advance and are tested in empirical studies while the conditions of the tests are carefully controlled (Tacconi 1998). Positivism requires the phenomena under study to be clear and expects an undeniable truth as the outcome of empirical tests. The positivist paradigm was initially meant to characterise physical science in general and physics in particular (Beed 1991).

Unlike positivism, constructivism is subjective, i.e. the observer and the object of research are considered as one entity. This approach is argued to be closer to managerial perspectives than the positivist view. Constructivism is usually applied when neither the boundaries between the object of research and the phenomena under study are clear nor an undeniable truth can be expected (Katzy and Dissel 2004). In fact, constructivism is especially useful in the context of discovery considering innovation, hypotheses development, or theory building. Although constructivism can be traced back to the work of Kant, the paradigm has actually evolved over the last three decades of the twentieth century (Tacconi 1998). During this time, the constructivist view has gained more and more attention in economics (Tacconi 1998) and strategic management research (Mir and Watson 2000; Kwan and Tsang 2001; Mir and Watson 2001).

In this study, the object of the research is the technology-based new venture while the phenomenon under study is the corresponding growth of this particular type of embryonic and fast growing organisation. In this case, the boundaries between the object and the phenomenon are not clear. Neither can we expect an undeniable truth as an outcome of this research effort. Instead, I intend to gain new insights into the growth processes of start-up companies in technology-based industries. To obtain this knowledge, an intensive information exchange between the inquirer and the object of research is necessary. Consequently, I have chosen a constructivist approach. Theory plays an important role in constructivism (Mir and Watson 2000). Following Kant's critical view, I emphasise the interplay between knowledge that is given a priori, i.e. that is derived from theory and knowledge that has to be obtained through empirical observations.

1.5 RESEARCH METHODOLOGY

To analyse the growth processes of technology-based new ventures I conducted a survey among entrepreneurial firms. Due to the large sample size, this method is usually very reliable and enables the researcher to generalise the corresponding findings. The survey in this study has a longitudinal design. This design allows me to track the evolution of dynamic capabilities in a larger sample of entrepreneurial firms as discrete events over time.

The survey population comprises a set of German technology-based new ventures that survived a predefined observation period and thus are ex ante considered as successful. All sample firms are located in one region. By focusing on a certain geographical area, I eliminate environmental influences such as infrastructure, access to labour markets, educational and scientific institutions, government support, etc. These effects often have a significant impact on the evolution of start-up firms and may inhibit the comparability of the sample companies.

To ensure a large population of entrepreneurial ventures, I chose an innovative cluster for the survey. Innovative clusters facilitate regional entrepreneurial activity (Breshahan, Gambardella, and Saxenian 2001). In fact, entirely new industries such as semiconductors, biotechnology, microcomputers, or information and communication technologies have developed in specific geographic regions (Feldman 2001). A major source for the foundation of new firms is tacit knowledge. This knowledge is usually developed in regional clusters and cannot be diffused easily across geographic areas (Kenney and von Burg 1999; Audretsch and Thurik 2001). The entrepreneurial activity within the cluster is mostly determined by its regional strength (Sternberg 1996). This strength is often influenced by the existence of active research universities, strong local networks, and venture capital (Feldman 2001). A region with high entrepreneurial activity is the area around Munich. It is considered as “the heartland of the entrepreneurial régime” in Germany (Audretsch and Fritsch 2002, p. 117). In particular, the biotech cluster at Martinsried, a Munich suburb, still constitutes a major European centre for life sciences (Lehrer and Asakawa 2004a; Lehrer and Asakawa 2004b). Thus, I decided to limit the population of this study to technology-based new ventures in the Munich region.

To show the evolution of dynamic capabilities in technology-based start-ups, the observation period starts with the foundation of the company. However, to ensure a certain quality of data, I limited the time of observation. Otherwise, early observations could easily have been biased or entirely lost. To be able to nevertheless cover as many phases of the growth process as possible I focused on high-growth companies. In general, VC funding accelerates growth rates in entrepreneurial firms (Davila, Foster, and Gupta 2003). Consequently, I limited the population to companies that have received venture capital funding. Thus, I expect to observe more phases of growth than in companies that have not received any financial support from venture capital firms.

For the survey, I adopted a longitudinal, multi-method, multi-case field research design, which is in line with Hofer and Bygrave's (1992) propositions for entrepreneurial research. The approach relies on qualitative and quantitative data. The data includes questionnaires and semi-structured interviews. In addition, I collected information from a commercial database on venture capital funded companies and from public sources such as company web pages or press releases. The multi-method design increases the quality of the research and allows for triangulation (Davila and Foster 2005). In fact, triangulation (Jick 1979) is an important criterion for the constructivist research process (Tacconi 1998). The multi-case field design allows me to gather a sample that is large enough to examine whether certain findings can be generalised by applying statistical methods. Thus, the research is not limited to company-specific experiences.

1.6 EXPECTED RESULTS

1.6.1 Contribution to Theory

This dissertation contributes to theory in two different forms. First, I contribute to the concept of dynamic capabilities. Although accepted as important, the framework has been subject to various points of critique. Different scholars (e.g., Henderson and Cockburn 1994; Foss 1999; Williamson 1999; Priem and Butler 2001) argue that the framework is tautological, non-operational, theoretically vague, and lacks empirical grounding (Eisenhardt and Martin 2000; Barney 2001; Blum 2004). Although many scholars refer to

the concept for empirical research, most of them use it rather to establish the context than to underpin the concept directly. However, some empirical work (e.g., Henderson and Cockburn 1994; Makadok 1999) constitutes very concrete tests of the framework (Barney 2001).

In this dissertation, I operationalise the concept of dynamic capabilities to apply it to the growth processes of entrepreneurial firms. First, I identify the different capabilities that are required in a start-up company and thus address the criticism that the concept is non-operational. In addition, I contribute to the theory by describing the evolution of dynamic capabilities in entrepreneurial ventures. Finally, I enrich the strategic management framework by providing empirical grounding through the multi-method, multi-case field research described in the previous chapter.

The second major contribution to theory focuses on the field of entrepreneurship research. By applying the concept of dynamic capabilities, I develop a framework that allows the tracking of the growth processes of technology-based new ventures over time. I identify differences in the growth processes of start-up companies and link these characteristics to performance.

1.6.2 Contribution to Practice

The practical contribution of this dissertation addresses entrepreneurs as well as investors, universities, incubators, venture coaches, and consultants. By identifying the different capabilities that are needed to grow a technology-based new venture, business founders realise which capabilities they have to develop to be successful as entrepreneurs. Management teams could either invest in learning to develop the required knowledge or hire additional managers to complete the team and thus close the skill gaps. In addition, training could be another means of skill development.

The contribution to entrepreneurial education at universities goes in the same direction. The curriculum and the teaching material could be adapted to the respective needs of business founders and management teams. The advantages of this study for investors, consultants, coaches, and incubators are similar. All these entities support entrepreneurs with their start-up companies and could benefit from this dissertation because they could

adapt their advice to the concrete needs of a technology-based new venture and thus accelerate the growth of the firm.

1.7 STRUCTURE OF THE STUDY

The first chapter defines the research objectives and the research questions as well as the research epistemology and methodology of this dissertation. In addition, I provide details of the expected contributions of the study and the corresponding structure.

The theoretical part of the dissertation starts with the second chapter. Here I conduct a literature review in the field of dynamic capabilities and familiar concepts such as the resource-based view of the firm, organisational learning, and organisational change and development to denote the growth processes of technology-based new ventures. Therefore, I reflect on different models aiming at the explanation of start-ups' organisational development. The models result in a concept that depicts the evolution of dynamic capabilities in technology-based new ventures over time and links this emergence to performance. In addition, the concept enables a corresponding operationalisation. While reviewing the literature, I derive different hypotheses that support the theoretical links of the concept by addressing the characteristics of the growth processes under study. The hypotheses comprise exogenous as well as endogenous influences on the growth processes of start-up firms. However, the concept and the hypotheses are not solely based on theories and approaches in the respective fields. Following a constructivist epistemology, I triangulate the findings from the literature review with quotes from the interviews conducted in the course of this study.

The theoretical part closes with the third chapter. In this section, I merge the derived concept with the different hypotheses into one consistent research framework that represents the theoretical basis for this dissertation. However, this framework still incorporates several open questions and issues that are related to the entrepreneurial growth processes. In chapter three, I list these additional points of interest in a section that focuses on explorative aspects of this study. In addition, I reflect on the operationalisation of the developed concept.

The empirical part of the study starts with the fourth chapter. Here I explain the characteristics of the empirical research. The section comprises the sample characteristics, the contact process and response pattern, and a non-response analysis that indicates whether the respondents differ significantly from firms that refused to participate in the survey. In addition, chapter four reflects on the statistical methods that are applied to test the various hypotheses and to provide additional explorative insights addressing the identified open issues.

The fifth chapter contains all the statistical analysis performed in this research effort. The chapter is divided into two main parts. The first comprises the descriptive statistics. This section provides insights into the characteristics of the sample. Therefore, I also offer some basic findings on the evolution of dynamic capabilities in the entrepreneurial firm. The second part of chapter five comprises all the interpretative statistics. This section again can be divided into two subsections. The first includes all statistical tests and regressions that are necessary to test the hypotheses derived in chapter two, while the second subsection focuses on several further regression models that contribute mainly to the explorative part of the study.

The theoretical part of the dissertation ends with the sixth chapter. This section follows the structure of the interpretative statistics and includes the discussion of the results. Again, the first part focuses on the hypotheses derived in chapter two, while the second part addresses largely the explorative character of the dissertation that includes various open questions and research gaps as well as additional findings from the research data.

The dissertation ends with the seventh chapter. Here I reflect on the initial research question and the theoretical and practical contribution of the dissertation. In addition, I explain certain limitations of the study. Finally, I show possible directions for future research efforts related to the field of organisational development and growth in technology-based new ventures.

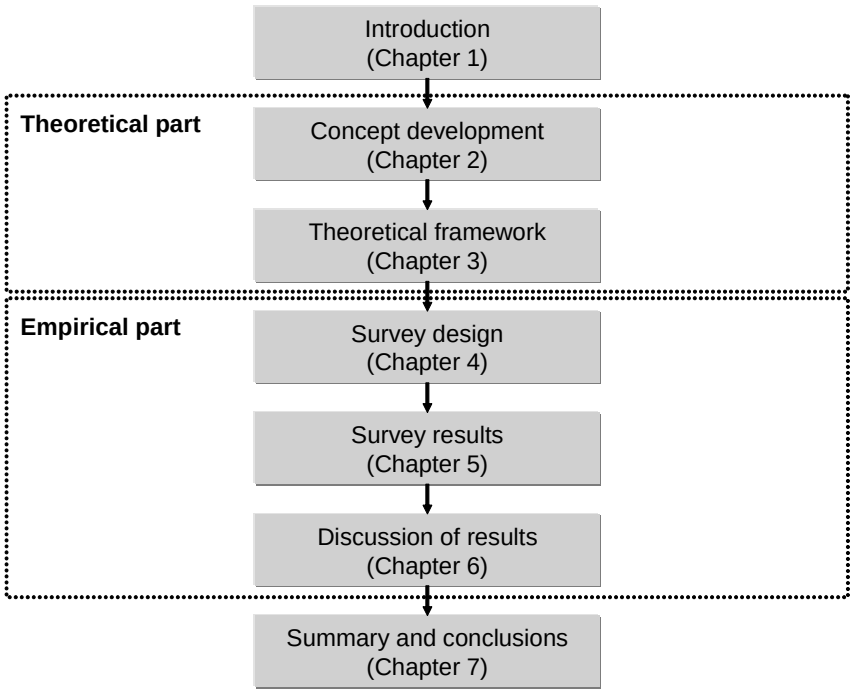

Figure 1 General dissertation outline

2 CONCEPT DEVELOPMENT

2.1 A RESOURCE-BASED VIEW OF ENTREPRENEURSHIP

As already indicated in the introduction, the dynamic capabilities framework is based on the resource-based view of the firm. Therefore, I start with a review of the literature in this particular field and then offer insights on different theoretical underpinnings of the concept. In addition, I provide an overview of important company resources and link the concept to the case of technology-based new ventures. Finally, I identify resources which are especially important in the early stages of entrepreneurial growth.

2.1.1 Introduction to the Resource-Based View of the Firm

The resource-based view as a strategic management framework is mainly based on the work of British economist Edith Penrose and her seminal publication "The theory of the growth of the firm" from 1959. Within a resource-based view, organisations are considered as bundles of resources (Peteraf 1993; Eisenhardt and Schoonhoven 1996). In general, resources can be defined as stocks of available factors owned or controlled by an organisation (Amit and Schoemaker 1993). According to Penrose (1959), the returns of a company can largely be associated with the characteristics and the heterogeneity of its resource base. However, for 25 years this argument has not attracted much attention. At first, in 1984, Birger Wernerfelt referred to Penrose's ideas when he argued that the evaluation of firms according to their resource base could lead to insights that differ substantially from traditional approaches in strategic management. Contrary to the market-based approach (Porter 1980; Porter 1985), the resource-based view of the firm takes an inside-out perspective on organisations in order to explain competitive advantage. Thus, the concept is often referred to as a counterpart to market-based considerations (Wernerfelt 1984), which complements Michael Porter's seminal work (Henderson and Cockburn 1994).

Since Birger Wernerfelt's publication in 1984 the resource-based view of the firm has attracted much attention among scholars in strategic management. The concept has been

used for theoretical and empirical contributions in many different fields (Barney, Wright, and Ketchen Jr. 2001). Functional applications of the concept cover product development (e.g., Verona 1999; Blum 2004), human resource management (e.g., Lado and Wilson 1994; Wright, McMahan, and Abagail 1994; Kamoche 1996; Barney and Wright 1998), marketing (e.g., Möller and Anttila 1987; Day 1994a; Hooley, Broderick, and Möller 1998; Srivastava, Shervani, and Fahey 1999; Srivastava, Fahey, and Christensen 2001), and information technology (e.g., Mata, Fuerst, and Barney 1995; Ross, Beath, and Goodhue 1996; Powell and Dent-Micallef 1997; Bharadwaj 2000). But also alliances and partnerships (e.g., Barney 1999; Minshall 1999; Hitt, Dacin, Levitas et al. 2000) and the internationalisation of firms (e.g., Peng 2001) have been subject to resource-based research.

Compared to classical economic theory (e.g., Ricardo 1817), the resource-based view of the firm suggests a more specific and differentiated understanding of an organisation's resources (Gruber and Harhoff 2002). Barney (1991) extended the understanding for company resources which could lead to sustainable competitive advantage. Therefore, he distinguishes between competitive advantage and sustained competitive advantage. A competitive advantage can be achieved when a firm is able to implement a strategy that creates value while not being simultaneously implemented by a current or a potential competitor. This competitive advantage can only be sustained when competitors are not able to duplicate the benefits of the firm's strategy. Under perfect resource homogeneity and resource mobility, an organisation would not be able to achieve any sustained competitive advantage (Barney 1991). Thus, he defined the heterogeneity and immobility[4] of resources as prerequisites for his framework. In general, resources can be considered as immobile if they cannot be traded (Peteraf 1993). In his framework, Barney (1991) introduced different requirements for resources. In order to lead to sustained competitive advantage, resources must be valuable, rare, imperfectly imitable, and not substitutable. Peteraf (1993) further developed the concept by claiming ex ante and ex post limits to competition as additional prerequisites for the framework.

[4] Different examples for the immobility of resources are given by Dierickx and Cool (1989).

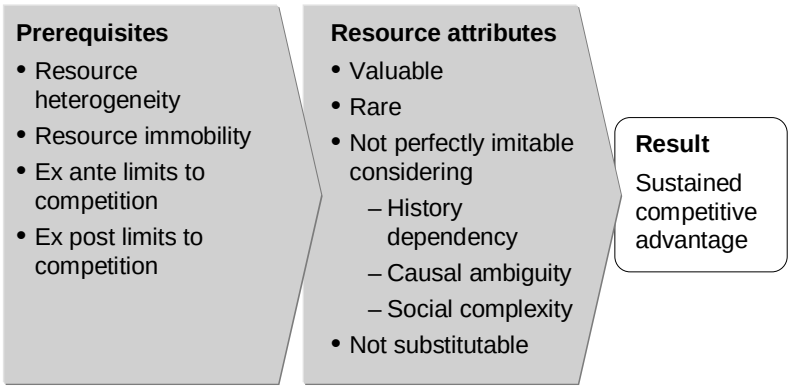

Figure 2 Resource-based framework (adapted from: Barney 1991; Peteraf 1993)

In summary, the resource-based view can be considered as a powerful theoretical framework in order to understand how firms can achieve competitive advantage and how this advantage can be maintained over longer periods of time (Barney 1991; Teece, Pisano, and Shuen 1997; Eisenhardt and Martin 2000).

2.1.2 Identifying Firm Resources

Firm resources can comprise machinery, in-house knowledge of technology, employment of skilled personnel, trade contacts, brand names, efficient procedures, or capital (Wernerfelt 1984). Resources can be clustered in different ways. A prominent approach differentiates between tangible and intangible resources (e.g., Penrose 1959; Hall 1992; Hall 1993). Examples for intangible resources include patents, contracts, intellectual property rights, databases, trade secrets and reputation as well as people networks (Hall 1992).

A different categorisation scheme was offered by Barney (1991). According to this framework, resources can be clustered into physical capital resources, human capital resources, and organisational capital resources. The first group includes a firm's physical technology, plant and equipment, the location, and the access to raw materials. Human capital resources are generally considered main drivers for business success. The influence of organisational members on economic performance is mainly founded on their know-how (Hall 1992). Human capital resources comprise the experience,

judgment, training, intelligence, relationships, and insights of the firm's managers and employees. The third group of resources covers the company's formal reporting structure, different formal and informal planning, controlling, and coordinating systems. Grant (1991) further developed Barney's resource typology by adding technological resources, financial resources, and reputation as additional categories (Miller and Shamsie 1996). The following picture provides an overview of firm resources that could lead to a firm's competitive advantage.

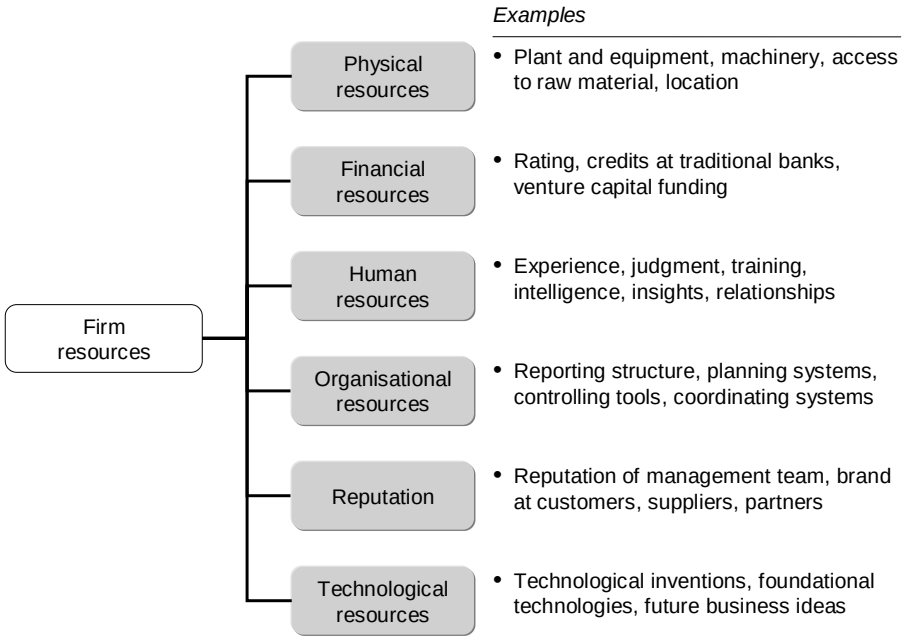

Figure 3 A typology of firm resources (adapted from: Barney 1991; Grant 1991)

2.1.3 An Entrepreneurial Perspective on the Resource-Based View

The linkage between the resource-based view of the firm and new business development can initially be found in Schumpeter's definition of entrepreneurship as the creation of new resource combinations (Schumpeter 1934). Entrepreneurial vision and intuition are essential for discerning adequate inputs in a resource-based view. However, the combination of resources is not the only similarity between entrepreneurship and the resource-based view of the firm. Both fields incorporate the potential for extraordinary

returns due to different ways of competing, the constant existence of imitating competitors and the entrepreneurial vision at the heart of the organisation (Conner 1991).

Alvarez and Busenitz (2001) claim that entrepreneurial research can benefit significantly from a resource-based view of the firm (Barney, Wright, and Ketchen Jr. 2001). Entrepreneurs have special skills that facilitate opportunity recognition and the coordination of resources for the creation of new ventures. Individual skills and assets like entrepreneurial alertness and knowledge, insight and the ability to coordinate resources are inseparable from the entrepreneur. Thus, they are scarce and not imitable, and can be considered as resources in their own right (Alvarez and Busenitz 2001).

The establishment of an initial resource base is one of the most difficult tasks for the entrepreneur (Brush, Greene, and Hart 2001). Resource decisions with respect to new ventures are generally based on pure judgment considering only currently available information. This is due to the fact that young firms typically lack a solid customer base, administrative history, shared experience, and reputation (McGrath 1999). To succeed as an entrepreneurial venture, business founders have to develop a sound business model that links market needs and company resources (Ardichvili, Cardozo, and Sourav 2003). Therefore, they have to combine tangible and intangible resources, which could lead to a competitive advantage.

In general, market-based approaches in strategic management are based on structural and static considerations while a resource-based perspective shows many more similarities to entrepreneurship, which is based on change and the opportunity-oriented activities of the entrepreneur (McGrath and MacMillan 2000).

2.1.4 Resource Requirements in New Ventures

While large firms own a wide range of valuable resources, entrepreneurial firms face a severe resource scarcity in the beginning and thus have to establish a resource base in order to implement the business idea (Stinchcombe 1965; Romanelli 1989; Brush, Greene, and Hart 2001; Stuart and Sorenson 2003; Ravasi and Turati 2005). Entrepreneurs usually have a limited access to financial resources, material or labour markets. These resource restrictions reduce the power that start-up firms can impose on

markets and competitive conditions. Accordingly, new ventures have a limited ability to change the difficult environment they encounter (Romanelli 1989).

Stuart and Sorensen (2003) identified three different resources as most critical to launching a technology-based company. The first resource requirement for a new venture in high technology industries is a new idea and a foundational technology. However, new business ideas that exist are two a penny. Sometimes different entrepreneurs even come up with almost identical business ideas at the same time (Bygrave and Zacharakis 2003). Entrepreneurial opportunities occur due to different beliefs about the value of resources in society (Kirzner 1997). In the previous chapter, we have identified the entrepreneur's ability to recognise these opportunities as a valuable resource in their own right (Alvarez and Busenitz 2001). Thus, it requires the entrepreneur to identify the opportunity and decide to exploit it (Shane and Venkataraman 2000).

Another highly important resource new ventures initially require is funding (Schoonhoven, Eisenhardt, and Lyman 1990; Klofsten, Jonsson, and Simón 1999; Miller and Garnsey 2000; Lounsbury and Glynn 2001; Stuart and Sorenson 2003). Inadequate supply of capital resources has been identified as a major cause of young business failure (van Auken and Carter 1989). The following quote from the CEO of a software service firm stresses the importance of financial resources in the early stages of new venture growth.

> *"You can make as much revenue as you want. If there is no money in the bank account, you have to close down the business".*

Due to wealth constraints, entrepreneurs usually depend on external financing (Evans and Jovanovic 1989). However, entrepreneurial ventures encounter severe problems with respect to funding (Horwitch and Prahalad 1976). Technology-based companies are especially subject to high risk, can expect several years of negative cash-flow, and require substantial capital resources to finance research and development, production, and marketing (Gompers and Lerner 1999; van Auken 2001). In addition, traditional finance theory (e.g., Modigliani and Miller 1958; Tobin 1958) is usually not applicable to small

firms. Altogether this leads to an increased cost of capital, higher transaction costs, and limited sources of funds (van Auken and Holman 1995).

A possible solution to fund high-risk and capital intensive projects is venture capital (Gompers and Lerner 1999). As opposed to traditional banks that mainly focus on debt financing, VC firms provide equity financing. Venture capital has played a dominant role in funding a number of entirely new industries in the United States (von Burg and Kenney 2000). Although scholars proposed alternative ways of start-up financing such as leveraging social networks (McGrath 1996), subcontracting labour (Thorne and Churchill 1989), or minimising investments in fixed and specialised assets (Hambrick and MacMillan 1984), these sources mostly do not match the capital requirements of technology-based start-ups. Many start-ups are in desperate need of venture capital to realise their business model. The CEO of a sample company in the biotech sector revealed the tremendous efforts associated with the realisation of external funding in the following quote.

> *"One of the initial investors was not willing to fully support our second round of financing. This was a very difficult situation for us. Basically, it took us a year and about three quarters of my time. We went almost everywhere, presented, and used the rest of the time to update and rework the presentation. The management team had almost no time for anything but refining and presenting our business plan."*

To further reduce external funding, entrepreneurs might also engage in early licensing or limit financial resources for the growth of the company. Firms that want to completely avoid third-party funding pursue bootstrap finance (Bhide 1992), i.e. financial resources are generated solely from the firm's own cash-flow. However, these limitations usually compromise future growth (Gruber, Harhoff, and Tausend 2003). The following figure further clarifies this argument. Curve A represents a venture that was financed externally while curve B shows a company that relied on bootstrap finance. Although the burn rate

of firm B is much smaller in the beginning, the future cash-flow of company A exceeds company B by a long way.

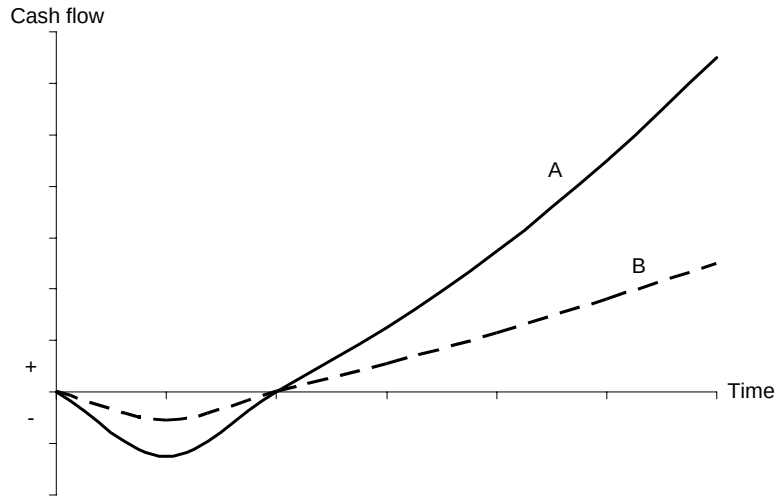

Figure 4 Alternatives of funding and corresponding cash-flows (adapted from: Gruber, Harhoff, and Tausend 2003)

Venture capitalists act as financial intermediaries in a market that is characterised by limited transparency and liquidity. The investments are usually not undertaken by the investors directly but handled indirectly through a fund. Investors such as large pension funds, assurance companies, or traditional banks allocate financial resources to these funds and the venture capitalist, as the fund manager, invests the financial resources in promising young firms with high growth potential. In return, the VC obtains a certain equity stake in these companies. Runtimes for venture capital funds vary between 7 and 13 years. VC firms tend to limit their investment activities to specific industries, locations, and investment stages.

Venture capital investments differ from typical investments in three aspects. First, venture capital is invested based on almost no performance history, at least for early stage deals. Second, compared to usual investors, venture capitalists are much more involved in their investments. Third, venture capital investments are illiquid in the short term since exits are mostly not possible in the early stages of new venture creation (Tyebjee and Bruno 1984). After a certain time, venture capitalists actively search for an exit opportunity, i.e.

they seek to materialise their investments with a reasonable upside. Therefore, different possibilities exist. The VC firm may exit the investment by pursuing an initial public offering, a full or partial sell to a third party, a secondary buy-in or buy-out, or a receivership if the company goes bankrupt (Wright and Robbie 1998). The venture capital business model is denoted in the following figure.

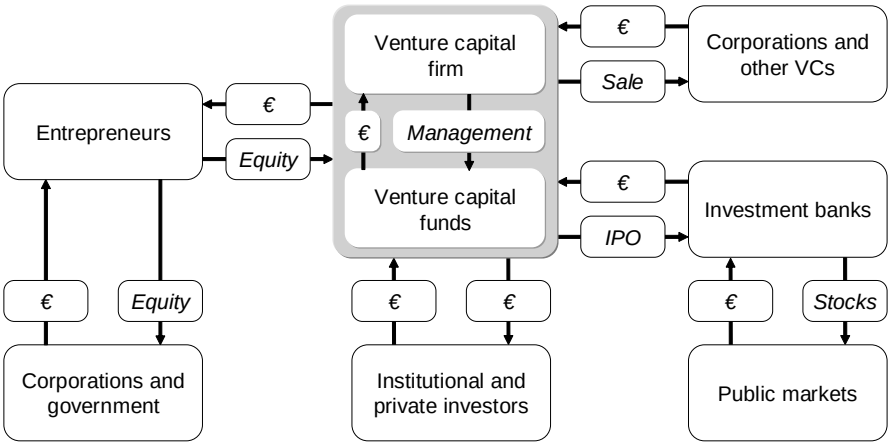

Figure 5 Venture capital business model (adapted from: Zider 1998; Gompers and Lerner 1999)

The third resource requirement of new ventures comprises employees with highly specialised human capital (Kamm, Shuman, Seeger et al. 1990; Lounsbury and Glynn 2001; Stuart and Sorenson 2003). Various scholars (e.g., Prahalad and Hamel 1990; Nelson 1991; Nonaka 1991; Henderson and Cockburn 1994; Nonaka 1994; Kogut and Zander 1996; Nahapiet and Ghoshal 1998) claim that knowledge and the ability to create and apply it are the most important sources of competitive advantage. This is especially true for dynamically competitive environments (Grant 1996a). Only through knowledge and skills are firms able to continuously innovate (Nonaka, Toyama, and Nagata 2000). Consequently, entrepreneurial firms are heavily reliant on available know-how. Knowledge as an intangible resource (Hall 1992) is embedded in the members of the business organisation. Consequently, technology-based new ventures need specialised human capital resources to acquire the knowledge that is necessary to exploit entrepreneurial opportunities. This proposition is in line with the results of different

studies (e.g., Cooper, Gimeno-Gascon, and Woo 1994; Thakur 1999) that revealed the importance of human capital as a determinant of new venture performance (Ensley, Pearson, and Amason 2002).

First, entrepreneurs need to assemble a founding team comprising key technologists and managers who assume senior positions at the new firm (Stuart and Sorenson 2003). In fact, industry-specific human capital is a major determinant of new venture survival (Roure and Maidique 1986; Cooper, Gimeno-Gascon, and Woo 1994; Shepherd, Douglas, and Shanley 2000). Functional experts are necessary to get away from the traditional model of the lonely entrepreneur as a "jack-of-all-trades" (Galbraith 1982) who covers most functions but masters only a few (Schoonhoven, Eisenhardt, and Lyman 1990). The top management team is highly important for three different reasons. First, capable senior managers are required to complement the founder's skills and knowledge to create and grow the new business. Especially in technology businesses, entrepreneurs often lack the necessary business acumen (Roberts 1991; Brush, Greene, and Hart 2001). Second, a superior founding team is generally helpful to attract potential investors. Venture capitalists usually apply the quality of the start-up's founding team as an important evaluation criterion for their investment decision (Tyebjee and Bruno 1984; MacMillan, Siegel, and Subbanarasimha 1985). In fact, VC investors sometimes even compromise the business opportunity if they have the chance to invest in a superior team (Muzyka, Birley, and Leleux 1996; Wright and Robbie 1998). Third, an exceptional management team can provide an entrepreneurial venture with highly-valuable access to further resources such as specialised labour or social capital resources (Ucbasaran, Lockett, Wright et al. 2003).

The following picture denotes the establishment of an initial resource base in technology-based new ventures. The dotted lines show influences mainly focusing on the venture capitalist's decision regarding the funding of the entrepreneurial firm. These influences obviously comprise the business idea and the founding technology but also, and sometimes with a stronger emphasis, the entrepreneur and the founding team of the start-up company. In addition, the entrepreneur has a major influence on the configuration of the founding team since the founder often has to convince senior executives to give up relatively secure jobs at large corporations (Stuart and Sorenson 2003).

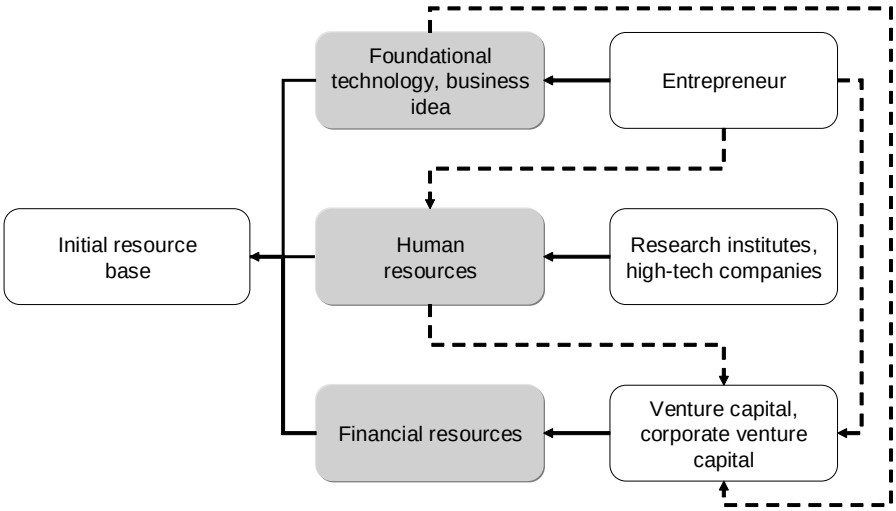

Figure 6 New ventures' resource requirements, sources, and influences

2.2 DYNAMIC CAPABILITIES AND NEW VENTURE GROWTH

Having reflected on the resource-based view of the firm as a theoretical underpinning, I use this section to introduce the dynamic capabilities framework. First, I integrate resources and capabilities to establish a link between both concepts. Afterwards, I explain the dynamic capabilities framework in detail. To gain further insights, I differentiate between entrepreneurial and dynamic capabilities and provide a list of dynamic capabilities that are of major importance for the success of a technology-based new venture. The section closes with a perspective on the evolution of dynamic capabilities in organisations.

2.2.1 Integrating Resources and Capabilities

The resource-based view does not solely consider a firm's resources but also the ability to deploy, coordinate, and alter this resource base. While some scholars (e.g., Barney 1997; Peteraf and Bergen 2003) consider these abilities also as resources, they are typically

referred to as an organisation's capabilities. Firms need capabilities to alter their resource base in order to capitalise on existing opportunities in their industries (Zahra and George 2000). Capabilities are intangible and information-based processes (Prahalad and Hamel 1990; Amit and Schoemaker 1993; Grant 1996a) that are firm-specific and evolve through complex interactions among the resources of a company (Conner and Prahalad 1996; Kogut and Zander 1996). They can abstractly be thought of as "intermediate goods generated by the firm to provide enhanced productivity of its resources, as well as strategic flexibility and protection for its final product or service" (Amit and Schoemaker 1993, p. 35).

There are two specific differences between resources and capabilities. Contrary to resources, capabilities are firm-specific since they are embedded in the firm's organisation and its processes (Makadok 2001). Different from resources, capabilities are based on the development, transfer, and exchange of information through the human capital of an organisation. Gruber and Harhoff (2002) provide a simple but comprehensive differentiation between resources and capabilities when they propose that resources are everything a firm "has" and capabilities address the abilities of the firm, i.e. everything the organisation "can" do. Summing up, from a resource-based perspective, an organisation's competitive advantage is mainly contingent upon its unique resources and capabilities (Deeds, DeCarolis, and Coombs 1999; Miller, Eisenstat, and Foote 2002).

Firms often develop capabilities in their functional areas or by combining different types of resources at the corporate level. Their primary goal is the enhancement of productivity and effectiveness (Amit and Schoemaker 1993). However, seeking for ultimate excellence can also have a negative impact on the firm's performance. This is true in the case of capabilities as well. Therefore, a firm has to avoid the development of core rigidities. Core rigidities are the downside of core capabilities and can evolve under different circumstances. A typical example is a long period of success for a company and the corresponding loss of alertness for new market trends. In order to mitigate core rigidities, firms should regularly evaluate and rethink their business systems to overcome static processes (Leonard-Barton 1992). This is especially important in dynamic environments where the boundary conditions change over short periods.

2.2.2 Dynamic Capabilities and Organisational Routines

The reason why many new technology businesses fail can often be found in the high-velocity environments they usually face. As we have learned from chapter 1.1, these conditions incorporate high levels of uncertainty. Uncertainty usually implies "a lack of predictability, of structure, of information" (Rogers 1962, p. 6) and has to be clearly distinguished from risk. In the case of risk, ex ante calculations can be performed that indicate the probability for an event to occur. This is not possible in the case of uncertainty. Uncertainty is a key component of entrepreneurship. In fact, only uncertainty can explain extraordinary profits as well as failures of entrepreneurial firms (Knight 1921; Brouwer 2002). Uncertainty in entrepreneurship can be associated with the market, the technology, the competition, and the environment (Bahrami and Evans 1989). Market uncertainty represents the unpredictability of customer demand and end user preferences (Sapienza and Gupta 1994). Technological uncertainty is related to the design of products and services and the production processes. In general, sources of product development may range from existing bodies of knowledge to unknown technologies that are not yet developed. While the first group is associated with low uncertainty, entirely new technologies imply high levels of uncertainty (McGrath 1995; Shenhar and Dvir 1996; Davila 2000; Dissel 2003). Since entrepreneurial firms usually focus on innovation, they have to cope with high levels of technological uncertainty. Competitive uncertainty includes the formation of alliances or the unforeseen entry of a competitor. The fourth aspect of uncertainty accounts for the changes in industry standards (Bahrami and Evans 1989).

Within these changing environments, firms have to continually acquire, upgrade, and develop resources to grow and maintain a competitive position in the market (Wernerfelt and Montgomery 1988). Thus, companies require the ability to adapt to new settings with minimal resources in a very short period of time (Nelson and Winter 1982; Hayes and Pisano 1994). Consequently, entrepreneurial firms have to reconfigure their resource base quickly. The capabilities of manipulating a firm's resource configuration in order to adapt to high-velocity environments are referred to as dynamic capabilities (Eisenhardt and Martin 2000). In line with the definition of Teece, Pisano, and Shuen (1997) Eisenhardt and Martin (2000) define dynamic capabilities as a "firm's processes that use resources -

specifically to integrate, reconfigure, gain and release resources - to match and even create market change. Dynamic capabilities are thus the organisational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve, and die." (p. 1107). Firms which are able to build these dynamic capabilities can gain competitive advantage in dynamic environments (Teece, Pisano, and Shuen 1997; Eisenhardt and Martin 2000; Zollo and Winter 2002).

The dynamic capabilities framework has attracted much attention during the past decade. Publications include the discussion of intra-firm selection processes (Madsen and McKelvey 1996), product development (Deeds, DeCarolis, and Coombs 1999; Verona and Ravasi 2003; Blum 2004), international firm expansion (Luo 2000), industry organisation (Madhok and Osegowitsch 2000), innovation (Galunic and Eisenhardt 2001), and the performance of different firms within a single industry (Zott 2003).

Since the dynamic capabilities framework as a strategic management concept is comparatively recent, there have been several discussions among scholars with respect to its meaning. Zollo and Winter (2002) question the limitation of dynamic capabilities to environments which are subject to disruptive change. They refer to the fact that firms integrate, generate, and reconfigure competencies regardless of their environment. Hence, they define a dynamic capability as "a learned and stable pattern of collective activity through which the organisation systematically generates and modifies its operating routines in pursuit of improved effectiveness" (p. 340). With this approach, Zollo and Winter (2002) contradict Eisenhardt and Martin's (2000) definition of dynamic capabilities as emergent and unstable processes in high-volatility markets. In addition, they disagree with Eisenhardt and Martin's proposition that dynamic capabilities are routines.

For the remainder of this study, I use a definition that integrates elements of both seminal publications discussed in the previous paragraph. Thus, I characterise dynamic capabilities as the organisation's learned patterns that enable the firm to configure its organisational setup, comprising the adjustment of the resource base as well as the generation and adaptation of organisational routines to increase its economic performance. I further define the learned patterns as complex bundles of accumulated knowledge and skills (Day 1990; Desarbo, Di Benedetto, Song et al. 2005).

Dynamic capabilities facilitate the creation and adaptation of operating routines (Zollo and Winter 2002). Routines are denoted as rules, forms, procedures, conventions, strategies, and technologies (Levitt and March 1988) that determine the behaviour of organisations under particular circumstances (Nelson 2002). In their character, routines can be described as functionally similar patterns of actions (Pentland and Rueter 1994). This definition is in line with Grant (1991), who describes routines as "regular and predictable patterns of activity which are made up of a sequence of coordinated actions by individuals" (p. 122). These behavioural patterns are followed repeatedly. Routines are business practices, which result in an outcome that is predictable and specifiable. There are routines to set prices, to hire workers, to promote employees, or accounting routines (Dosi, Marengo, Bassanini et al. 1999; Nelson and Nelson 2002).

According to Nelson and Winter (1982), organisational routines can be categorised into three different groups. The first group comprises general operating routines. These procedures determine the production output of a firm in different settings considering financial resources and other constraints that affect the firm's actions. The second cluster comprises routines which define the investment behaviour of the firm. These procedures mainly influence the growth and decline of a firm (Dosi and Nelson 1994). The third group includes deliberate processes that continuously search for desirable changes in the operating processes. These routines are also referred to as search routines (Zollo and Winter 2002).

Routines are adaptable (Becker 2004) and thus are especially important under conditions of uncertainty, complexity, and information overload (Becker and Knudsen 2005). Routines can make important contributions in situations of pervasive uncertainty. They support actors in their choice of a certain action. In fact, routines could enable decision-making in situations that are subject to environmental turbulence. This is because routines constrain their strategic responses. The ability of routines to help individuals to deal with pervasive uncertainty stems from the fixing of certain parameters, which results in two different effects. First, the predictability is increased. Second, it frees cognitive resources at the same time (Becker and Knudsen 2005).

2.2.3 Entrepreneurial and Dynamic Capabilities

A firm's performance is determined by its routines and the routines of other economic actors that interact with the organisation such as competitors, suppliers, or customers. Organisational growth is mainly caused by changes in the operating routines. These changes can comprise the creation and wide application of superior new routines, and the abandonment of older ones (Nelson 2002). Consequently, entrepreneurial firms require dynamic capabilities to establish organisational routines. In the following paragraphs, I denote the different functional areas where technology-based new ventures need these capabilities.

Dynamic capabilities in new ventures are often confused with entrepreneurial capabilities, although there are differences between both constructs. Entrepreneurial capabilities represent the ability to identify an opportunity and establish the resource base that is necessary to start the exploitation. The development of this initial resource base is mainly the task of the founder (Chandler and Hanks 1994). Entrepreneurial capabilities are primarily linear and, therefore, decision makers focus solely on the opportunity (Arthurs and Busenitz 2006). Reflecting on chapter 2.1.4, entrepreneurial capabilities thus mainly address the acquisition of financial and human capital resources in addition to the identification of the entrepreneurial opportunity, which comprises the business idea and the foundational technology.

Dynamic capabilities on the other hand are mostly recursive. They aim at the continuous adaptation and reconfiguration while considering an existing opportunity and an initial resource base. Dynamic capabilities combine knowledge in order to find a recombination that allows the organisation to meet its performance goals. Therefore, the focal point continuously moves between external influences from the product markets or the target customer base, but also from comparison of the firm's capabilities with the capabilities of competitors who target similar market segments (Arthurs and Busenitz 2006). In the remainder of this study, I focus on the dynamic capabilities of technology-based new ventures.

Technology-based new ventures need a wide variety of different dynamic capabilities in order to turn a start-up firm into a large company over time. Following Peteraf and

Bergen's (2003) proposition, I identify these capabilities in different functional areas of the firm. As a starting point, I reflect on the resources that are most critical for a new venture. Although these resources are acquired through entrepreneurial capabilities, they still build the initial resource base, which has to be adjusted, reconfigured, and thus managed through the firm's dynamic capabilities.

The first resource technology-based new ventures need is an idea and a foundational technology, which creates an entrepreneurial opportunity. From this point on, the exploitation of this opportunity is the primary goal of the start-up company. To achieve certain targets, companies usually engage in strategic planning. However, planning efforts in entrepreneurial firms have often been subject to criticism (e.g., Carter, Gartner, and Reynolds 1996; Bhide 2000). Critics argue that entrepreneurs should directly engage in resource acquisition, marketing, and promotion activities instead of planning (Delmar and Shane 2003).

Various scholars (e.g., Mintzberg 1990; Ansoff 1991; Mintzberg 1991; Goold 1992) controversially discussed the benefits of planning by contrasting planning efforts against organisational learning. But planning and learning are not exclusive. Instead, planning can be considered as a method of proactive learning where managers absorb knowledge from their environment (Castrogiovanni 1996). We have learned that high-velocity environments are characterised by high uncertainty. Different researchers (Armstrong 1982; Grinyer, Al-Bazzaz, and Yasai-Ardekani 1986; Smeltzer, Fann, and Nikolaisen 1988) argue that planning may reduce this uncertainty. This is in line with the findings of Shrader, Mulford, and Blackburn (1989) who found a correlation between strategic planning intensity and perceived uncertainty in small firms.

Following Carpenter, Lazonick, and O'Sullivan (2003), innovative enterprises should engage in strategising in order to allocate investments in their resource base. According to Matthews and Scott (1995), the planning practices in entrepreneurial firms are more sophisticated than in ordinary small businesses. Delmar and Shane (2003) revealed the positive impact of pre-start-up business planning on new venture performance while McGrath and MacMillan (2000) promote milestone planning as an important tool for entrepreneurial ventures. Reflecting on these findings, technology-based new ventures require strategic planning capabilities.

Financial resources are especially scarce for small growing firms in a technology-intensive industry. Thus, start-up firms need to manage these resources carefully. In order to distribute, control, and monitor funds, new ventures need resource allocation capabilities (Burgelman 1994; Grant 1996a; Gartner, Starr, and Bhat 1998; Eisenhardt and Martin 2000). In fact, high-growth firms launching new products on the market usually apply tight cost controls (McDougall and Robinson Jr. 1990). However, not only the allocation of financial resources is important in entrepreneurial firms, but in addition, start-ups require the ability to evaluate the outcomes of their spending. From chapter 2.1.4, we have already learned that these investments are especially high in technology-based new ventures (Gompers and Lerner 1999; van Auken 2001). Thus, firms need to monitor the results from these investments. Summing up, start-ups need financial planning and evaluation capabilities.

The next scarce resource we have identified is human capital in the form of highly specialised employees. Skilled labour has to be managed properly. In dynamically competitive markets where knowledge is strategically highly important, human resource management (HRM) is a key capability (Grant 1996a). This is in line with a study from Heneman, Tansky, and Camp (2000) that reveals that young entrepreneurs usually have major concerns regarding the management of human resources in their organisations.

Most publications in strategic human resource management focus on HR practices as sources of competitive advantage. However, from a resource-based perspective, single isolated HR practices cannot create sustainable competitive advantage for a firm. Even when implemented as high performance work practices they are not safe from imitation. Only organisations that shift from a traditional sub-functional view of HR to an integrated and highly interdependent human resource system can sustain competitive advantage (Barney and Wright 1998; Barney, Wright, and Ketchen Jr. 2001). Although theoretically valid, this argument has never found empirical support (Huselid 1995). On the other hand, various scholars (e.g., Steffy and Maurer 1988; Terpstra and Rozzell 1993; Huselid 1995; Delaney and Huselid 1996) have demonstrated that superior human resource management practices have a positive influence on firm performance. Organisations that do not invest in HRM run the risk of competitive disadvantage (Barney and Wright 1998).

Human resource management comprises the attraction, development, motivation, and retention of organisational members (Barney, Wright, and Ketchen Jr. 2001). The motivation of employees is an especially important influence on new venture performance (Pavett and Lau 1983; Hofer and Sandberg 1987; Baron and Markman 2003). It is usually difficult for start-ups to attract capable managers from large corporations and convince them to give up their relatively safe environment for a position in an initially fragile firm that is subject to high uncertainty (Stuart and Sorenson 2003). To actually attract, motivate, develop, and retain highly skilled managers and workers, an entrepreneurial firm must plan for its human resources, and evaluate and reward individual performance. This is in line with the findings from Schuler and MacMillan (1984) who identified performance appraisals as a key HRM practice. Summing up, human resource planning and evaluation are important capabilities which entrepreneurial firms need to develop a highly skilled human resource base.

While I derived the first dynamic capabilities from the initial resource requirements of the entrepreneurial firm, I intend to derive further capabilities from the results of an established and operating resource base. Reflecting on chapter 1.2, the foundation of entrepreneurial businesses is usually based on the invention of a new technology and aims at technological innovation. Consequently, start-ups aim at transforming their first "idea to technology" or foundational technology into a new product. In general, entrepreneurial firms need to develop a portfolio of new products in a short period of time to realise early cash-flows, to increase external visibility and legitimacy, to gain early market share and thus increase the probability of survival (Schoonhoven, Eisenhardt, and Lyman 1990). The importance of product development has increased tremendously over the past decades. For many industries, the ability to develop new products has become the most important factor in deciding whether a company succeeds or fails (Brown and Eisenhardt 1995; Schilling and Hill 1998). This is especially true for start-up firms in high technology industries (Rothaermel and Deeds 2006). In fact, the main source of competitive advantage for technology-based new ventures is the rapid development of innovative products and services attracting potential customers on the market. Superior technological capabilities also support the development of foreign sales (Leiblein and Reuer 2004). Thus, technology-based new ventures require product development

capabilities to succeed on the market (Grant 1996a; Deeds, DeCarolis, and Coombs 1999; Rangone 1999).

Innovation as the commercialisation of inventions (Schumpeter 1934) requires capabilities to develop new products as well as the ability to launch the product on the market. Consequently, technology companies require marketing capabilities in addition to product development skills (Verona 1999). During high technological turbulence which entrepreneurial firms usually face, marketing capabilities are highly intertwined with the ability to develop new products (Song, Droge, Hanvanich et al. 2005). In fact, ascertaining new customer needs was identified as a pre-eminent component of product development management (Srivastava, Shervani, and Fahey 1999).

New ventures typically face a lack of trust (Ali and Birley 1998). One reason therefore is the liability of newness (Carroll and Delacroix 1982; Freeman, Carroll, and Hannan 1983; Singh, Tucker, and House 1986) that entrepreneurial firms are confronted with. To meet market needs and acquire and retain profitable customers, entrepreneurial firms have to establish a market orientation (Gruber 2003). This is especially important for the commercialisation of scientific inventions (Katzy 2005b). Firms that are better prepared to react on market requirements and anticipate changes are generally expected to achieve sustainable competitive advantage and extraordinary profitability. Market-oriented firms (Kohli and Jaworski 1990; Narver and Slater 1990; Jaworski and Kohli 1993) have superior skills regarding customer understanding and satisfaction (Day 1994a). For market-driven firms, the customer has first priority (Deshpandé, Farley, and Webster Jr. 1993). In general, market-oriented organisations are able to create, communicate, and utilise information about customers and competitors (Kohli and Jaworski 1990). Various scholars (e.g., Narver and Slater 1990; Deshpandé, Farley, and Webster Jr. 1993; Jaworski and Kohli 1993) found empirical evidence for a positive association between market orientation and company performance.

Market-oriented firms have superior marketing capabilities. These capabilities can be categorised in market sensing and customer linking. Market sensing denotes the ability to sense trends and events in the market. Firms with superior market sensing capabilities are able to predict the results of actions such as attracting and retaining customers more accurately than their competitors do. Market sensing enables organisations to react to

information in an optimal way. Due to a superior knowledge regarding the market, firms are able to develop innovative technologies that have applications in a wide variety of different industries (Day 1994a).

Customer linking comprises the management of customer relations which is considered a core business process in market-oriented firms (Srivastava, Shervani, and Fahey 1999). Strong customer relationships are based on trust and reputation and thus are generally hard to imitate by competitors (Srivastava, Fahey, and Christensen 2001). Establishing and maintaining close relationships with valuable customers is a key priority for all types of business organisations (Yu 2001; Day 2003).

Marketing capabilities are highly important for start-up firms (Shepherd, Douglas, and Shanley 2000; Gruber 2004), especially for those that have a strong technology base (Dutta, Narasimhan, and Rajiv 1999). The importance of marketing in entrepreneurial ventures was further emphasised by a survey among venture capitalists who rated marketing as the most important business function with respect to new venture success (Hills and LaForge 1992). However, many entrepreneurs have only limited understanding of marketing (Hisrich 1992; Coviello, Brodie, and Munro 2000). In this case, the required skills and capabilities have to be developed internally or they have to be acquired externally on the labour market.

The ability to manage partnerships and alliances is an important dynamic capability for a firm competing in turbulent environments (Minshall 1999; Minshall 2003; Rothaermel and Deeds 2006). Partnership management could comprise the establishment of policies or the monitoring of the respective partner. In addition, companies could agree on certain milestones for their collaboration. Market-based assets create substantial competitive advantage for firms. Relational market-based assets comprise customer relations but also relationships to partners (Srivastava, Shervani, and Fahey 1998). Alliance management matches potential partners with the firm's resource base in order to create a fruitful relationship beneficial for both organisations. As opposed to companies in low technology sectors that prefer mergers and acquisitions, firms competing in technology-intensive environments usually form non-equity partnerships and alliances (Hagedoorn and Duysters 2002).

In relationships between entrepreneurial firms and large corporations, the former can benefit from their larger partners in different ways. Young growing firms typically lack the necessary reputation when they try to sell their innovative products on the market. Thus, legitimacy is an important resource for new ventures (Zimmerman and Zeitz 2002). In order to mitigate this problem, partnerships with larger companies may provide the necessary legitimacy (Hennart 1988; Baum and Oliver 1991; Hitt, Ireland, Camp et al. 2001). Other support that larger corporations can offer to new ventures is access to organisational resources which small firms need to commercialise their technology. Examples therefore are distribution, manufacturing, or marketing resources (Alvarez and Barney 2001). In addition, entrepreneurial firms may engage in product development alliances (Eisenhardt and Schoonhoven 1996).

The following figure shows the different dynamic capabilities identified in this section. All of them are considered beneficial for the performance of technology-based new ventures and thus, organisational growth. For each of the capabilities I provide two examples to specify the different abilities. However, the indicated examples are by no means comprehensive.

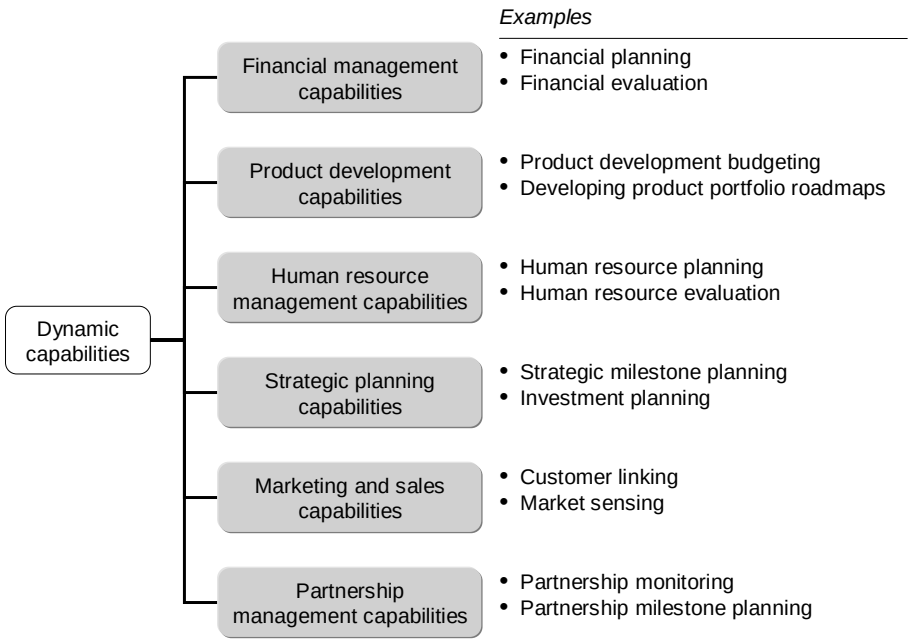

Figure 7 Overview of dynamic capabilities in technology-based new ventures

2.2.4 The Evolution of Dynamic Capabilities

Since young organisations do not have dynamic capabilities in the beginning, they have to develop these special skills over time (Kazanjian and Rao 1999; Ucbasaran, Westhead, and Wright 2001). However, the evolution of dynamic capabilities within organisations is a difficult and complex process. Many scholars (e.g., Nelson and Winter 1982; Teece, Pisano, and Shuen 1997; Zollo and Winter 1999) argue that capabilities stem from path-dependent processes (Eisenhardt and Martin 2000). The notion of path dependency is important since it explicitly incorporates the influence of a company's history on the evolution of capabilities.

The influence of history is substantial with respect to the knowledge of the firm. This knowledge is largely determined by organisational learning efforts. Learning mechanisms drive the evolution of dynamic capabilities in organisations (Eisenhardt and Martin 2000). Consequently dynamic capabilities can be considered as path-dependent in their own right (Helfat and Raubitschek 2000). They can either be imitated from other firms or

developed from scratch. In both cases, organisational learning is necessary since the new venture has never engaged in this particular activity before (Helfat and Peteraf 2003). The proposition that dynamic capabilities stem from the learning efforts of organisations was emphasised by various other scholars as well (e.g., Lant and Mezias 1992; Deeds, DeCarolis, and Coombs 1999; Winter 2000; Hitt, Ireland, Camp et al. 2001; Geroski and Mazzucato 2002; Zollo and Winter 2002; Mathews 2003; Zahra and Filatotchev 2004). In addition, some researchers (e.g., Kogut and Zander 1992; Grant 1996b) identified the gain of knowledge as the only sustainable competitive advantage of firms. This argument is in line with the work of Bierly and Chakrabarti (1996) and Ireland et al. (2001) who argue that learning is a capability in its own right and represents the main driver of all other company capabilities and competencies.

Entrepreneurial ventures need to invest continuously in learning efforts. This requirement has two main reasons. First, high growth incorporates an increase in organisational size and complexity in a short period. This development usually imposes significant challenges on the management team of the entrepreneurial firm. In many cases young organisations do not have the experience to cope with these challenges, and thus have to develop corresponding capabilities (Sexton, Upton, Wacholtz et al. 1997). However, difficulties do not solely stem from internal transformations. In fact, high-velocity environments impede difficult challenges on the start-ups as well. Consequently, entrepreneurial firms must be able to renew their capabilities to react to market dynamics. Otherwise they may easily turn into core rigidities (Leonard-Barton 1992) or competence traps (Levitt and March 1988). Only companies that are able to replace inhibiting mechanisms within their organisation can successfully compete in dynamic markets (Verona and Ravasi 2003). Consequently, entrepreneurial firms have to learn continuously in order to generate and update their capabilities (Lei, Hitt, and Bettis 1996; Teece, Pisano, and Shuen 1997; Hitt, Ireland, Camp et al. 2001). This continuous learning of new capabilities has a positive impact on firm survival and growth (Autio, Sapienza, and Almeida 2000).

The following figure indicates the linkages between learning, dynamic capabilities, and routines in the organisation. While dynamic capabilities evolve from learning efforts, they drive the development of primary processes and operating routines, which create

economic rents. The construct of primary processes and operating routines is also referred to as operating core (Mintzberg 1979; Mintzberg 1980). The firm's resources are inputs to the processes and routines. To ensure the sustainability of the economic rents, the primary processes and routines have to be updated regularly.

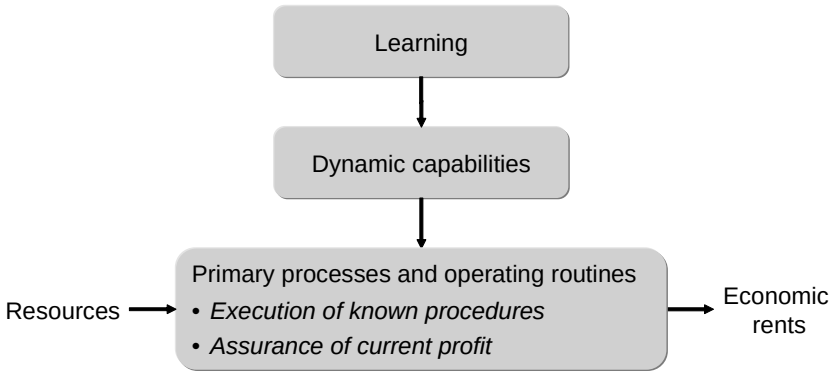

Figure 8 The link between learning, dynamic capabilities, and routines (adapted from: Zollo and Winter 2002)

2.3 CAPABILITY LEARNING IN NEW VENTURES

According to the previous chapter, learning plays a major role in the development of dynamic capabilities. Learning is also central to Edith Penrose's resource-based perspective of company growth. This is especially true for small firms (Thompson and Wright 2005). In fact, different theoretical and empirical contributions (e.g., DiBella, Nevis, and Gould 1996; Nicholls-Nixon, Cooper, and Woo 2000; Ireland, Hitt, Camp et al. 2001; van Gils and Zwart 2004) indicate a link between learning and new venture performance. However, research on learning in entrepreneurial firms is still in its early days (Minniti and Bygrave 2001). In this section, I provide insights into organisational learning in general and entrepreneurial learning in particular to develop an understanding of the evolution of dynamic capabilities in technology-based new ventures. The section closes with various hypotheses concerning different drivers for learning in entrepreneurial firms.

2.3.1 Definition of Organisational Learning

Organisational learning has to be clearly distinguished from individual learning, although individual learning is highly important to organisations. In fact, organisational learning cannot occur without individual learning (Argyris and Schön 1978). But the sum of the different members' learning efforts is not organisational learning. Organisations do not have brains but cognitive systems and memories. These mechanisms are developed and shared by their members and generate views and ideologies comparable to the development of an individual's personality, habits, and beliefs. Although individuals are regularly replaced by others and leadership may change, the organisation's memory maintains certain behaviours, mind maps, rules, norms, or values over time (Fiol and Lyles 1985). Organisational learning enables firms to understand and interpret their environments in order to evaluate realistic strategies (Daft and Weick 1984).

Many researchers have developed definitions for organisational learning. Argyris (1977) describes learning in organisations as a process enabling individuals to react to changes in the external and internal environment. Thereby, the organisational members detect errors that they correct to maintain the key features of the firm. Peter Senge, another well-known scholar in this field, defines organisational learning as a "fundamental shift or movement of mind, enabling the environment to be perceived differently, and to realise that the organization's actions create problems and solutions" (Kloot 1997, p. 49).

Scholars from many different disciplines have addressed organisational learning. Psychologists define learning as a shift in performance when the stimulus does not change (Weick 1991). From a psychological perspective, the basic assumption for organisational learning is that firms understand and interpret their internal and external environment with respect to their individual frames of reference. In this respect, Weick developed his enactment principle, which proposes that organisational members develop collective perceptions of the firm's environment (Romme and Dillen 1997). This summary of beliefs is mostly unique for a particular firm. It leads to a firm-specific culture and language that facilitates agreement on insights and experiences (Argyris 1991).

Contingency theory also serves as a basis for research into organisational learning (e.g., Meyer 1982; Hutchins 1991). The theory was developed as a response to management approaches supporting the existence of one best solution towards the design of operational processes within a firm (Fisher 1998). Contingency theory aims at understanding the interrelations within and among subsystems of organisations and between the firm as a whole and its environments. The theory attempts to interpret and understand the behaviour of organisations under changing conditions. Therefore the multivariate nature of organisations is at the heart of the approach (Kast and Rosenzweig 1973). Contingency theory sees firms as open systems that adapt themselves to their environment. Thus, organisational learning is mainly regarded as an adaptation process (Cangelosi and Dill 1965).

Concepts and ideas from system dynamics can also be applied to understand organisational learning. From this perspective, human organisations are complex and dynamic. Consequently, ordinary cause-effect models cannot be applied to understand learning activities in firms. On the other hand, elements from system dynamics such as positive and negative feedback are useful for shedding light on the firm's learning processes. In this sense, these concepts can be used to demonstrate that social reality comprises circles of causality (Romme and Dillen 1997). Under a system dynamics perspective, organisational learning is considered as an overarching and cohesive process. Important contributions to this field include de Geus (1988), Stata (1989), or Kim (1993).

According to information theorists, organisational learning can be broken down into a process that sheds light on the locus and character of the respective learning effort (Romme and Dillen 1997). This process contains four elements that are closely interlinked: knowledge acquisition, information distribution, information interpretation, and knowledge codification (Fiol and Lyles 1985; Levitt and March 1988; Huber 1991; Day 1994a; Day 1994b; Sinkula 1994; Bierly and Chakrabarti 1996; Kloot 1997). Knowledge can be acquired in different ways. Firms can draw from the knowledge that is available at the organisation's birth. Another possibility is to observe other organisations. This practice is often referred to as second-hand learning. Organisations can also gain knowledge by grafting, i.e. acquiring carriers of knowledge such as human resources. Grafting is considered a quick way to increase the knowledge base. A fourth possibility of

gathering knowledge is the active search for information. Finally, organisations can learn by experience which is also known as learning-by-doing (Huber 1991; Kloot 1997).

Compared with the behavioural process of knowledge acquisition, the distribution of information is a deliberate cognitive process. Behavioural research in organisational learning does not consider the benefits of group activities where people collectively identify the best way to execute organisational tasks (Cangelosi and Dill 1965). A collective distribution of information across the firm enables individuals and organisational units in their learning efforts (Garvin 1993). The sharing of information can also resolve problems of information asymmetry that occur when individuals or units possess different depths and breadths of information (Bartlett and Ghoshal 1993). Collective learning is most efficient when individuals articulate and discuss their impressions and meanings and challenge each others' points of view (Duncan and Weiss 1979). Organisational competences evolve when employees learn more about the link between their actions and the corresponding performance implications. To efficiently improve these competences, individuals should engage in knowledge articulation efforts such as constructive discussions, debriefs, or performance evaluations (Zollo and Winter 2002).

The next step in the organisational learning process is the interpretation of information. Through information interpretation, the acquired and distributed data is given meaning. The process comprises the translation of events and the creation of shared understandings and conceptual schemes among organisational members (Daft and Weick 1984). An organisation's cognitive maps such as frames of reference or mental models have a major influence on the interpretation of information (Nystrom and Starbuck 1984; Miller 1993; Argyris 1994). Organisational learning generally increases with the variety of shared interpretations (Huber 1991). A high level of disagreement is beneficial for firms that compete in high-growth industries (Slater and Narver 1995). However, these benefits are contingent upon a firm's ability to resolve such conflicts. Otherwise, disagreement inhibits fast strategic decision-making, which is necessary in high-velocity environments (Bourgeois III and Eisenhardt 1988; Eisenhardt 1989).

The last construct of organisational learning is knowledge codification. Knowledge that is articulated and codified is subject to a more rapid and efficient diffusion in the

organisation (Kogut and Zander 1992; Zander and Kogut 1995; Zollo and Winter 1999). Learning presumes the accumulation and storage of knowledge (Levitt and March 1988). Otherwise, firms have to repeat their mistakes and have to discover solutions to specific problems over and over again (Day 1994a). The codification of knowledge has two major advantages compared with pure articulation. First, the quality of the shared knowledge is higher since writing requires much more logic and consistency than oral communication. Second, organisational members who do not participate in knowledge sharing efforts are still able to benefit from information captured through written tools (Zollo and Winter 2002).

2.3.2 Knowledge Codification and Management Control Systems

In organisations, knowledge can be stored in different ways. Some of the knowledge is codified in the product concepts, designs, or the brand equity. Other knowledge assets are incorporated in the individual skills and know-how of the various organisational members (Nonaka, Toyama, and Nagata 2000). Other important repositories of a firm's knowledge are organisational routines and daily operations as well as documents, manuals, specifications, patents, or databases. In fact, a large amount of a firm's knowledge about how to perform tasks is stored in its operating routines (Nelson and Winter 1982; Huber 1991). These knowledge assets are not tied to certain individuals. Consequently, the know-how can be retained if key people leave the firm (Kazanjian 1984; Kogut and Zander 1992). They generally survive significant employee turnover within firms. Routines capture the implications from experiences and make them available to organisations and their members in such a way that single individuals within the firm do not need to have the experiences for themselves. Since routines are transferred through education, socialisation, professionalisation, imitation, or job rotation, they are also a valuable means for the distribution of knowledge (Levitt and March 1988). The importance of documents and routines for the codification of knowledge was also emphasised by various other scholars (e.g., Winter 1988; Kogut and Zander 1992; Zander and Kogut 1995; Zollo and Winter 2002; Figueiredo 2003).

Similar to written documents such as manuals or specifications, routines comprise solutions to certain problems (Levitt and March 1988; Grant 1991; March, Sproull, and

Tamuz 1991; Grant 1996b; Phillips 2002; Lillrank 2003). However, unlike documents, routines are able to store tacit knowledge as well (Teece, Pisano, and Shuen 1997; Knott 2003). In addition, they capture individual knowledge and knowledge that is collectively held (Becker 2004). Thus, routines can be termed as a firm's organisational memory (Dodgson 1993).

To codify knowledge, primary processes and operating routines are usually accompanied by a special type of routine that adopts the role of a control device in a closed control loop. These routines are referred to as management control systems (MCS). MCS are "formal, information-based routines and procedures used by managers to maintain or alter patterns in organizational activities" (Simons 1994, p. 170). They are necessary for adaptive learning in organisations since they are important knowledge repositories (Davila 2005). MCS measure the gap between target and actual outcome within operating routines and thus influence the efficiency of organisational processes. Organisations apply management control systems to gather and use information, which supports planning, and controls and enables decision-making throughout the firm.

In addition, MCS guide the behaviour of employees in the way they make decisions and so that they act in a way that is beneficial to the organisation (Chow, Shields, and Wu 1999; Horngren, Datar, and Foster 2003). To influence the behaviour of employees, management control systems comprise two important features: accountability and feedback (Lowe 1971). MCS are often supported by management information systems (Lorange and Scott Morton 1974) and are subject to documentation.

Management control systems are highly important for entrepreneurial ventures. In chapter 2.2.2, I have already indicated that start-up companies usually face a high level of uncertainty in different fields. As a subset of organisational routines, management control systems are a means to reduce uncertainty through the provision of data needed to fill information gaps (Tushman and Nadler 1978). Since growth is associated with the reduction of uncertainties (Dissel 2003), MCS play an important role in the development of technology-based new ventures.

Researchers applied different theories and approaches to investigate the role of management control systems in organisations. In particular, transaction cost economics

theory[5] (Coase 1937; Williamson 1975; Williamson 1979; Williamson 1981), contingency theory[6] (Hofer 1975), agency theory[7] (Akerlof 1970; Spence 1973; Pauly 1974; Jensen and Meckling 1976; Rothschild and Stiglitz 1976; Holmström 1979), and organisational approaches have been applied to research efforts in this particular field.

According to organisational approaches towards control (e.g., Thompson 1967; Ouchi 1979), two different control strategies exist. First, control can be accomplished through performance evaluation, which comprises monitoring and rewarding. Measurement plays an important role in this first organisational control strategy. In general, there are two different approaches towards performance evaluation. Managers can measure either the behaviour of an individual or the corresponding outcomes of this behaviour. Which of the two directions is actually applied depends on the available information about the respective process. To control the employee's behaviour, the actual task has to be well understood. If the results of the transformation process have to be assessed, they have to be measurable (Eisenhardt 1985).

Second, control can be pursued through minimising the differences between preferences of organisational members. This strategy is also referred to as clan control (Anderson and Oliver 1987). To reduce individual divergences the employees have to internalise the organisation's goals. As a requirement therefore, they have to understand these objectives completely. Instead of monitoring and evaluating, this second strategy focuses on people processes such as training or events that foster socialisation (Eisenhardt 1985).

The two organisational control strategies are highly interrelated. If a company has accurate evaluation systems in place, it can tolerate high goal diversity among its employees. On the other hand, an organisation whose members are aligned towards the

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[5] Although there are not many applications of transaction cost economics in MCS research, different scholars (e.g., Tiessen and Waterhouse, 1983; Van der Meer-Kooistra and Vosselman, 2000) applied the theory to research in management accounting. Speklé (2001) recently developed a transaction cost theory of management control.

[6] Different contingency-based research efforts (e.g., Bruns and Waterhouse 1975; Merchant 1981; Govindarajan 1988; Fisher 1995; Libby and Waterhouse 1996; Fisher 1998; Marginson 1999; Reid and Smith 2000; Luther and Longden 2001; Haldma and Lääts 2002; Jermias and Lindawati 2004) have been conducted over the past decades. Chenhall (2003) recently provided a comprehensive overview of contingency theory-based efforts in this direction.

[7] An important agency-based contribution to MCS research was provided by Holmström (1980).

firm's targets can basically forego a lack of precision with respect to its performance evaluation mechanisms (Ouchi 1979). Organisational control theory incorporates three different strategies: two strategies from performance evaluation and clan control. The following figure shows Ouchi's (1979) adaptation of Thompson's (1967) initial framework indicating the relationships between task characteristics and strategies of organisational control.

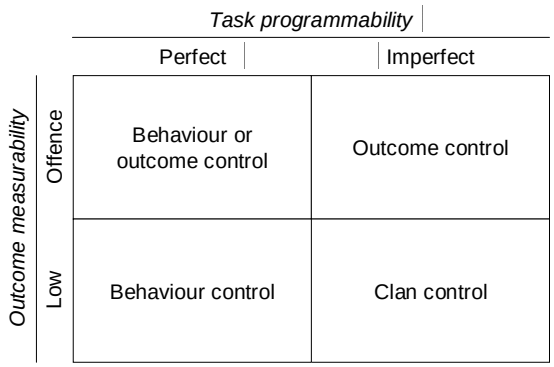

Figure 9 Control strategies in organisational theory (adapted from: Ouchi 1979; Eisenhardt 1985; Anderson and Oliver 1987)

The typology from Thompson (1967) and later Ouchi (1979) was further developed by Merchant (1998). This refined typology considers three different types of management control: action control, results control, and personnel control. Action control covers systems that denote actions organisational members are expected to take. Results control represents systems that influence the individuals' actions by measuring the corresponding outcomes. Management systems for personnel control align the actors' personal objectives with those of the company and thus influence the actions of organisations. MCS for action and results control can be considered as direct control systems. Since personnel control systems influence employees' actions through communicating company objectives, they can be defined as indirect control systems (Davila 2005).

2.3.3 A Model of Learning in New Ventures

From a system dynamics perspective, organisational learning can be clustered into single-loop and double-loop learning (Argyris and Schön 1978). Single-loop learning, which is also referred to as first-order or lower-level learning, identifies and corrects failures without changing the mental models behind it; i.e. the basic rules and objectives remain the same. Due to the unchanged context, single-loop learning is considered as adaptive learning in the form of a single feedback loop. Single-loop learning aims at solving problems within a given context in order to increase efficiency (Argyris 1977; Nicholls-Nixon, Cooper, and Woo 2000). It focuses on specific activities and behaviours, and results in repetition and routines such as successful programmes or rules for decision-making (Fiol and Lyles 1985). This focus is often referred to as functional rationality, which is based on the knowledge gained through simple problems in the past. Single-loop learning is highly imitable and thus makes only a limited contribution to a firm's competitive advantage (Lei, Hitt, and Bettis 1996). Due to its routinised character and the absence of a systematic attempt to change, lower-level learning does not contribute to the creation of dynamic capabilities.

A higher form of learning is double-loop learning (Argyris 1977). This form is also referred to as generative learning (Ravasi and Turati 2005), higher-level, or second-order learning. Contrary to single-loop learning, double-loop learning comprises changes of the norms and rules that underlie actions and behaviours (Argyris and Schön 1978). Double-loop learning "can lead to the recognition of new goals or means to achieve goals" (Lant and Mezias 1992, p. 49). Consequently, it requires a more thorough exploration process. This process assumes the form of a double feedback loop. Higher-level learning activities result in long term effects on the entire organisation (Nicholls-Nixon, Cooper, and Woo 2000). While lower-level learning is often the outcome of repetitive actions, second-order learning is a cognitive process where repetitions are almost meaningless (Romme and Dillen 1997).

Contrary to lower-level learning, higher forms of learning can have a significant impact on competitive advantage, especially in highly dynamic environments where continuous renewal is of major importance (Lei, Hitt, and Bettis 1996). Double-loop learning fosters

the creation of heuristics, cognition, and insights, which are necessary to define and solve complex problems related to high-technology products and processes. In fact, higher-level learning can be converted into intangible resources, skills, and core competences (Lei, Hitt, and Bettis 1996). Consequently, this type of learning has substantial impact on the creation of dynamic capabilities.

The following figure is based on the findings from the previous sections and chapter 2.2.4. It denotes the links between dynamic capabilities, routines, single-loop, and double-loop learning. Single-loop learning occurs within a control loop that comprises management control systems, primary processes, and operating routines. Double-loop learning, on the other hand, takes place outside the operating core and influences the entire set-up of the primary processes and operating routines by enabling the organisation to generate, adapt, or replace them through the creation of dynamic capabilities.

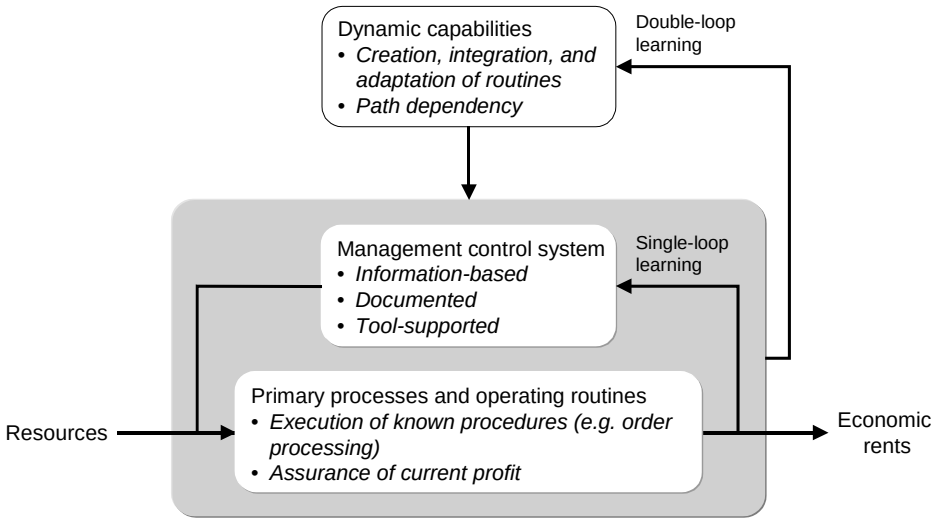

Figure 10 Types of learning and the evolution of dynamic capabilities in organisations

2.3.4 Drivers for Entrepreneurial Learning

Entrepreneurial learning is often described as the continuous process that facilitates the development of knowledge necessary to start, grow, and manage a new venture (Politis 2005). Learning in start-ups is a continuous and highly dynamic process over the entire

lifetime of the organisation. Entrepreneurial learning is not limited to the initial years of the young firm (Cope 2005).

In the start-up phase of technology-based new ventures, entrepreneurial learning is dominated by higher-level learning. Single-loop or adaptive learning assumes a less important position in the early stages of organisational development (Cope 2005; Ravasi and Turati 2005). Second-order learning is especially important in turbulent environments (Virany, Tushman, and Romanelli 1992). One reason for this therefore is the fact that entrepreneurial firms need to develop certain skills in order to establish processes and routines rather than focus on efficiency increases.

Entrepreneurial learning is mostly experiential, i.e. start-up firms acquire knowledge through experiences (Bahrami and Evans 1989; Cope 2005; Politis 2005). Experience-based learning fosters the creation of tacit knowledge (Zollo and Winter 2002), which is considered as an important source of competitive advantage. In fact, experimentation, prototyping, and learning-by-doing facilitates the creation of capabilities in high-technology firms (Verona 1999).

Experiences can be gained in two different ways. On the one hand, entrepreneurs may have prior business experiences that they can leverage. However, since technology-based new ventures are usually established around innovations, past experiences are mainly useful to solve managerial problems. On the other hand, start-ups have to experiment and thus invest in learning-by-doing to resolve technological challenges (Rothaermel and Deeds 2006). Based on instinct and existing knowledge, founders make certain decisions and wait for the corresponding outcomes. Once the consequences of the performed actions become available, entrepreneurs repeat only those decisions that outperformed the initial goals (Minniti and Bygrave 2001).

Organisational learning can be influenced in different ways. In the following sections, I provide various drivers that are supposed to have a positive impact on learning in technology-based new ventures. In order to test for these influences, I formulate various hypotheses, which will be tested in the remainder of this document.

2.3.4.1 CEO Experience

Company leaders have substantial influence on the performance of young, small firms (Eisenhardt and Schoonhoven 1990). Leadership is highly important for the creation of knowledge in organisations. Capable leaders have a positive influence on the knowledge conversion rate. They formulate a knowledge vision and facilitate the organisational culture to continuously enhance the knowledge base of the firm (Nonaka, Toyama, and Nagata 2000). In order to gain expertise, firms need to acquire external knowledge. However, a firm's ability to evaluate and use outside information depends on prior related knowledge (Cohen and Levinthal 1990). In fact, "entrepreneurs learn by updating a subjective stock of knowledge accumulated on the basis of past experiences" (Minniti and Bygrave 2001, p. 5).

In general, prior experiences of founding teams turned out to be beneficial to start-up firms in high-technology industries (van de Ven, Hudson, and Schroeder 1984; Schoonhoven, Eisenhardt, and Lyman 1990; Cooper, Gimeno-Gascon, and Woo 1991; Schefczyk and Gerpott 2000). While younger managers need to try out different options until they find a beneficial and thus repeatable practice, experienced top managers could have already gained this knowledge, which is an important asset for a start-up firm (Cooper and Bruno 1977). This could hold especially true for basic managerial abilities. With respect to financial tasks such as budgeting or financial forecasting, experienced managers could provide valuable knowledge for an entrepreneurial firm (Davila 2005). In addition, if the CEO is an expert with respect to the foundational technology, this could imply additional benefits for a technology-based new venture (Schoonhoven, Eisenhardt, and Lyman 1990). Consequently, I formulate the following hypothesis.

Hypothesis 1 *CEO experience has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.*

2.3.4.2 Organisational Size

The second driver for learning in new ventures is firm size[8]. Although entrepreneurial learning is mostly experiential and thus dominated by the principle of learning-by-doing, new ventures do not necessarily develop all their capabilities internally (Zahra and Filatotchev 2004). By increasing the number of employees, organisations acquire knowledge through grafting; i.e. they gain access to knowledge that was not available before (Huber 1991).

However, not only the acquisition of knowledge increases with the number of organisational members. Organisations need to interpret the knowledge; i.e. the collected data is given meaning (Daft and Weick 1984). From chapter 2.3.1 we have learned that the outcome of organisational learning improves with the number of shared interpretations. Consequently, we can assume that the exchanges of different interpretations of acquired and distributed knowledge increase with the size of the entrepreneurial venture. The fact that the number of possible interactions between employees rises much faster than the actual increase of employees (Davila 2005)[9] further supports the argument. Since entrepreneurial learning fosters the creation of dynamic capabilities, I put forward the following hypothesis.

Hypothesis 2 *Organisational size has a positive influence on the evolution of dynamic capabilities in technology-based new ventures.*

2.3.4.3 Internationalisation of Sales

New ventures tend to approach international markets relatively early in their organisational life cycles (Oviatt and McDougall 1994). Internationalisation can be considered as an important event in the development of new ventures. Entrepreneurial

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[8] In this study, size is defined as the number of employees. This is consistent with many different empirical studies in the field of entrepreneurship.

[9] The number of possible interactions among organisational members follows the formula $\frac{n(n-1)}{2}$ and describes an exponential relationship.

firms enter foreign markets for three main reasons: institutional factors such as regulations, industry factors such as increased competition, and organisational factors. New ventures can thus realise additional growth and returns (Bloodgood, Sapienza, and Almeida 1996; Zahra, Ireland, and Hitt 2000). International expansion of start-up firms in the initial years is often limited to foreign sales. However, new ventures need to consider that successful internationalisation may require a change of the initial strategy, which has been successful for domestic sales (McDougall and Oviatt 1996). Internationalisation is especially promising for technology-based new ventures. Comparing new product successes with failures, the corresponding markets of the former group are larger, highly international, and indicate higher international growth rates (Cooper and Kleinschmidt 1990).

According to empirical research, early internationalisation of entrepreneurial firms has a positive and significant influence on the breadth and depth of technological learning. In addition, the breadth of learning is further driven by knowledge integration (Zahra, Ireland, and Hitt 2000). Although highly important, the internationalisation of a start-up firm still imposes significant challenges on the management team. Learning in entrepreneurial ventures is very effective when triggered by critical events or challenges (Cope 2005). Consequently, I formulate the following hypothesis.

Hypothesis 3 *The Internationalisation of sales has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.*

2.3.4.4 Organisational Age

Another driver for organisational learning is organisational age. Although a company may not be growing, the management team and the employees do not stop learning. We already know that entrepreneurial learning is a continuous and dynamic process, which is mainly driven by experiments and learning-by-doing. Thus, firms invest time in trying out different alternatives with respect to technology, organisation, sales approach, and other functional areas. After a certain period, a technology-based new venture may find out which processes and structures match their business model in the best way. Once this

dominant design has been identified, the processes are conducted repeatedly. The gathered knowledge can then be codified into formal procedures. Consequently, I suggest the following hypothesis.

Hypothesis 4 *Organisational age has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.*

2.3.4.5 CEO Replacement

The dismissal of the founder as the company's CEO is an important event during the growth phases of entrepreneurial firms (Greiner 1972; Greiner 1998) and is considered as a learning mechanism in organisations (Tushman and Rosenkopf 1996). Executive replacement is an effective means of facilitating double-loop learning in business firms (Greiner and Bhambri 1989). Tushman, Newman and Romanelli (1986) refer to the situation of General Radio to illustrate how CEO replacement could support the shift from single-loop to double-loop learning.

The facilitation of higher-level learning through CEO succession is due to the increase of divergence of knowledge and experiences within the management team of the entrepreneurial firm. This effect results in a change of skills and knowledge as well as a change in communication and decision-making processes within the executive team (Lant and Mezias 1992). Thereby, organisations can strengthen their ability to adapt to changing environments which is especially important in turbulent technology-intensive settings (Virany, Tushman, and Romanelli 1992). Summing up, I formulate the following hypothesis.

Hypothesis 5 *CEO replacement has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.*

2.3.4.6 CFO Recruitment

We have already addressed executive succession as an important means of facilitating higher-order learning in organisations. Another way to increase the heterogeneity in the

management team is the recruitment of additional top managers. By hiring highly skilled senior executives and thus extending the top management team, new ventures can increase their managerial capacity (Miller 1983; Miller and Toulouse 1986), which is important for company growth (Penrose 1959). While the replacement of the founder has a positive influence on the performance of firms in turbulent environments, the results may even be better when keeping the CEO but changing the management team (Virany, Tushman, and Romanelli 1992). The positive influence of recruiting a CFO on managerial capabilities was emphasised by the CEO of an internet publishing company.

> *"I simply needed somebody who knows the business of mid-sized companies. I brought in this new CFO whom I knew as a professional manager with experience in restructuring and controlling and told him that he should care about finance and human resources (…) Our CFO had six or seven years of experience in human resource management. He brought all the human resource practices and systems to the organisation and implemented them."*

Considering the engineering and science background of many founding teams, new ventures may lack personnel with a strong background in the management of finance. Thus, technology-based start-ups often hire managers with financial expertise. The existence of financial skills within the top management team has a major influence on the performance of young firms (Thompson, Stuart, and Lindsay 1996). The extension of a technology-oriented founding team is supported by empirical research which promotes a negative association between founding team heterogeneity and team member entry (Ucbasaran, Lockett, Wright et al. 2003). Thus, I derive my next hypothesis.

Hypothesis 6 *Hiring a CFO has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.*

2.3.4.7 Venture Capital Funding

Venture capital investors are often regarded as pure financial intermediaries (Sapienza and Timmons 1989), who provide equity financing to entrepreneurial firms in order to realise extraordinary profits when exiting the business via initial public offering, trade sale, or secondary buyout. However, an increasing body of literature rejects this argument by referring to additional professional services which venture capitalists typically provide for entrepreneurial firms (Perry 1988; Sapienza and Timmons 1989; Sapienza and Amason 1993). Management teams are often willing to accept a lower valuation of their business if they have the chance to get funding from a VC with a high reputation and a substantial track record (Hsu 2004). Thus, start-up companies expect superior guidance and coaching, and access to a larger and more valuable network.

VC investors acquire substantial knowledge on how to support fast growing entrepreneurial firms. Due to their active involvement in their portfolio companies, venture capitalists are able to provide helpful advice (Sahlman 1994; Cyr, Johnson, and Welbourne 2000). They act as sounding boards or provide access to various networks and communities (Fried and Hisrich 1995). In addition, they support their portfolio companies through activities such as recruitment of senior executives, mentoring, strategic advice, or legitimisation in order to attract customers and strategic partners (Hellmann and Puri 2000). In particular, strategic activities are regarded as a major contribution by VCs to their portfolio companies (Fried, Bruton, and Hisrich 1998). Some venture capital firms even provide intensive operating support. That is why investors are often described as "consultants with a financial interest" (Fried and Hisrich 1995, p. 102). A serial entrepreneur and CEO of a mobile software company comments on the relationship to VCs in the following quote.

> *"The working relationship to the investors that we currently have is very productive. The investors are very constructive since they do not solely focus on control but contribute significantly to the development of the business. (…) They provide us with contacts on the customer as well as on the partner side. (…) If the development of the business deviates*

> *from the initial plan, less experienced investors, which do not know the markets tend to panic, seek to exchange people, and try to make a quick exit."*

The value added by venture capitalists is especially effective if their contribution is complementary to the start-up's own organisational learning capabilities. From a dynamic capabilities perspective, venture capitalists could act as catalysts with respect to strategy formation by strengthening the firm's resource base (Wijbenga, Postma, van Witteloostuijn et al. 2003). The positive influence of equity investors on entrepreneurial firms has found empirical support in a recent study (Hellmann and Puri 2002), based on a survey of venture-backed start-up companies located in the Silicon Valley region[10]. The authors revealed that venture capitalists have a major impact on the professionalisation of start-up firms, especially in the area of human resource management.

Venture capital in the US has a much longer history than in Europe. In the course of this argument, the non-financial value added by European VC firms has often been questioned. However, European venture capital is growing fast and its importance for entrepreneurship is increasing (Bottazzi and Da Rin 2002). Although there are significant local differences between VC firms, these differences are less continent-specific than country-specific (Manigart, De Waele, Wright et al. 2000). In addition, the largest academic study in the industry to date[11] revealed that European investors have been able to catch up with the US during the past decades (Bottazzi, Da Rin, and Hellmann 2004). Thus, I formulate the following hypothesis.

Hypothesis 7 *VC funding has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.*

[10] The survey was conducted in the course of the Stanford Program on Emerging Companies (SPEC). Additional publications from this research effort include Davila, Foster, and Gupta (2003), Baron, Hannan, and Burton (2001), Baron and Hannan (2002), or Baron, Burton, and Hannan (1999).

[11] Summary Report on the Survey of European Venture Capital (SEVeCa)

2.4 A CAPABILITY-BASED MODEL OF NEW VENTURE GROWTH

In the previous sections of this second chapter, I identified a set of dynamic capabilities which technology-based new ventures require in order to survive and succeed in turbulent environments. In addition, I developed a model that explains how learning drives the emergence of these capabilities. Finally, I provided a list of drivers that are expected to facilitate entrepreneurial learning in young and fast growing organisations.

Although these findings offer various aspects of start-up growth, we have not yet adopted an end-to-end perspective on the entrepreneurial growth process. Consequently, I dedicate this last section of this chapter to the organisational change and development of technology-based new ventures. Therefore, I review various theories and models in order to develop a new approach explaining how dynamic capabilities evolve in start-up companies over time.

2.4.1 Models of Company Growth

Scholars developed a wide variety of approaches and theories to explain development and change in organisations[12]. In particular, life cycle, stage-of-growth, and evolutionary models have regularly been applied to denote the growth processes of firms (Gruber, Harhoff, and Tausend 2003). Life cycle models[13] are based on a biological analogy. Similar to the life cycle of organisms, organisation researchers developed an organisational life cycle (Kazanjian 1988). Models can cover single companies but also entire groups of organisations (e.g., McKelvey and Aldrich 1983; Hannan and Freeman 1984). Many different life cycle models have been developed over the past decades. All of these approaches imply the idea that company growth follows predictable patterns, which occur at discrete periods of time (Smith, Mitchell, and Summer 1985). Another assumption behind most life cycle models is that actions taken by management with

[12] An overview of four basic theories for organisational change and development is given by van de Ven and Poole (1995) as well as Weick and Quinn (1999).

[13] A comprehensive overview of organisational life cycle models is given by Hanks et al. (1993).

respect to current problems drive the transition to the following stage (Dodge and Robbins 1992). Discrete life cycle stages differ in various dimensions such as age, size, targets, structure, control, communication, leadership, key personnel and reward systems. Life cycle models are often used to analyse changes in strategies, priorities, problems (Kazanjian 1988), politics (Gray and Ariss 1985), and formalisation (Walsh and Dewar 1987) as firms grow.

Organisational life cycle models vary in the number of their stages. Various approaches have three (e.g., Smith, Mitchell, and Summer 1985), four (e.g., Quinn and Cameron 1983; Tyebjee, Bruno, and McIntyre 1983; Mintzberg 1984; Kazanjian 1988; Kazanjian and Drazin 1989; Dodge and Robbins 1992; Dodge, Fullerton, and Robbins 1994), five (e.g., Miller and Friesen 1983; Miller and Friesen 1984), and more stages (e.g., Adizes 1979). Due to their general character, life cycle models serve as the basis for more elaborate stage-of-growth and evolutionary models (Gruber, Harhoff, and Tausend 2003).

Life cycle models for organisational development do not only vary with respect to the number of stages. In addition, they can be categorised in relation to the type of firms they address. While most models concern the development of organisations in industries of moderate growth, there are specific models that focus on the evolution of fast growing high-technology firms. A life cycle model for this specific group of firms was developed by Kazanjian (1988) and Kazanjian and Drazin (1989). The four stages of their life cycle model are denoted in the following table.

Table 1 Life cycle stages and dominant problems (Kazanjian 1988)

	Stage 1: Conception and development	Stage 2: Commercialisation	Stage 3: Growth	Stage 4: Stability
Focus	Invent and develop product Secure financing Identify market opportunities	Learning about product functionality and quality Learning about scaling the production	Avoid problems of ineffectiveness and inefficiency Balance profit against future growth	Expand product portfolio Expand into new markets Expand into new regions
Dominant problems	Construction of prototype Selling product and business idea to financiers	Acquiring adequate facilities Establishing vendor network Development of product support capability	Produce, sell, and distribute at high volume Attain profitability Definition of roles, responsibilities, and policies	Maintain momentum of growth Keep market position
Structure	Non-existent	Limited	Evolving	Formal structure Internal control systems

Similar to life cycle models, stage-of-growth approaches use discrete stages to explain organisational development. However, stage-of-growth models assume a discontinuous development of the firm that is influenced by various crises. In addition, organisations do not necessarily have to pass all stages defined in the model. Instead, they may skip certain stages of growth or stop in their development and remain at one specific stage. Important implementations of this class for entrepreneurial ventures comprise the approach from Churchill and Lewis (1983) and Galbraith's (1982) five stage model which explicitly addresses technology-based new firms.

Table 2 Five stages of life cycle model of organisational development (Galbraith 1982)

	Stage 1: Proof of principle	Stage 2: Model shop	Stage 3: Start-up	Stage 4: Natural growth	Stage 5: Strategic manoeuvring
Task	Invention and development	Quality and test	High volume production	Achieve profitability	Dominate a niche
People	Jacks-of-all-trades, risk takers	Jacks and some special risk takers	Specialists, non-technical start-up types	Business people, planners	Planners and strategists
Reward systems	Equity, non-bureaucratic climate	Non-bureaucratic climate	Ground floor advancement, career	Career, salary	Career, salary, bonus
Decision processes	Informal, personal contact	Informal, meetings, personal contact	Formal, systems and procedures, budgets	Formal control, planning, budgets, MIS	Five-year plans, profit centre
Structures	Informal, little need	Functions and hierarchy begin	Functional organisation, centralised	Functional with overlays, decentralised	Matrix, profit centres, decentralised
Leader	Quarterback	Player/coach	Coach	Manager	Strategist

Evolutionary models combine the characteristics of life cycle models with those of stage-of-growth approaches. Here the discrete stages of company growth follow a predefined sequence. Evolutionary models consider organisational crises and the corresponding influences on the development of the firm (Gruber, Harhoff, and Tausend 2003). Important evolutionary models for organisational growth and change appear in the publications of Scott and Bruce (1987) as well as Greiner (1972; 1998). Although Greiner's work is one of the earliest models for organisational development (van de Ven and Poole 1995), it is considered as a baseline in this field (Hanks, Watson, Jansen et al. 1993). The following table shows the five phases of Greiner's evolutionary model of company growth.

Table 3 Organisational practices in five growth phases (adapted from: Greiner 1998)

	Phase 1: Creativity	Phase 2: Direction	Phase 3: Delegation	Phase 4: Coordination	Phase 5: Collaboration
Management focus	Make, sell	Operational efficiency	Market expansion	Consolidation of organisation	Problem solving, innovation
Organisational structure	Informal	Centralised, functional	Decentralised, geographical	Line staff, product groups	Matrix of teams
Top-Management style	Individualistic, entrepreneurial	Directive	Delegation	Control	Participation
Control system	Market results	Standards, cost centres	Reports, profit centres	Plants, investment centres	Mutual goal setting
Management reward emphasis	Ownership	Salary, merit increase	Individual bonus	Profit sharing, stock options	Team bonus

2.4.2 Forms of Change in Organisations

Reflecting on the various models for organisational development and change in the previous section, two questions remain open. The first one addresses the shift from one stage to another, while the second focuses on the role of learning and dynamic capabilities within a model of entrepreneurial growth. Assuming that the prior theoretical considerations as well as the different life cycle, stage-of-growth, and evolutionary models can be applied, these components should be compatible. In order to answer these questions, I reflect on the characteristics of change in organisations.

Organisational change occurs in two different ways. The first form of change is continuous, evolving, and incremental and is associated with repetitive action, routines and inertia. However, these continuous periods of incremental change are interrupted by episodes of revolutionary change, which are often described as deep change or transformation (Bacharach, Bamberger, and Sonnenstuhl 1996; Weick and Quinn 1999). Incremental change is also referred to as first-order change, while the result of revolutionary episodes is defined as second-order change. Second-order changes “refers to changes in cognitive frameworks underlying the organization's activities, changes in the deep structure or shared schemata that generate and give meaning to these activities”

(Bartunek and Moch 1994, p. 24). First-order change, on the other hand, is prescribed by deterministic laws and results in minor alterations in current beliefs (Weick and Quinn 1999).

2.4.3 Linking Organisational Change to New Venture Growth

The interplay of episodic and continuous change is reflected in Greiner's model of organisational development. The key idea behind this model is that the problems companies typically face are mainly rooted in the past instead of present events. This argument is closely linked to the findings of European psychologists who claim that an individual's behaviour is mostly determined by events and experiences in the past. The future only plays an inferior role. By applying this idea to the challenges of organisational development, it is possible to identify different phases that are passed through by firms as they grow. Every phase starts with a longer period of evolution and ends with a sudden and short period of revolution. While the former is characterised by stability and continuous growth, the latter is dominated by disruptive organisational change (Greiner 1972; Greiner 1998).

Evolutionary stages of stable growth do not require any major changes with respect to management patterns. On the contrary, the subsequent stages of revolution need substantial changes regarding the applied management practices. While traditional patterns match the requirements of smaller size and age, they are not appropriate for more mature[14] companies. Firms that hold on to traditional practices face severe problems and run the risk of failure. Instead, organisations must find new management patterns that serve as a basis for the next period of evolutionary growth (Greiner 1972; Greiner 1998). Greiner's evolutionary model is depicted in the following figure.

[14] In this particular context, an increase of maturity is associated with an increase in organisational age and size.

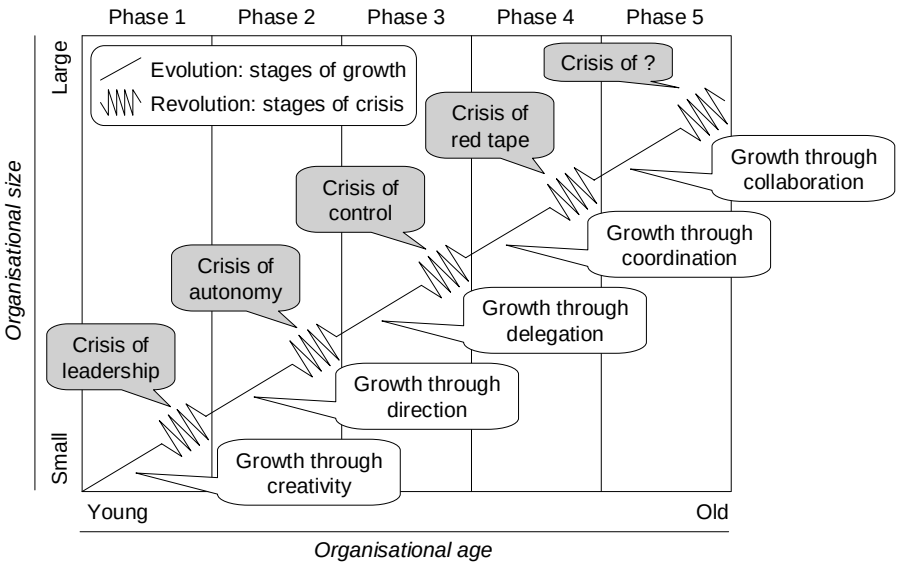

Figure 11 Evolutionary model of organisational development and change (Greiner 1972; Greiner 1998)

In Greiner's model, evolutionary periods are characterised by first-order changes, which are incremental. The changes occur within the routines of the organisation. To implement this incremental evolutionary change, firms need to acquire, distribute, and interpret knowledge that enables them to identify the need for change. In other words, the organisation has to learn. However, since the change is implemented within the frameworks that underlie the organisation's activities, the corresponding learning effort is adaptive as well; i.e. single-loop learning occurs.

As the firm grows, established practices become obsolete. Although the firm becomes more and more efficient within the existing routines, the effectiveness of the organisation is reduced substantially. This is because the existing processes and routines do not match the challenges the entrepreneurial firm encounters as it further increases in maturity. Thus, the organisation requires new routines and processes and the new venture suffers a crisis. On the other hand, crises usually facilitate higher-level learning in entrepreneurial firms (Cope 2005). In fact, shocks or jolts are necessary for "unlearning, new higher-level learning and re-adaptation to take place" (Fiol and Lyles 1985, p. 808). Reflecting on the previous chapters, the occurrence double-loop learning fosters the development of dynamic capabilities. With new capabilities in place, start-up firms are able to change

their resource base and implement new routines and processes. Hence, the organisation is subject to second-order change. After this stage of crisis, the next period of evolutionary change is about to start. The following figure denotes the learning characteristics in periods of evolutionary and revolutionary change. While stages of crisis are associated with double-loop learning and the development of dynamic capabilities, processes, and routines, stages of growth are dominated by single-loop learning within the existing processes and routines. The model below shows the synthesis of Greiner's evolutionary model of organisational development, the different types of learning, and the creation of dynamic capabilities.

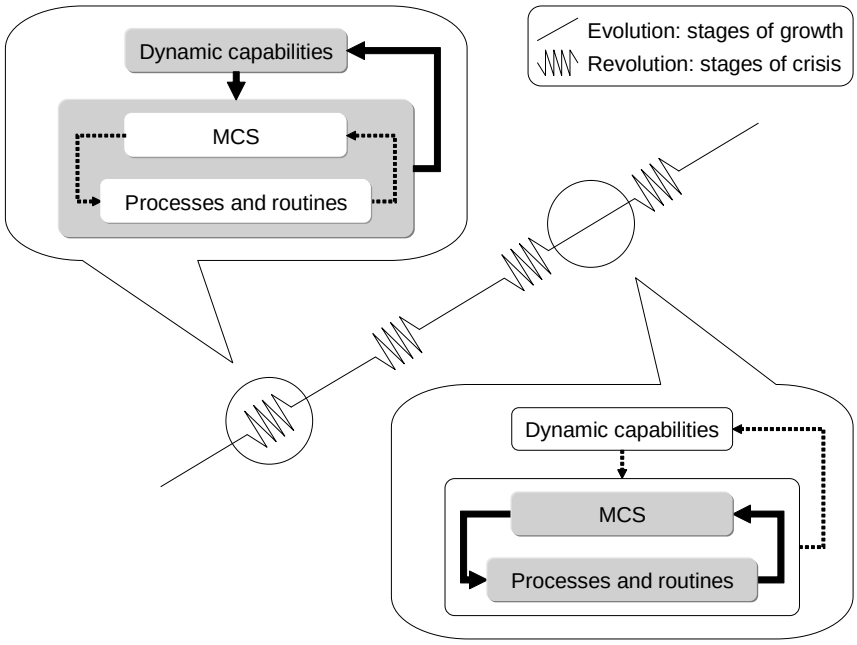

Figure 12 Linking evolutionary and revolutionary stages to the development of dynamic capabilities

Reflecting on the model in the figure above, we have gained a deeper understanding of the evolution of dynamic capabilities in entrepreneurial firms. Nevertheless, there are still several open questions. In chapter 2.2.3, I identified the different capabilities a technology-based new venture requires in order to survive and implement rapid growth. Although all these capabilities evolve in stages of crisis, we do not know the sequence

and the timing of capability development. However, these questions are highly important to understand the growth processes of entrepreneurial firms. In the following sections, I will further elaborate on this particular aspect of company development.

2.4.4 Path Dependency of Company Growth

To understand the sequencing and timing of capability development in technology-based new ventures, I reflect on the notion of path dependency as an important element of organisational research (Sydow, Schreyögg, and Koch 2005). Path dependency is mostly neglected in microeconomic theory where firms encounter an unlimited range of technologies and markets. Changes of product or factor costs are immediately addressed by replacing technologies according to criteria of value maximisation. Irreversibility does not exist in the end. In microeconomic theory, company history does not constrain future investments. Thus, path dependency is not considered, which represents a major limitation (Teece, Pisano, and Shuen 1997).

Contrary to microeconomic theory, the notion of path dependency advocates the relevance of history. In fact, "history matters" since "bygones are rarely bygones" (Teece, Pisano, and Shuen 1997, p. 522). Path dependency is highly important with respect to the development of organisations. Reflecting on chapter 2.2.4, dynamic capabilities are path dependent and determined by the learning efforts of the firm. Different scholars (e.g., Dierickx and Cool 1989; Helfat and Peteraf 2003; Rothaermel and Deeds 2006) identified three main aspects of these learning efforts: current resource endowments, past decisions as well as managerial competence and experience.

In the following three chapters, I elaborate on these three determinants of capability development to investigate further the growth processes of technology start-ups regarding the timing and sequencing of dynamic capability evolution. Therefore, I derive various hypotheses that address the characteristics of entrepreneurial growth paths. In addition, I formulate hypotheses that link certain paths to company performance. Although this approach does not consider the entire process of organisational development, it sheds light on very specific elements of new venture growth.

2.4.4.1 Resource-Based Paths

In this chapter, I focus on resource endowments to denote entrepreneurial growth paths. Once a person decides to exploit a technology-based opportunity by launching a company, he needs to acquire certain resources. Following chapter 2.1.4, a technology-based new venture requires a foundational technology and a business idea, financial resources, and employees with highly specialised human capital. Assuming that the entrepreneur provides the idea, the start-up still needs the technology, funding, and a highly skilled team. As indicated in chapter 2.2.3, start-up companies require entrepreneurial capabilities to establish this initial resource base.

As soon as these resources are acquired, the new venture needs to develop dynamic capabilities with respect to its current resource endowments. These capabilities are necessary to manage and further develop the initial resource base. In chapter 2.2.3, I identified different capabilities that are necessary to grow an entrepreneurial venture. According to the initial resource base, technology-based new ventures will initially focus on the development of dynamic capabilities in the field of financial management, human resource management, and strategic planning.

Although I assume that entrepreneurial firms will initially focus on the development of capabilities that enables them to manage their resource base in the best way, I expect some start-ups to need more time to establish dynamic capabilities in these fields than other firms. Firms that are slow in developing these capabilities face a competitive disadvantage since they encounter a period where they are not able to manage their initial resource base in the best possible way. Hence, I formulate the following three hypotheses.

Hypothesis 8 *An early emergence of financial management capabilities has a positive influence on new venture performance.*

Hypothesis 9 *An early emergence of strategic planning capabilities has a positive influence on new venture performance.*

Hypothesis 10 *An early emergence of human resource management capabilities has a positive influence on new venture performance.*

While some capabilities have to be developed very early in the life cycle of a new venture, others need more time to evolve. An important example is product development. Before products can actually be developed, the entrepreneurial firm has to engage in enhancing the foundational technology. From previous chapters we have already learned that entrepreneurial firms usually focus on innovation and thus have to cope with high uncertainty in different areas. Although information on functionality and design might support the effort, employees prefer experimentation and prototyping to resolve uncertainty on the technical side (Pisano 1994; Chesbrough 2003). However, the resolution of high technological uncertainty requires reasonable investments with respect to money and time (Roussel 1983). Consequently, I derive the following hypothesis.

Hypothesis 11 *The development of product development capabilities requires more time than financial management, HRM, and strategic planning capabilities.*

Dynamic capabilities in the field of marketing and sales can generally be expected to evolve later in the process of new venture creation. In general, one might assume that a product or service has to be developed first before it can actually be sold on the market and consequently, marketing and sales capabilities evolve after product development skills. However, from previous chapters we have learned that product development and marketing and sales activities are intertwined to a large extent (Verona 1999). Thus, capabilities in both fields should evolve almost in parallel. In any case, technology-based new ventures have to establish an initial resource base comprising a foundational technology and a business idea, human resources, and financial resources before they can engage in developing marketing and sales capabilities. Thus, I formulate the following hypothesis.

Hypothesis 12 *The development of marketing and sales capabilities requires more time than financial management, HRM, and strategic planning capabilities.*

A third capability that is expected to need more time to evolve is the ability to manage partnerships and alliances. The importance and benefits of partnerships have already been discussed in chapter 2.2.3. There, I also explained the necessity for corresponding capabilities to manage partnerships properly. Adopting a corporate perspective, large companies usually partner with entrepreneurial firms to gain access to new technologies (Alvarez and Barney 2001). However, these technologies have to be developed first. From the previous paragraphs, we have learned that the development of new technologies is costly and time consuming.

In addition, partnerships with mature companies are not necessarily beneficial for the entrepreneurial venture. While the larger partner gains access to a new technology, the entrepreneurial firm often receives only minimal benefits. Alvarez and Barney (2001) identified different means to mitigate the risk of losing all the value of an alliance to the larger partner. Among others, new ventures can use detailed contracts to legally define the alliance, they can bring other resources besides a single technology to the partnership, or they can establish a trust-based relationship (Alvarez and Barney 2001). However, none of these protective strategies is applicable in the very early stages of new venture growth. To develop detailed contracts, a start-up firm must engage lawyers, who are costly and thus not affordable for a young firm that is notoriously short on financial resources. The same is true for the provision of additional resources. While start-ups could offer their engineering knowledge in later stages, they need their human capital resources to implement the business model in the beginning. Establishing a relationship with a larger company that is based on trust requires substantial effort and time and is not expected to happen during the initial phases of start-up growth. Summing up, I derive the following hypothesis.

Hypothesis 13 *The development of partnership management capabilities requires more time than financial management, HRM, and strategic planning capabilities.*

2.4.4.2 Decision-Based Paths

In this section, I focus on different decisions an entrepreneur makes during the development of a start-up firm. A very early decision focuses on the industry segment for the entrepreneurial firm. The choice of industry can have a significant impact on the growth path of a technology-based new venture. A segment that is different when compared with other technology industries is biotechnology. As opposed to software, hardware, and service firms, life science ventures do not push customer-linking skills in the beginning.

Biotech companies cannot approach the market with a new product and immediately start to market it. Instead they have to pass many different preclinical and clinical tests until they get the approval from a government agency to actually launch their drugs on the market (Kellogg and Charnes 2000). For the first phases, the failure rates are usually very high (Jägle 1999). In addition, the process requires substantial financial investments and long periods of time without generating any revenues (Shan, Walker, and Kogut 1994). While biotech companies are purely focused on the development of particular drugs, entrepreneurial firms in other industries have to develop market sensing and customer linking capabilities in order to attract and retain customers. Therefore, they invest in learning efforts in the fields of marketing and sales.

When biotech companies finally get their products approved, they do not invest in production facilities and sell their drugs to patients. This is because large-scale production facilities in the health care sector require substantial investments. Instead, successful biotechnology ventures license their drugs to large incumbents who possess the financial resources to produce at high volume. Marketing and selling the products is often handled through partnerships. Although licensing deals may generate substantial revenues for the entrepreneurial firm, they are usually not realised by sales employees. In most cases, members of the top management team work on these deals. Thus, biotech ventures do not need to develop marketing and sales capabilities, which is expressed in the next hypothesis.

Hypothesis 14 *The biotechnology industry has a negative influence on the development of marketing and sales capabilities in technology-based new ventures.*

The development of innovative products is highly important for the success of most entrepreneurial ventures. This is equally true for biotechnology and semiconductor firms as well as for software and engineering companies. Although highly important for all these sectors, there are industry-specific differences with respect to product development practices in technology-based new ventures. These differences are mainly due to external influences on product development formalisation.

Product development in the biotechnology sector is very complex and requires highly specialised equipment. To ensure an efficient throughput, process steps are documented and formalised. However, this is not the only reason for the formalisation of product development routines in the life science sector. Biotechnology companies are subject to extensive restrictions regarding the approval of their products. During the development of new drugs, firms in the life science industry have to file several times with the United States Food and Drug Administration (FDA) (Kellogg and Charnes 2000). The FDA supervises the quality of the drugs as well as the product development processes. To ensure process quality, the government agency applies certain criteria for the development of new drugs. These requirements consider specific formalisations of the process. The requirements of the FDA are not limited to American biotech firms. The life science sector is a global industry; i.e. as a European biotech venture, it is common practice to file with the FDA. In addition, European agencies demand formalisation as well.

From the previous paragraphs, we have learned that entrepreneurial firms in the biotech sector require tremendous financial resources to finance the development of new drugs. These firms usually rely on different rounds of funding. Thus, the top management team attempts to show a high degree of professionalisation in its core competence, i.e. drug development. Hence, the formalisation of product development routines can also be considered as a signalling effort to impress potential investors and partners. Summing up, I derive the following hypothesis.

Hypothesis 15 *The biotechnology industry has a positive influence on the formalisation of product development routines in technology-based new ventures.*

Another important decision for an entrepreneur is to internationalise the business. In chapter 2.3.4.3, we have learned that the internationalisation of sales is an important event in the development of technology-based new ventures. However, the decision to sell its products and services internationally imposes different challenges upon new ventures. The young firm needs to develop a good understanding of the markets abroad and its corresponding customers. In addition, entrepreneurial firms selling internationally require access to new customers, which involves the recruitment of new sales people who are familiar with the characteristics of the market or the development of a partnership with a local distributor. In any case, the complexities of the sales function within the entrepreneurial venture increases substantially. Thus, the firm needs to develop substantial marketing and sales skills to manage the additional complexity adequately. Consequently, the internationalisation of sales operations in entrepreneurial firms is most likely accompanied by an emergence of marketing and sales management capabilities. Consequently, I formulate my next hypothesis.

Hypothesis 16 *The internationalisation of sales has a positive influence on the emergence of marketing and sales management capabilities in the years after going international.*

The internationalisation of sales operations usually increases the total addressable market substantially. Although entrepreneurial firms have not addressed a large percentage of the national target customers in the early stages, they may be able to increase the number of addressable innovators and early adopters (Rogers 1962; Moore 2002) willing to buy their innovative products and services.

According to the previous hypothesis, the internationalisation of sales triggers the development of managerial capabilities in the field of marketing and sales. However, this emergence of capabilities does not only ensure the performance of international sales operations, but also brings the entire marketing and sales function of a technology-based new venture to the next level. Thus, marketing and sales become more effective and a

start-up firm is able to increase its revenues substantially. The following hypothesis reflects these considerations.

Hypothesis 17 *The internationalisation of sales has a positive influence on revenue growth in the year of going international as well as in the subsequent years.*

2.4.4.3 Competence-Based Paths

In this section, I reflect on the experiences and competences of the entrepreneur as an important influence on the evolution of dynamic capabilities in new ventures. Referring to chapter 2.3.4.1, past experience enhances entrepreneurial learning and thus has a positive influence on the entrepreneur's competencies. These competencies comprise skills and knowledge as well as personality traits. They are considered as the ability to perform the entrepreneur's job role successfully (Man, Lau, and Chan 2002). In fact, learning enables entrepreneurs to develop and grow, and thus become capable managers (Rae and Carswell 2000; Cope 2005). However, organisational growth is not only driven by managerial competencies. It also requires the continuous development of additional managerial abilities (Katzy 2005a). In fact, founders cannot succeed if they are not able to grow with their company (Willard, Krueger, and Feeser 1992). Not all entrepreneurs are able to learn and develop in a way that will enable them to run the company in the end.

Organisations require entrepreneurial and managerial capacities. While entrepreneurial services drive the generation of new products and services, managerial services administer the corresponding routines to exploit these new opportunities (Barringer and Jones 2004). The effective growth of the firm is contingent upon the organisation's ability to add managerial capacity (Penrose 1959). Business founders often lack this capacity. They are considered as being unsuited for the managerial role (Greiner 1972; Greiner 1998). The comments of the CEO of a high technology venture in the semiconductor industry on the replacement of the founder support this argument.

> *"The founder was replaced as CEO because he had no managerial experience. This person was a brilliant technologist*

> *but he had no skills in marketing, sales, finance, human resources, patents, and legal affairs. In fact, at the moment I mainly focus on finance, human resources, patent rights, and legal affairs."*

While entrepreneurs are often well suited to cope with the high uncertainties of early growth stages, the entrepreneurial characteristics often do not match the challenges of a larger and more formalised organisation (Mintzberg 1973). As the firm becomes bigger, managers have to delegate decision-making authority. However, many entrepreneurs are not able to hand over performance control (Churchill and Lewis 1983). Thus, in many new ventures, founders are replaced by professional managers (Kerr 1982; Gupta 1984; Davila 2005). This argument is supported by Boeker and Karichalil (2002) who found a relationship between firm size and founder departure. In chapter 2.3.4.5, I have already elaborated on the impact of CEO replacement on double-loop learning and thus on capability emergence in technology-based new ventures.

However, replacing the founder does not happen immediately from one day to another. The replacement of the entrepreneur as CEO is usually triggered by investors or board members who recognise a negative development of the company and link this performance gap to the insufficient skill set of the current CEO. Since the labour law in Germany imposes certain restrictions on legal business entities, the owners or the supervisory board cannot replace a CEO from one day to the next. In fact, the replacement needs reasonable time. During this time, technology-based new ventures lack leadership and guidance and will most likely show a weaker performance. Hence, I derive the following hypothesis.

Hypothesis 18 *Founder succession has a negative influence on new venture performance in the years prior to the replacement of the CEO.*

The replacement of the founder is expected to have a negative association with new venture performance in the years prior to CEO succession. However, the picture will most likely not change substantially during the time of replacement and shortly after the event. Although founder succession can have a positive influence on double-loop learning and

consequently on the development of capabilities, the new CEO needs time to bring the entrepreneurial firm back on course and perform all the necessary tasks that have not been carried out during the prior leadership crisis. Consequently, the growth rates of technology-based new ventures may not increase immediately after the founder has been replaced. Hence, I derive the following hypothesis.

Hypothesis 19 *Founder succession has a negative influence on new venture performance in the years after the replacement of the CEO.*

3 THEORETICAL FRAMEWORK

3.1 BASIC MODEL

In the previous chapters, I have developed a concept that aims at explaining the evolution of dynamic capabilities in technology-based new ventures by linking the strategic management framework to entrepreneurial learning and organisational development and change. In the course of this effort, I have derived various hypotheses that support this concept and the underlying approaches and theories. To denote the links between the concept and the different hypotheses, I provide a summary of the different findings from the theoretical part of this study in this third chapter.

To categorise the hypotheses, I define three reading points in the model that has been initially described in chapter 2.3.3. The first point (1) addresses the performance of start-up companies and thus measures the employee growth rates of entrepreneurial firms. The second reading point (2) focuses on the influences on double-loop learning. Finally, the third point (3) indicates the various types of dynamic capabilities that could evolve in a technology-based new venture. These capabilities are based on the literature review conducted in chapter 2.2.3. The three points are indicated in the following figure.

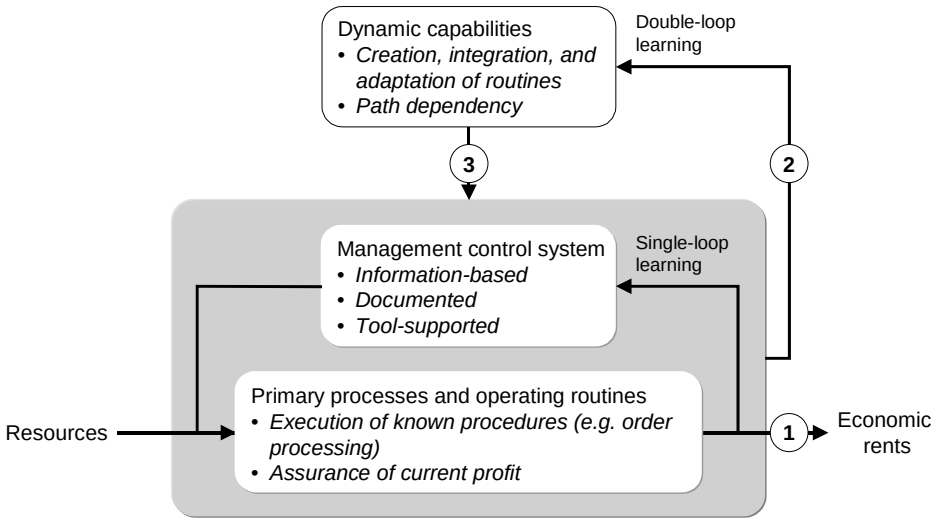

Figure 13 Reading points in the model for the evolution of dynamic capabilities in technology-based new ventures

3.2 OVERVIEW OF HYPOTHESES

In general, there are four different types of hypotheses. The first category addresses the different drivers for entrepreneurial learning in technology-based new ventures. Most of them are outlined in chapter 2.3.4 of this study. These drivers are expected to have a positive impact on the emergence of dynamic capabilities in entrepreneurial firms. To control these influences, I apply the second and third reading point (2-3). The hypothesised influences include the experience of the CEO, the size of the organisation, the internationalisation of sales, the age of the organisation, the replacement of the CEO, the introduction of a professional financial manager or CFO, and venture capital funding. All these drivers are supposed to have a positive impact on all functional types of dynamic capabilities. Functional preferences are not considered for this set of independent variables.

Three similar hypotheses are outlined in chapter 2.4.4.2. They comprise drivers which affect specific functional capabilities. First, the biotechnology industry is expected to have a negative influence on the emergence of marketing management capabilities. In

addition, the same segment is expected to have a positive association with the formalisation of product development routines in technology-based new ventures. Finally, the internationalisation of sales should have a positive impact on the evolution of dynamic capabilities in the field of marketing and sales. The following table indicates this first group of hypotheses in the sequence of their theoretical development.

Table 4 Categorisation of hypotheses focusing on drivers of entrepreneurial learning

	Hypothesis
1	CEO experience has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.
2	Organisational size has a positive influence on the evolution of dynamic capabilities in technology-based new ventures.
3	The Internationalisation of sales has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.
4	Organisational age has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.
5	CEO replacement has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.
6	Hiring a CFO has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.
7	VC funding has a positive influence on the emergence of dynamic capabilities in technology-based new ventures.
14	The biotechnology industry has a negative influence on the development of marketing and sales capabilities in technology-based new ventures.
15	The biotechnology industry has a positive influence on the formalisation of product development routines in technology-based new ventures.
16	The internationalisation of sales has a positive influence on the emergence of marketing and sales management capabilities in the years after going international.

The next group of hypotheses focuses on the linkage between the timing of dynamic capability emergence and the performance of technology-based new ventures. Here, the hypotheses address very specific capabilities. The early emergence of financial management capabilities, human resource management capabilities, and strategic planning capabilities is expected to have a positive impact on new venture performance. The performance is measured as the growth rate of the entrepreneurial firm. To test these hypotheses, I measure between the first and the third reading point (1-3). The three hypotheses in this group are developed in chapter 2.4.4.1.

The third category of hypotheses is outlined in the same chapter as the second group. These hypotheses address the sequencing of various groups of functional capabilities in technology-based new ventures. Here, the evolution of product development capabilities, marketing and sales capabilities, as well as the emergence of partnership management capabilities is expected to follow the development of financial management, human resource management, and strategic planning capabilities. To test the three hypotheses in this group, I apply the third reading point (3).

The last group of hypotheses is outlined in the chapters 2.4.4.2 and 2.4.4.3 and link drivers for the emergence of dynamic capabilities with new venture performance. Specifically, the internationalisation of sales is expected to influence revenue growth positively. In addition, the replacement of the CEO is expected to have a negative influence on the growth rates of firms in the years prior to and after the succession. To test the hypotheses I measure between the first and second reading point (1-2). The following table shows the second, third, and fourth group of hypotheses in this dissertation. In addition, it indicates the applied reading points.

Table 5 Categorisation of hypotheses

	Hypothesis	1-2	1-3	3
8	An early emergence of financial management capabilities has a positive influence on new venture performance.		✓	
9	An early emergence of strategic planning capabilities has a positive influence on new venture performance.		✓	
10	An early emergence of human resource management capabilities has a positive influence on new venture performance.		✓	
11	The development of product development capabilities requires more time than financial management, HRM, and strategic planning capabilities.			✓
12	The development of marketing and sales capabilities requires more time than financial management, HRM, and strategic planning capabilities.			✓
13	The development of partnership management capabilities requires more time than financial management, HRM, and strategic planning capabilities.			✓
17	The internationalisation of sales has a positive influence on revenue growth in the year of going international as well as in the subsequent years.	✓		
18	Founder succession has a negative influence on new venture performance in the years prior to the replacement of the CEO.	✓		
19	Founder succession has a negative influence on new venture performance in the years after the replacement of the CEO.	✓		

3.3 EXPLORATIVE ASPECTS OF THE STUDY

So far, I have developed a concept for the evolution of dynamic capabilities in entrepreneurial firms and the corresponding impact on new venture performance. To test the concept, I have derived various hypotheses that are summarised in the previous section. However, the growth processes of technology-based new ventures incorporate many additional questions that cannot be hypothesised by conducting a thorough literature review. These aspects are also important and provide further insights into the development of start-up companies in technology-based industries. In the following paragraphs, I address these open issues and research gaps and thus add an explorative part to the dissertation. Therefore, I pose several questions focusing on the various topics of interest.

The first question focuses on the drivers of specific functional capabilities that are not covered in the hypotheses 14 to 16. While the initial hypotheses mainly address all dynamic capabilities, there may be functional differences with respect to the influence of the various drivers outlined in chapter 2.3.4. Thus, the first question is formulated as follows.

> *What is the influence of the drivers identified for the emergence of dynamic capabilities in general on specific groups of functional capabilities?*

A second interesting aspect of the growth processes of technology-based new ventures is the endogeneity of dynamic capabilities and organisational size. While some scholars might propose that certain managerial capabilities are necessary for technology-based new ventures to grow, others may not accept this argument and rather see the emergence of capabilities as a logical consequence of an increase in size. These two perspectives represent a classical "chicken-and-egg" problem that is almost impossible to hypothesise. Thus, I pose the following question to address this open issue.

> *Do dynamic capabilities drive the growth of the firm or do they automatically emerge when new ventures increase the number of employees?*

The last question further elaborates on the path dependency of dynamic capability evolution discussed in chapter 2.4.4. Although the derived hypotheses in this particular chapter address the aspect of capability sequencing, they do not incorporate an entire sequence of dynamic capability emergence in technology-based new ventures. In addition, the hypotheses do not consider the performance implications of different paths of evolution. These open issues are subject to the last explorative question.

> *How does the sequence of dynamic capability evolution influence new venture performance?*

3.4 CONCEPT OPERATIONALISATION

In this study, I attempt to denote the emergence of dynamic capabilities in technology-based new ventures. However, since capabilities are complex bundles of accumulated knowledge and skills, it is almost impossible to control for their occurrence. To mitigate this problem, I reflect on management control systems as organisational knowledge repositories. As laid out in chapter 2.3.2, MCS are interlinked with the processes and routines of the operating core of the firm. In fact, they are important means for adaptive learning within the organisation's routines.

As soon as the company enters a revolutionary period of change, the existing routines and processes are not sufficient any more and thus have to be adapted or replaced. In entrepreneurial ventures, they often have to be developed from scratch. Adapting or introducing new processes and routines consequently leads to a change in the organisation's control systems. Without adapted control mechanisms in place the organisation would not be able to learn within this new set of routines, i.e. engage in first-order learning.

However, to implement second-order change, organisations need dynamic capabilities. The existence of dynamic capabilities is prerequisite for the generation, adaptation, and replacement of organisational processes and routines. Since new organisations do not possess these capabilities, they have to be developed as well. I assume that effective organisations will only engage in the development of dynamic capabilities if they have to

implement second-order changes. This is in line with the argument that entrepreneurial firms face a substantial resource scarcity, especially in the very early days. Thus, the generation of new processes and routines indicates the prior emergence of additional dynamic capabilities within the firm. Since new processes and routines always emerge together with corresponding management control systems, the occurrence of MCS can be applied as an indicator for the development of dynamic capabilities in technology-based new ventures. From chapter 2.3.2, we have learned that MCS are mostly supported by management information systems. In addition, they are documented in different forms. Consequently, their emergence can be tracked over time. Recapitulating on these findings, I am able to control for the evolution of dynamic capabilities by focusing on the emergence of management control systems in entrepreneurial firms.

The following figure shows the operationalisation applied in this study. According to this model, start-up companies can cope with a certain level of organisational challenges without changing the organisational processes and routines. These challenges are determined by various factors. Important influences in this respect are size in terms of number of employees but also organisational structure as well as age. As firms grow older, their environment could change substantially and thus new challenges may be imposed on the organisation. A change in the organisational structure could add complexity to the company and thus lead to new challenges.

During an evolutionary period, the firm increases its efficiency. However, when a certain level of challenges is reached, the current set-up does not allow for additional growth. A crisis referred to as revolution occurs and firms develop dynamic capabilities to generate new routines and processes in order to cope with the new challenges. These new processes and routines automatically trigger the development of management control systems. With this updated operating core in place, the entrepreneurial firm enters the next evolutionary period and the venture can further develop.

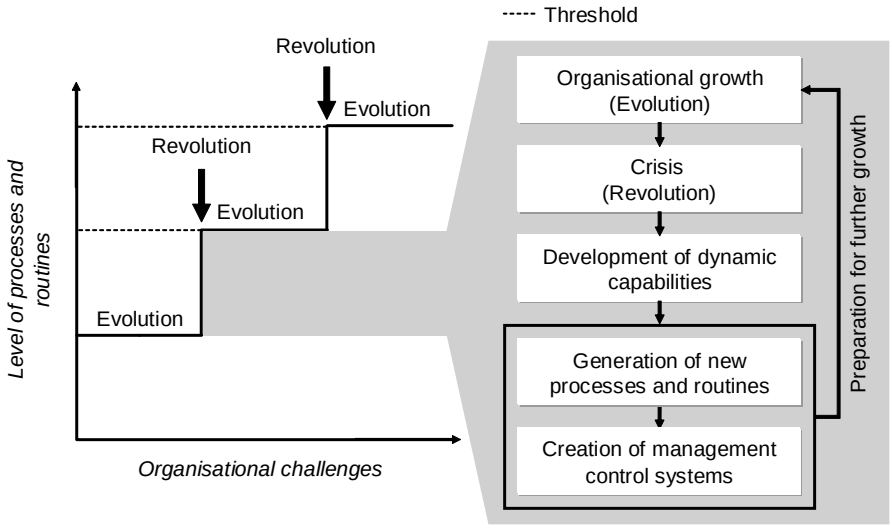

Figure 14 Concept operationalisation

Although the existence of a MCS can be theoretically identified, firms may interpret the adoption of a management control system in different ways. To mitigate this problem, I introduce criteria which systems have to fulfil in order to be considered as management control systems. The emergence of a MCS is only considered if the respective routine or structure is either documented in written form or recurrently and purposefully executed. In the following tables, I outline various management control systems. Therefore, I define MCS for each functional capability identified in the second chapter of this dissertation. The following table denotes management control systems that are associated with financial planning, strategic planning, and human resource planning capabilities. The lists of systems are adapted from Davila and Foster (2005).

Table 6 Classification of management control systems for planning

	Management control system
Financial planning capabilities	Cash-flow projections Sales projections Operating budget
Strategic planning capabilities	Investment budget Strategic milestones (non-financial) Product portfolio plan Customer development plan (plan to develop the market) Headcount/human capital development plan
Human resource planning capabilities	Core values Mission statement Organisational chart Codes of conduct Written job descriptions Orientation programme for new employees Company-wide newsletter

The next table provides a wide variety of management control systems that are associated with financial evaluation capabilities, as well as capabilities that are required for the evaluation of human resources.

Table 7 Classification of management control systems for evaluation

	Management control system
Financial evaluation capabilities	Capital investment approval process Operating expenses approval process Variance analysis (financial performance against budget) Customer acquisition costs Customer profitability analysis Product profitability analysis
Human resource evaluation capabilities	Performance objectives (written) Evaluation reports (written) Linking compensation to performance Individual incentive programmes

The last table comprises management control systems that are associated with product development capabilities, marketing management capabilities as well as partnership management capabilities.

Table 8 Classification of MCS for product development, marketing and partnerships

	Management control system
Product development capabilities	Project milestones Concept testing process Actual progress to plan (comparison reports) Project selection process Product portfolio roadmap Budget for development projects Team composition guidelines Progress monitoring system Product quality monitoring system
Marketing and sales management capabilities	Sales targets for salespeople Market research projects Sales force compensation system Sales force hiring and firing policies Reports on open sales Customer feedback Sales process manual Sales force training programme Collaboration policies Customer relationship management (CRM) system Sales force effectiveness reports
Partnership management capabilities	Partnership development plan Partnership development reports Policies for partnerships Partnership milestones Partner monitoring system

4 SURVEY DESIGN

4.1 POPULATION AND SAMPLE

4.1.1 Description of the Sample

Referring to chapter 1.5, the sample companies are located in the Munich region. All these entrepreneurial firms are funded by venture capitalists or corporate venture capitalists. They are either privately owned or publicly listed. Thus, no subsidiaries are considered in the sample. In addition, the new ventures are associated with high technology industries such as semiconductors, life sciences, or information and communication technologies.

While many research efforts in entrepreneurship (e.g., Zahra, Ireland, and Hitt 2000) limited the firm maturity of their population to six years, the companies considered in this study have a maximum age of twelve years. Although older companies are usually not used for research purposes in this field, organisations that are twelve years old can still be considered as entrepreneurial firms (Fallgatter 2004). The reason for the relatively long observation period is due to the corresponding increase of observations. However, I do not consider older firms to ensure that the availability and reliability of data addresses the initial years of company history. The approach is in line with efforts from Davila (2005) and Davila and Foster (2005) who applied a longer observation period for their longitudinal research efforts in this field as well.

The population is limited to companies that grew to a number of 10 to 150 employees at the end of the observation period. To identify these firms, I applied VentureSource, a commercial database that focuses on venture capital-backed companies. VentureSource is provided by VentureOne, a leading venture capital research firm being part of Dow Jones. The global database accounts for a high coverage in Europe and comprises information concerning the size, age, industry, business model, funding, and the investors of the entrepreneurial firms. The following table indicates the basic survey parameters for this study.

Table 9 Survey parameters

	Criteria
Location	Munich region
Funding of the companies	Venture capital-backed
Ownership	Independent or publicly-listed
Association of the companies' business model	High technology
Eligible business models	Software, hardware, biotechnology, and services
Year of formation	1992 or later
Size according to sampling database	10 to 150 employees

The applied multi-method, multi-case field research design considers the commercial database VentureSource, questionnaires, interviews, and public sources such as websites and press clippings to obtain an objective picture of the sample firms. Companies that participated in the study needed to answer three different questionnaires focusing on general management, financial management, and business development. The general management questionnaire was mainly answered by the CEO or the managing director and it considers the emergence of management control systems in the field of strategy and human resource management as well as certain events in the company's history.

The financial management questionnaire was meant to be filled out by the CFO or the financial manager and covered financial evaluation and financial planning MCS. Again, the questions covered different events in the firm's history. In addition, this second questionnaire includes the financial history of the company, comprising revenues, profits, employees and R&D-related employees per year, as well as the timing and volume of the different financing rounds.

The last questionnaire focuses on business development, covering management control systems and events in the field of product development, partnerships and alliances as well as marketing and sales. In addition, the questionnaire requests details on the partnerships of the sample companies as well as the internationalisation of the business. The questionnaire was meant to be answered either by the business development manager or by the head of marketing and sales.

In addition to the questionnaires, up to three interviews were conducted at each company. The interviews covered the same topics as the questionnaires. They were meant to be held with the CEO, the CFO and the business development manager of each company. The semi-structured interviews comprised open-ended questions and were coded along predefined schemes. Due to the complexity and volume of the questionnaires, the interviews were also very useful for clarification purposes.

4.1.2 Contact Process and Response Pattern

For contacting the sample companies, I directly called a member of the management team to provide facts about the content of the project and the participation requirements with respect to time and disclosure of sensitive information. In most cases, the call was conducted with either the CEO or the CFO of the company. With those executives who indicated their interest during the initial call, I agreed on a follow-up email containing documents for further clarification and the survey questionnaire. If the executive was neutral, I skipped the questionnaire in the first email and conducted a second call before I provided the questionnaire.

After the firm received all relevant documents for the study, I called the contact person again to clarify whether the entrepreneurial firm is willing to participate. When the firm indicated its willingness, I defined the sampling process for this particular company. This step comprised the scheduling of the executive interviews as well as the return of the questionnaire. The firms were able to either send back the completed questionnaire before the interviews or complete it during the interviewing process.

The applied database VentureSource indicated 818 venture capital-backed firms in Germany that met the requirements on age and size. After excluding all companies outside the Munich region[15], the number decreased to 161 new ventures. To validate the coverage of the initial database, I screened German venture capital firms that are active in the Munich region. This search indicated three additional firms that met the requirements for the sample companies. Out of the 164 companies, 66 went out of business during the

[15] I included all companies with a postal zip code from 81000 to 85999.

observation period. Another three firms were acquired during this time. Seven ventures were ineligible in some other way, i.e. some firms were too small, others were not technology-based, or their headquarters were located outside the region. After these corrections, the total population covered 88 technology-based new ventures. With 44 participating companies, the response rate is 50%. In the following table, I refer to the sampling process for this study.

Table 10 Response pattern of the survey

	Companies	Percentage
VC-backed companies in Germany (VentureSource)	**818**	
- VC-backed outside the Munich region (VentureSource)	657	
VC-backed companies in the Munich region (VentureSource)	**161**	
+ Additional companies from VC screening	3	
VC-backed companies in the region	**164**	
- Companies that went out of business	66	
- Companies that were acquired	3	
- Companies ineligible in some other way	7	
Total population	**88**	**100%**
- Eligible companies that declined participation	44	50%
Sample of companies	**44**	**50%**

I limited the study to technology-based entrepreneurial firms. However, there are still differences regarding the industry segments of the sample companies. In general, I categorise the participating firms into biotech, software, service and other technology companies. The last group comprises firms that provide technological products to their customers. Examples for this cluster include companies in the semiconductor, medical technology, or laser industry. The following table indicates the industry split of the sample firms.

Table 11 Industry split of sample

	Number of companies	Percentage
Biotechnology	7	16%
Software	12	27%
Other technology	13	30%
Services	12	27%
Sample companies	**44**	**100%**

4.1.3 Non-Response Analysis

In order to assess whether the sample is representative for the initial population or biased, I conducted different statistical tests. First, I compared the number of firms for the various industry sectors defined in the previous chapter with the distribution of the eligible companies, which declined to participate. The results are indicated in the following table.

Table 12 Industry split of responding and non-responding companies

	Respondents		Non-respondents	
	Total	Percentage	Total	Percentage
Biotechnology	7	16%	16	36%
Software	12	27%	11	25%
Other technology	13	30%	8	18%
Services	12	27%	9	21%
Observations	44		44	
Pearson chi-square	5.18			
P	0.16			

A chi-square test indicates that the industry split does not differ significantly between the respondents and those firms that did not participate in the study. To further test for a possible bias in the sample, I compared the age and the size of both groups at sampling time. Therefore, I used the information indicated in the VentureOne database. The statistics of the comparison are provided in the next table.

Table 13 Age and size of responding and non-responding companies

	Age		Employees	
	Mean	SD	Mean	SD
Respondents	5.84	0.35	43.50	4.92
Non-respondents	6.14	0.43	39.22	3.79
Z	-0.49		0.16	
p	0.62		0.87	

A non-parametric Mann-Whitney test shows no significant difference in terms of age and size between technology-based new ventures that responded and those firms that declined to do so. Overall, the consideration of statistical tests comparing respondents with non-respondents along three different key characteristics revealed no significant difference between both portfolios. Thus, I assume no obvious bias in the response pattern.

4.2 STATISTICAL METHODS

To elaborate on the implications and drivers for dynamic capability evolution and thus organisational learning in technology-based new ventures, I requested a variety of time-varying information from each participant. The longitudinal character of the study offers the possibility of providing a much more accurate and detailed picture of the learning efforts in entrepreneurial firms. However, the statistical modelling of longitudinal data sets is much more complex than for ordinary time-invariant research designs.

For this study, I used three different groups of statistical analyses: group comparison tests, linear and count data regression models for panel data, and simultaneous-equations models. Due to the high complexity of different statistical methods applied in this study, the choices for the statistical software package were limited. For the tests and regressions, I used Stata/SE for Windows version 8.0. The package is provided by Stata Corporation and it covers most econometric analyses. In the following sections, I introduce the main statistical methods applied in this study.

4.2.1 Group Comparison Tests

To evaluate differences in performance and timing of MCS emergence, I apply several mean comparison tests. Therefore, I split the population into two groups and compare the means of both groups in order to identify significant differences. To compare the means of different groups, two main approaches can be applied: parametric and non-parametric tests. Parametric tests assume the test variable to be normally distributed. In addition, standard parametric tests require the variances of both groups to be equal. However, often, this is not the case. The problem of unequal variances is also referred to as the Behrens-Fisher problem (Sachs 1997) and can be solved with a Welch parametric t test (Welch 1937) that allows for unequal variances. Parametric tests can be paired or unpaired. In this dissertation, I apply both types.

When the assumption of a normally distributed test variable must be rejected, a non-parametric test has to be applied. This test does not make any assumptions regarding this distribution. Different non-parametric tests exist. In this study, I apply the Wilcoxon matched-pairs signed-rank test (Sachs 1997; Voß 2000), the Mann-Whitney two-sample statistic (Mann and Whitney 1947), and the Kruskal-Wallis equality of populations rank test (Kruskal and Wallis 1952). Compared to other non-parametric and parametric tests, the Kruskal-Wallis rank test allows for more than two groups.

In many cases, I run tests for different groups of management control systems. Although the test variable is normally distributed for some of the groups, this is not true for all of them. Therefore, I mostly report parametric as well as non-parametric test statistics to keep the results comparable while accounting for non-linear test variables. Non-parametric tests are often used to validate the results of parametric tests, e.g. the Mann-Whitney test is very robust and often used to validate highly significant parametric tests (Sachs 1997).

4.2.2 Panel Data Regression Models

The study adopts a longitudinal design allowing for various observations over time for each company under study. This imposes a major challenge on the statistical methods applied (Lin and Carroll 2001). General regression models assume the independence of

the observations in the sample. However, I conducted a variety of measurements per firm, which can hardly be assumed as being independent. Instead, the probability is high that the longitudinal character results in correlated observations (Pan, Louis, and Connett 2000). For the estimation of regression parameters, these correlations have to be considered. Otherwise the risk for incorrect conclusions is high (Ballinger 2004). The standard linear regression model assumes only one correlation over time, which is because the same firm is present across the panel. However, this assumption is often not applicable for economic relationships where an event in one period could have a substantial impact on the next periods. In a simple error component model, this serial correlation or autocorrelation is not allowed (Baltagi 2005). Thus, we have to test for autocorrelation and consider this effect in our models.

Two regression models are pre-eminent for the analysis of longitudinal data. We can either apply an efficient random-effects model or a more reliable fixed-effects model (Greene 2003; Baltagi 2005). Although the random-effects model is more efficient, there are situations where the results of this model are not valid. To test whether a random-effects model can be applied, a Hausman specification test (Hausman 1978) has to be carried out. In case the Hausman test rejects the random-effects model, a fixed-effects model has to be applied. However, this model has a clear shortcoming since it does not allow for time-invariant explanatory variables. Since I use industry variables to identify the influence of certain segments such as biotechnology, I need a model that allows for those variables in case a random-effects model must be rejected.

A reasonable alternative is the generalised estimating equation (GEE) method that has attracted more and more attention over the past years (Albert 1999). The GEE method (Liang and Zeger 1986; Zeger and Liang 1986) is referred to as the marginal or population-averaged model (Zeger, Liang, and Albert 1988). Models based on the GEE method have regularly been used in entrepreneurial research (e.g., Baron, Hannan, and Burton 2001; Davila and Foster 2005) and represent a powerful mean to analyse longitudinal data with time-invariant variables (Baron, Hannan, and Burton 2001).

Another important aspect of panel data regressions is heteroskedasticity. A model with standard error components assumes that the regression disturbances show the same variance across firms and time. However, this is often not the case for panel data

representing economic situations. Thus, we have to test for heteroskedasticity and consider the effect in our regression models. To account for heteroskedasticity across panels we can use a cross-sectional time-series linear model using feasible generalized least squares (FGLS). This model is a random-effects model and allows for time-invariant independent variables (Greene 2003).

For the regression models, I use two different types of response variables. First, I apply standard Gaussian distributed dependent variables resulting in linear regression models for panel data. Second, I apply count data models. Count data analysis has been applied in a wide variety of empirical studies. For the corresponding statistical analysis, different scholars (e.g., Davila 2005) used Poisson models for research in entrepreneurship. With respect to count data, Poisson distributions have two major advantages compared to ordinary Gaussian distributions. The Poisson distribution is discrete and does not consider negative values (Sachs 1997). However, Poisson models make a strong assumption regarding the structure of the variance. For a data set to follow a Poisson distribution, the mean has to equal the variance (Voß 2000).

Many data sets do not fulfil this requirement. In various practical examples, the variance exceeds the mean. This state is defined as overdispersion. To handle overdispersed count data, the Poisson distribution can be replaced by a negative binomial distribution (Rao and Scott 1999). In general, the Poisson distribution represents a special form of the negative binomial distribution (Voß 2000). For the latter distribution, the variance can exceed the mean. Thus, the strict requirement of the Poisson distribution is not necessary and regressions with overdispersed count data can be carried out.

4.2.3 Simultaneous-Equations Models

In certain cases, we are confronted with different jointly dependent variables, which are also referred to as endogenous variables. Often we are not able to explain how these variables are related to each other. To elaborate on this question, we can formulate systems of equations that comprise various endogenous variables. The equations are regression models such as fixed- or random-effects implementations discussed in the previous chapter. The number of jointly dependent variables has to equal the number of

equations. These systems of equations can be solved iteratively. They are referred to as simultaneous-equations models (Greene 2003). Most statistical programmes like Stata have functions implemented to solve such systems. However, these routines are typically limited to standard linear regression models. To solve more complex panel data regressions, simultaneous-equations models have to be solved manually by running the different regressions repeatedly until the results converge to a certain value.

In this dissertation, I apply a simultaneous-equations model with two equations and two corresponding endogenous variables. The equations are structural equations since they are derived from theory. The dependent variable in the first equation represents the independent variable in the second equation and vice versa. The system of equations in this study comprises panel data regressions and thus has to be solved iteratively with the deployed software package.

5 SURVEY RESULTS

The survey results are presented in the following sections. First, I provide some basic descriptive statistics including summary means, quartiles, and medians for general characteristics of the sample firms, as well as for the adoption times of all management control systems considered in this study. In addition, I indicate time-dependent data on revenues, employees, funding, and other characteristics of the sample companies.

In the subsequent section, I present the test results regarding the different hypotheses derived in chapter 2 and summarised in chapter 3. The statistical methods applied have been introduced in chapter 4.2. Afterwards I leave the initial research path, which is mainly driven by the various hypotheses. Reflecting on the questions formulated in chapter 3.3, I elaborate on the drivers for the emergence of different functional dynamic capabilities, the endogeneity of dynamic capabilities and organisational size and the performance implications of different paths of skill development. Finally, I focus on the early emergence of capabilities that have not been hypothesized.

5.1 DESCRIPTIVE STATISTICS

The first part of this section provides descriptive statistics that further specify the sample for this study. The following table indicates the age of the firm, the number of CEOs, and the experience of the most experienced CEO in the company's history. In addition, the table shows the lifetime maxima of employees, R&D-related employees, revenues, and net income. The last information indicates the cumulated funding across the sample. The table offers the means, medians, standard deviations, as well as maxima, minima and first and third quartiles for every figure.

Table 14 Characteristics of sample companies

	Mean	SD	Min	Q1	Median	Q3	Max
Number of CEOs	1.41	0.76	1.00	1.00	1.00	2.00	4.00
CEO experience	10.89	7.82	0.00	5.00	10.00	15.00	40.00
Company age	5.70	2.41	3.00	4.00	5.00	7.00	12.00.
Employees	53.75	45.33	10.00	23.00	35.00	75.00	250.00
R&D employees	20.39	24.59	0.00	6.00	14.50	22.00	115.00
Revenues (€ '000)	4,727.95	5,559.05	0.00	1,000.00	2,600.00	6,500.00	26,000.00
Net income (€ '000)	142.86	1276.77	-1413.00	-433.00	0.00	200.00	4000.00
Funding (€ '000)	15,510.00	15,540.00	0.00	5,100.00	11,000.00	20,000.00	61,420.00

CEO experience, employees, R&D employees, revenues, and income indicate the maximum values during the observation period. Funding indicates the cumulated funding over the entire observation period of the company.

Regarding the table above, the sample companies experienced only very few CEO replacements. In fact, most of the new ventures have never replaced the founder as CEO. The experience of the CEO shows a wide spread. While there are companies founded by individuals who have never worked before, other start-ups have CEOs with 40 years of prior work experience. In the next table, I provide the development of various company characteristics over the first five years in the sample's history. Therefore, I provide means, medians, and standard deviations for each year.

Table 15 Longitudinal development of different company characteristics

	Year 1	Year 2	Year 3	Year 4	Year 5
Employees					
Mean	7.88	18.95	28.31	35.08	38.54
Median	5.00	12.00	20.00	30.00	27.50
Standard deviation	8.27	17.50	24.52	27.14	28.31
R&D employees					
Mean	2.95	6.95	11.68	13.61	15.04
Median	2.00	5.00	8.00	9.00	10.00
Standard deviation	3.94	7.38	14.70	20.22	16.73
Revenues (€ '000)					
Mean	152.51	611.65	1,451.02	2,426.03	3,152.88
Median	0.00	350.00	1,000.00	1,469.00	2,600.00
Standard deviation	391.71	740.48	1,629.13	2,409.28	3,106.00
Net income (€ '000)					
Mean	-335.21	-4,901.36	-4,152.40	-3,042.87	-1,878.89
Median	-71.00	-2,602.50	-2,512.00	-1,100.00	-643.00
Standard deviation	465.01	6,335.88	4,947.90	4,510.82	5,919.49
Cumulated funding (€ '000)					
Mean	1,570.34	5,860.24	9,098.12	11,142.47	14,820.75
Median	250.00	3,000.00	3,850.00	5,150.00	9,980.00
Standard deviation	2,293.84	9,207.80	13,433.67	14,263.51	15,653.14

The first year is the year of foundation and most likely does not cover a full annual period. Since some of the new ventures considered in this study are only three years old, the number of observations decreases with year four.

While the prior information indicates general characteristics and performance data, the following table shows details of particular events in the history of technology-based new ventures. To provide this information, I count the number of years until the event occurred in each company. The considered events comprise the first investment from a venture capital firm, the replacement of the initial CEO, the recruitment of a dedicated financial manager, the promotion to or the introduction of a CFO, the first external audit, and the first international sales. An important event that is missing is the initial public offering. However, only one firm in the sample went public during the observation period. Again, the table provides means, medians, standard deviations, minima, and maxima, as well as first and third quartiles.

Table 16 Event history of sample companies

	Mean	SD	Min	Q1	Median	Q3	Max
Time to venture capital	1.31	1.81	0.00	0.00	1.00	2.00	7.00
Time to CEO replacement	5.27	2.52	2.00	3.00	4.00	7.00	10.00
Time to financial manager	1.97	1.86	0.00	1.00	1.00	3.00	6.00
Time to CFO	2.23	1.96	0.00	1.00	2.00	4.00	6.00
Time to first external audit	2.03	1.91	0.00	1.00	1.00	3.00	7.00
Time to international sales	2.36	2.00	0.00	0.00	1.00	2.00	9.00

In the following, I provide details on the adoption of the different management control systems considered in this study. The next figure shows the emergence of the eight main functional groups of MCS denoted in chapter 3.4 over time. The horizontal axis denotes the year in the company's life while the vertical axis indicates the mean system intensity of the sample for different groups of MCS. Therefore, system intensity represents the percentage of systems adopted in one functional group of MCS according to the tables provided in chapter 3.4.

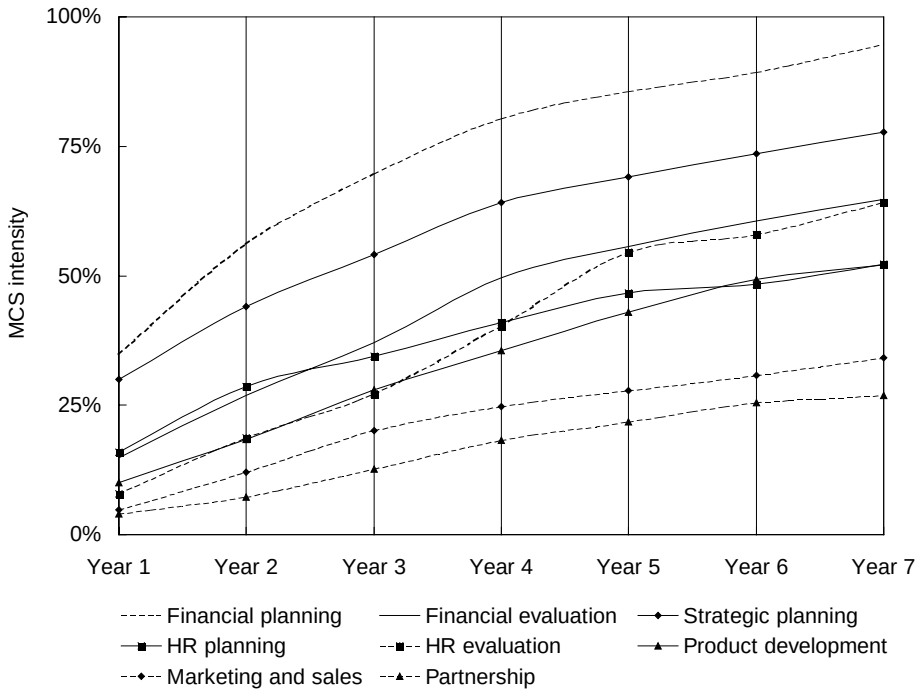

Figure 15 MCS adoption over time

Although the different groups comprise varying numbers of MCS, the figure above offers interesting implications. Many companies have already adopted various systems in the year of founding. According to the various graphs, new ventures emphasise strategic and financial planning MCS in their initial years. In fact, these two groups are adopted faster than other systems. A second group of MCS that is adopted in start-up companies comprises financial evaluation, human resource planning and evaluation as well as product development MCS. While human resource evaluation MCS seems to be less important in the first three years, this group catches up in years four and five. The existence of management control systems in the field of marketing and sales is marginal in the initial years. Although the emergence increases slightly in year three, not many systems in this field are actually adopted. As the last group, partnership MCS seems to play only a minor role in technology-based new ventures.

In the following, I indicate the adoption characteristics for the various MCS in the different functional areas representing the derived dynamic capabilities. Therefore, I provide means, medians, first and third quartiles, as well as standard deviations for the timing of MCS adoption. The last column accounts for the percentage of entrepreneurial firms in the sample that have adopted the particular MCS during the observation period. The table below focuses on the adoption of strategic planning MCS.

Table 17 Adoption characteristics of strategic planning MCS

	Mean	SD	Q1	Median	Q3	Adoption
Investment budget	1.57	1.90	0.00	1.00	3.00	95%
Strategic milestones	1.64	1.84	0.00	1.00	3.00	89%
Product portfolio plan	1.91	1.78	0.00	1.50	3.00	77%
Customer development plan	1.85	1.81	0.00	1.50	3.00	45%
Headcount development plan	1.58	1.93	0.00	1.00	3.00	82%

On average, all MCS are adopted in the first two years. While the majority of firms have implemented investment budgets, milestones, portfolio plans, and development plans for the ramp-up of their personnel, only 45% of the sample companies have implemented customer development plans. The following table indicates the adoption patterns for financial planning MCS in entrepreneurial firms.

Table 18 Adoption characteristics of financial planning MCS

	Mean	SD	Q1	Median	Q3	Adoption
Operating budget	1.57	1.81	0.00	1.00	2.00	100%
Cash-flow projections	1.67	1.98	0.00	1.00	3.00	98%
Sales projections	1.88	1.98	0.00	1.00	3.00	91%

Financial planning comprises operating budget, cash-flow, and sales projections. On average, all three MCS are adopted in the first two years. Reflecting on the median, a large percentage of the sample firms implement these systems within the first year of existence. Financial planning MCS are adopted by almost all technology-based new ventures considered in this study. The next table focuses on the adoption of MCS in the field of financial evaluation.

Table 19 Adoption characteristics of financial evaluation MCS

	Mean	SD	Q1	Median	Q3	Adoption
Product profitability	2.96	2.03	2.00	3.00	4.00	52%
Customer profitability	2.47	1.61	2.00	3.00	4.00	43%
Customer acquisition cost	2.92	1.98	2.00	3.00	4.00	30%
Variance analysis	2.05	1.87	1.00	1.50	3.00	95%
Opex approval process	2.23	2.12	0.00	2.00	4.00	87%
Capex approval process	2.18	2.13	0.00	2.00	3.00	89%

For this group of systems, there are reasonable differences regarding the adoption patterns of the various MCS. Here, not all systems are implemented by the majority of the firms. The analysis of customer acquisition cost, as well as customer and product profitability, indicate adoption rates between 30% and 52%. On the other hand, the adoption rates for variance analyses and approval processes for operational and capital expenditures exceed 85%. On average, all financial evaluation systems are implemented in the third year of existence. The next table provides information on the adoption of human resource planning MCS.

Table 20 Adoption characteristics of human resource planning MCS

	Mean	SD	Q1	Median	Q3	Adoption
Mission statement	2.29	2.14	0.00	1.50	4.00	77%
Core values	2.75	2.71	1.00	2.00	3.50	45%
Codes of conduct	2.81	3.06	0.00	2.00	5.00	36%
Organisational chart	1.76	2.23	0.00	1.00	3.00	95%
Written job descriptions	2.56	2.40	1.00	2.00	4.00	77%
Company-wide newsletter	2.29	2.26	1.00	1.00	4.00	39%
Orientation programme	2.83	2.79	0.00	2.50	5.50	27%

Again, there is a huge spread regarding the adoption characteristics of the different management control systems in this particular field. While organisational charts are developed by almost all sample firms within the second year, only very few companies adopt core values, codes of conduct, a company-wide newsletter, or an orientation programme for new employees. 77%of all ventures have developed a mission statement and written job descriptions. The following table focuses on human resource evaluation MCS.

Table 21 Adoption characteristics of human resource evaluation MCS

	Mean	SD	Q1	Median	Q3	Adoption
Performance objectives	3.33	2.25	2.00	3.00	5.00	68%
Evaluation reports	3.03	2.28	1.00	3.00	4.00	68%
Compensation to performance	2.92	2.09	1.00	3.00	4.00	82%
Individual incentive programmes	3.31	2.02	2.00	3.00	4.00	59%

Human resource evaluation MCS are adopted by c. 60% of the entrepreneurial ventures in the sample. 82% of all sample firms link the compensation to the individual performance. However, compared to the prior groups of MCS, these systems are implemented rather late. In fact, three out of four MCS are adopted in year four. The next table provides information regarding the emergence of product development systems.

Table 22 Adoption characteristics of product development MCS

	Mean	SD	Q1	Median	Q3	Adoption
Project milestones	2.25	2.29	0.00	2.00	4.00	82%
Budgets for development projects	3.07	2.25	1.00	3.00	5.00	66%
Actual progress to plan	3.22	2.39	1.00	3.00	5.00	61%
Project selection process	3.21	2.57	0.00	3.00	5.00	43%
Product portfolio roadmap	2.92	2.17	2.00	2.00	4.00	55%
Team composition guidelines	3.11	3.02	0.00	3.00	5.00	20%
Concept testing process	2.35	1.70	1.00	2.00	3.00	59%
Progress monitoring system	2.61	2.28	0.50	2.00	4.50	64%
Product quality monitoring system	3.09	2.14	1.00	3.00	5.00	50%

On average, new ventures in the sample implement MCS in the field of product development in years three and four. The adoption rate across the considered MCS varies between 20% for composition guidelines for project teams and 82% for the adoption of project milestones. While product development milestones and budgets, as well as related progress reports and product development monitoring systems, are implemented in more than 60% of all firms, project selection processes are adopted in less than 45% of the companies. The adoption patterns of marketing and sales MCS are indicated in the next table.

Table 23 Adoption characteristics of marketing and sales MCS

	Mean	SD	Q1	Median	Q3	Adoption
Sales force training	3.69	3.12	1.00	4.00	5.00	30%
Hiring and firing policies	2.00	2.65	0.00	1.00	5.00	7%
Sales targets for salespeople	2.86	2.14	1.00	2.00	4.50	64%
Compensation system	3.15	2.13	2.00	2.00	5.00	61%
Collaboration policies	2.00	1.93	0.50	2.00	2.50	18%
Market research projects	2.50	2.93	1.00	1.00	3.00	32%
Reports on open sales	2.79	2.28	1.00	2.00	3.00	55%
Sales process manual	3.88	2.80	1.50	3.50	6.50	36%
Customer feedback	3.50	2.61	2.00	2.00	6.00	27%
CRM system	2.86	2.44	1.00	2.00	4.00	32%
Effectiveness reports	2.96	2.39	1.00	2.50	5.00	55%

Marketing and sales MCS show a very inhomogeneous adoption pattern. The adoption rates vary between 7% and 64%. In general, hiring and firing as well as collaboration policies in this field are not very popular among the sample firms. On the other hand, compensation systems, sales targets, reports for sales force effectiveness, and reports on open sales process are implemented in at least 55% of all technology-based new ventures considered in the study. Similar to the adoption rates, the adoption times vary as well. In fact, MCS in the field of marketing and sales are implemented in years three and four. The next table shows the adoption patterns of partnership MCS.

Table 24 Adoption characteristics of partnership MCS

	Mean	SD	Q1	Median	Q3	Adoption
Development plan	3.38	2.72	2.00	3.00	5.00	30%
Policies for partnerships	2.50	1.22	2.00	2.50	3.00	32%
Partnership milestones	3.13	2.63	1.00	2.50	5.00	36%
Partner monitoring system	3.44	2.96	1.00	3.00	5.00	20%
Development reports	3.46	2.07	2.00	4.00	5.00	30%

The adoption rates for partnership MCS are all below 40%. Most of the systems in this field are not adopted by technology-based new ventures during the entire observation

period. The firms in the sample implement most of the systems after more than three years on average. Only policies for partnerships are adopted after two and a half years.

5.2 INTERPRETATIVE STATISTICS

5.2.1 Tests of Hypotheses

In the following sections, I seek empirical evidence for the various hypotheses derived in chapter 2 and summarised in chapter 3.2. For all hypotheses, I apply particular groups of management control systems as proxies for dynamic capabilities in entrepreneurial firms. First, I focus on the different drivers derived in chapter 2.3.4. In the subsequent section, I reflect on the influence of early MCS adoption on new venture performance. Third, I analyse differences in adoption time between groups of management control systems. The last two sections address the influence of CEO replacement and the internationalisation of sales operations on new venture performance.

5.2.1.1 Drivers for MCS Emergence

In chapter 2.3.4, I have identified various drivers that are generally expected to have a positive influence on entrepreneurial learning and thus on the development of dynamic capabilities in technology-based new ventures. To control for MCS as proxies for dynamic capabilities, I use a count model described in chapter 4.2.2. Therefore, I count the adopted number of systems in each year of observation. As independent variables, I apply CEO experience, organisational size, internationalisation of sales, organisational age, the replacement of the CEO, the introduction of a CFO, venture capital funding, and the biotechnology as well as the software industry. The first seven variables were derived in chapter 2.3.4. Biotechnology and software as additional explanatory variables are added to control industry-specific influences that have been partially hypothesised in chapter 2.4.4.2.

CEO experience is coded as the CEO's years of actual work experience before entering the company under research. Organisational size is measured as the natural logarithm of the number of employees at the end of each year of observation. I used the logarithm in

order to mitigate non-linearity in the sample. The age of the company is coded as the number of years of existence. The internationalisation of sales, the replacement of the CEO, the introduction of a CFO, and venture capital funding are coded as binary variables that initially have the value zero and become one in the year the event occurs. Biotechnology and software are binary variables as well. However, they are time-invariant.

In order to deepen understanding of this, I utilise two different regression models. The first model does not consider all of the explanatory variables previously described. Instead, it focuses on age, size, the timing of venture capital funding, the replacement of the CEO, and CEO experience as independent variables. The second model additionally considers the introduction of a CFO, the timing of sales internationalisation as well as the biotech and software industry.

For the regression models, I apply a count data specification. The models are random-effects models for cross-sectional time-series datasets. The default for the response vector is a Poisson distribution. In case of overdispersion, I apply a negative binomial distribution instead. The following two equations denote the regression models.

$$MCS = \alpha_0 + \alpha_1 age + \alpha_2 employees + \alpha_3 venture\ capital + \alpha_4 CEO\ replacement + \alpha_5 CEO\ experience + \varepsilon \quad (1.1)$$

$$MCS = \alpha_0 + \alpha_1 age + \alpha_2 employees + \alpha_3 venture\ capital + \alpha_4 CEO\ replacement + \alpha_5 CEO\ experience + \alpha_6 introduction\ of\ a\ CFO + \alpha_9 international\ sales + \alpha_7 biotech\ industry + \alpha_8 software\ industry + \varepsilon \quad (1.2)$$

The first analysis accounts for all management control systems considered in this study. The results are indicated in the following table.

Table 25 Drivers for the emergence of MCS

	Model 1		Model 2	
	Coefficient	Z statistic	Coefficient	Z statistic
Organisational age	0.1106	5.64 ***	0.0858	4.23 ***
Organisational size	0.2475	4.88 ***	0.1375	2.84 ***
Venture capital	0.5965	4.41 ***	0.3548	2.86 ***
Replacement of CEO	-0.0696	-0.62	0.0672	0.60
CEO experience	0.0145	2.19 **	0.0099	1.24
Introduction of a CFO			0.6506	6.84 ***
International sales			0.3167	3.49 ***
Biotech industry			0.2427	1.26
Software industry			0.2888	1.95 *
Overdispersion (α)	0.1564		0.2120	
Observations	245		245	
Companies	44		44	
Wald χ^2	264.26		423.38	

Model 1 and model 2 are cross-sectional time-series random-effects count data regression models. A Poisson distribution is adopted for the dependent variable and tested for overdispersion. If the null hypotheses of no overdispersion must be rejected, the model adopts a negative binomial distribution for the dependent variable.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

According to the first model, the positive association of age, size, venture capital funding, and CEO experience and the emergence of management control systems is significant. The influence of founder replacement however shows a negative and non-significant impact on MCS adoption in entrepreneurial firms. Regarding the second regression model, size, age, and venture capital funding are still highly significant. On the other hand, CEO experience dropped out. Instead, the introduction of a CFO and the internationalisation of sales show a highly significant and positive association with the emergence of management control systems in general. In addition, the software industry is positively and significantly associated with MCS adoption.

In chapter 2.4.4.2, I derived two hypotheses that address the influence of the biotechnology industry on product development as well as marketing and sales MCS. To control for these propositions, I apply the same regression models as for the previous statistical analysis. However, instead of all MCS, I limit the dependent variable to the

number of systems for the respective functional group. The first two models focus on product development MCS. The results are shown in the following table.

Table 26 Drivers for the emergence of product development MCS

	Model 1		Model 2	
	Coefficient	Z statistic	Coefficient	Z statistic
Organisational age	0.1699	5.29 ***	0.1276	3.78 ***
Organisational size	0.2585	3.33 ***	0.1835	2.34 **
Venture capital	0.0418	0.23	-0.0022	-0.01
Replacement of CEO	0.2417	1.29	0.1888	1.01
CEO experience	-0.0021	-0.15	-0.0011	-0.08
Introduction of a CFO			0.3934	2.96 ***
International sales			0.3662	2.61 ***
Biotech industry			0.4362	1.38
Software industry			0.3655	1.54
Overdispersion (α)	0.4152		0.3735	
Observations	245		245	
Companies	44		44	
Wald χ^2	154.48		170.64	

Model 1 and model 2 are cross-sectional time-series random-effects count data regression models. A Poisson distribution is adopted for the dependent variable and tested for overdispersion. If the null hypotheses of no overdispersion must be rejected, the model adopts a negative binomial distribution for the dependent variable.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The first regression model reports a highly significant and positive association between age, size, and the adoption of product development MCS. The second model additionally indicates the introduction of a CFO and the internationalisation of sales operations to the list of positive and significant explanatory variables. In both models, venture capital funding, the replacement of the CEO, and CEO experience are not significantly associated with the emergence of product development MCS. The second model does not indicate any significance for biotech and software. The next functional group of management control systems covers the field of marketing and sales. The results are indicated in the following table.

Table 27 Drivers for the emergence of marketing and sales MCS

	Model 1		Model 2	
	Coefficient	Z statistic	Coefficient	Z statistic
Organisational age	0.2134	4.80 ***	0.1158	2.69 ***
Organisational size	0.2950	2.50 **	0.1100	1.03
Venture capital	0.4634	1.54	0.3318	1.22
Replacement of CEO	-0.1935	-0.76	0.0417	0.17
CEO experience	-0.0012	-0.07	-0.0101	-0.54
Introduction of a CFO			1.1403	5.41 ***
International sales			0.9356	4.44 ***
Biotech industry			-1.5442	-3.03 ***
Software industry			0.3835	1.19
Overdispersion (α)	0.9251		0.7348	
Observations	245		244	
Companies	44		44	
Wald χ^2	124.17		162.57	

Model 1 and model 2 are cross-sectional time-series random-effects count data regression models. A Poisson distribution is adopted for the dependent variable and tested for overdispersion. If the null hypotheses of no overdispersion must be rejected, the model adopts a negative binomial distribution for the dependent variable.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The first model reports a positive and significant influence of organisational age and size on the adoption of marketing and sales MCS. Turning to the second model, size is not significant any more and is replaced by the introduction of a CFO, international sales expansion, and biotechnology industry. While CFO hire and international sales operations show a positive association with the emergence of MCS in this particular field, the biotechnology industry variable has a negative association. VC funding, CEO replacement, and CEO experience are not significant in both models.

5.2.1.2 Early MCS Emergence and New Venture Performance

In chapter 2.4.4.1, I have identified different groups of capabilities for which an early emergence is expected to have a positive influence on new venture performance and thus on employee growth. To test this effect, I cluster the sample companies into two groups: the first one with high intensity of MCS, the second one with low system intensity. The

median is used as a differentiator between the two groups. The intensity of MCS is defined as the standardised percentage of systems adopted in each category. The sampling is repeated for the first four years. To control for differences in new venture performance, I compare the mean growth rates for the first five years of existence for both groups.

To obtain the growth rates for the different firms, I measure the organisational size at the end of each year of observation and divide it by the number of corresponding years of existence at this point. The results for the first year show the employees at the end of the foundational year. Each firm could be founded any time between the beginning of January and the end of December and thus the growth rate is not based on a full twelve-month period. However, the results are much more compelling, compared to an approach that starts with the second year of existence. In order to control for the differences in terms of company growth, I apply a Welch parametric t test. In addition, I use the non-parametric Mann-Whitney two-sample statistic to validate the results.

The first group of systems I control for its association with new venture growth covers financial planning. Unlike the initial plan, I can only cluster the sample firms in the first two years of existence. According to the descriptive statistics presented in chapter 5.1, the three financial planning systems are usually adopted rather early. Thus, clustering after year two does not provide enough observations in the low system intensity group. The results of the corresponding statistical tests are given in the following table.

Table 28 Time-dependent financial planning MCS intensity and company performance

	Year 1		Year 2	
Intensity	High	Low	High	Low
1 year growth	11.29	5.65	10.95	5.22
T value	2.24 **		2.27 **	
Z value	2.81 ***		1.95 *	
2 year growth	9.82	9.24	11.55	7.59
T value	0.22		1.48	
Z value	1.09		1.46	
3 year growth	9.02	9.72	11.25	7.79
T value	-0.31		1.39	
Z value	1.09		1.92 *	
4 year growth	9.08	8.62	11.16	6.74
T value	0.21		1.98 *	
Z value	0.67		1.83 *	
5 year growth	12.84	6.49	11.38	5.76
T value	1.76		2.23 **	
Z value	2.02 **		2.19 **	
Companies	17	27	20	24

The table indicates the comparison of mean employee growth rates in the first five years. Mean growth for a certain year is calculated as the number of employees at the end of each period divided by the number of years. The last row reveals the number of companies in each group according to the initial differentiation.
T values report the results of a Welch two-sample t test with unequal variances. Z values report the results of a Mann-Whitney test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

For both years of categorisation, firms with high system intensity show much higher growth rates than new ventures, which have a low intensity of MCS. However, the categorisation in the first year indicates significant differences only for the one- and the five-year growth rate. In addition, the number of companies in each group is very different. While the high intensity group accounts for only 17 firms, the low intensity cluster comprises 27 companies.

Categorising the firms in year two reveals significant differences with respect to the one-, three-, four-, and five-year growth rate of the sample companies. Except for years two

and three, the parametric as well as the non-parametric test indicates significance with respect to company growth. In addition, the number of ventures in both groups is much closer. To make the results more transparent, the following figure denotes the development of firm size for companies with high and low system intensity. The clustering was conducted according to the intensity in year two.

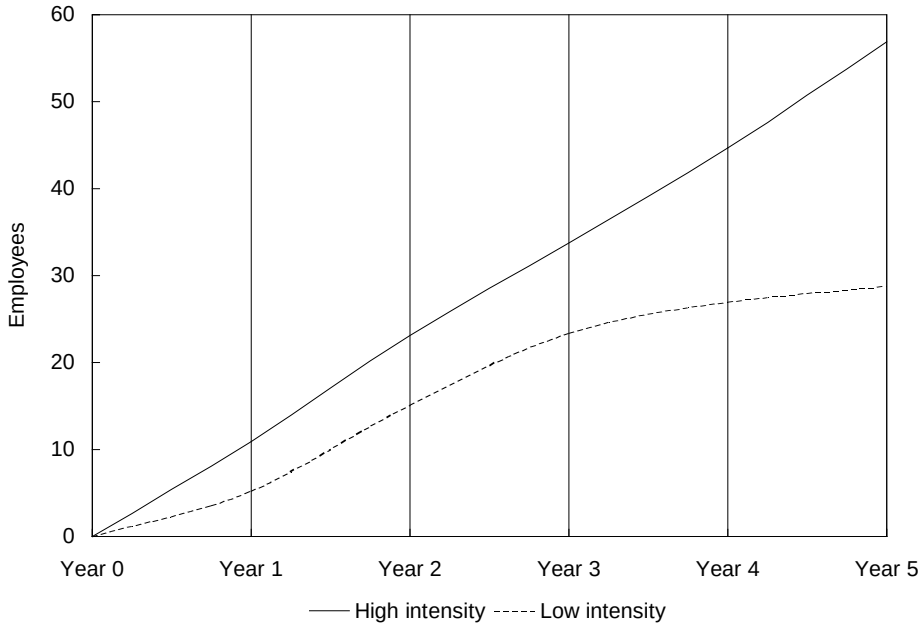

Figure 16 Financial planning MCS intensity in year two and company growth

According to the figure above, the high intensity group shows an almost straight line for employee development over time. The low intensity group grows much more slowly and the curve begins to flatten with year three. The next group of systems that I consider in my analysis focuses on financial evaluation. Again, I seek to identify an association between system intensity and company performance and thus an increase in employees. Unlike financial planning MCS, this category of management control systems allows for a categorisation in the first four years. The results are given in the following table.

Table 29 Time-dependent financial evaluation MCS intensity and company performance

	Year 1		Year 2		Year 3		Year 4	
Intensity	High	Low	High	Low	High	Low	High	Low
1 year growth	10.63	6.26	7.45	8.26	8.60	7.26	10.08	6.63
T value	1.63		-0.33		0.52		1.03	
Z value	1.71 *		0.21		0.39		0.91	
2 year growth	7.91	10.44	8.95	9.95	10.00	9.00	14.08	7.67
F value	-1.02		-0.37		0.37		1.87 *	
F value	-0.13		-0.08		0.69		1.67 *	
3 year growth	7.58	10.58	8.65	10.15	10.12	8.82	14.08	7.68
T value	-1.34		-0.60		0.52		2.16 **	
Z value	-0.38		0.34		1.66 *		2.47 **	
4 year growth	7.29	9.57	8.22	9.19	9.88	8.01	11.38	7.35
T value	-1.06		-0.44		0.85		1.90 *	
Z value	-0.96		-0.32		1.15		2.34 **	
5 year growth	6.20	8.16	8.47	7.31	9.43	6.94	11.14	6.44
T value	-0.63		0.42		0.86		1.61	
Z value	-1.28		-0.05		0.64		1.74 *	
Companies	17	27	20	24	20	24	13	25

The table indicates the comparison of mean employee growth rates in the first five years. Mean growth for a certain year is calculated as the number of employees at the end of each period divided by the number of years. The last row reveals the number of companies in each group according to the initial differentiation.
T values report the results of a Welch two-sample t test with unequal variances. Z values report the results of a Mann-Whitney test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

For financial evaluation MCS, the results are different compared to financial planning. Here, the categorisation in the first two years reveals a negative association between high system intensity and company growth. In fact, firms that heavily adopt financial evaluation systems in year one or year two show lower growth rates than firms which have a lower intensity at the end of the initial years of existence.

The picture changes when we focus on years three and four. Categorising the firms in year three, this indicates a better performance for firms that have high system intensity although the difference is only significant for the three-year growth rate. The

categorisation in year four further emphasises the dominance of firms with high system intensity. According to the applied statistical tests, the difference between the two groups is significant for the two-, three-, four-, and five-year growth. The following figure shows the differences in terms of employee development for high and low intensity firms clustered in year four.

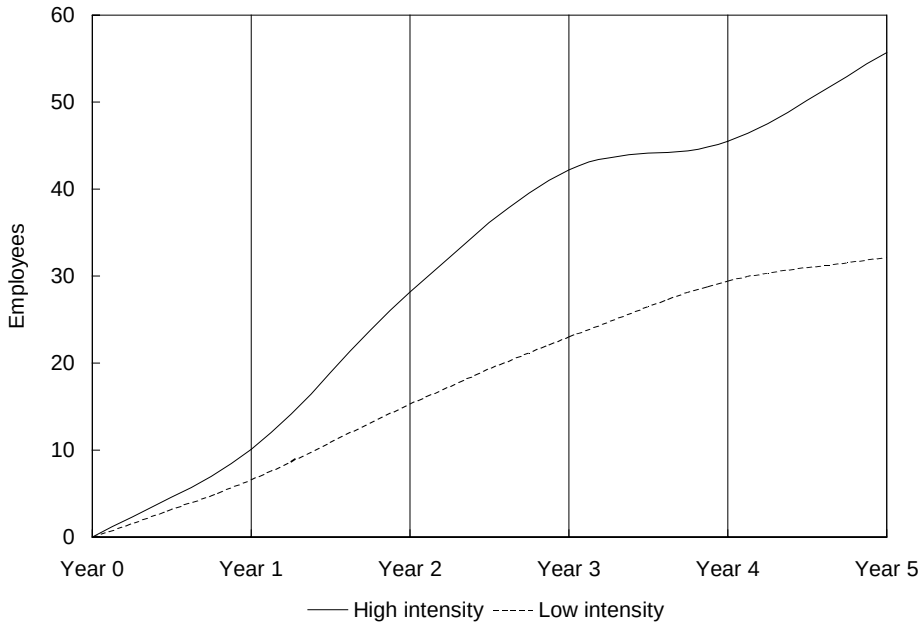

Figure 17 Financial evaluation MCS intensity in year four and company growth

The figure above supports the statistical tests. In fact, firms that show a higher intensity of MCS in year two have a steeper employee curve than new ventures with a lower adoption rate. The next group of systems that I address focuses on strategic planning. Again, the different systems in this group are usually adopted rather early. The results of the corresponding statistical tests are given in the following table.

Table 30 Time-dependent strategic planning MCS intensity and company performance

	Year 1		Year 2		Year 3		Year 4	
Intensity	High	Low	High	Low	High	Low	High	Low
1 year growth	11.05	4.86	10.00	5.86	9.60	5.50	8.27	7.55
T value	2.58 **		1.65		1.86 *		0.27	
Z value	2.69 ***		1.05		0.89		0.86	
2 year growth	10.55	8.40	9.52	9.43	8.68	10.65	9.63	10.24
F value	0.79		0.03		-0.67		-0.20	
F value	1.29		0.30		-0.49		0.68	
3 year growth	9.57	9.30	9.44	9.43	8.92	10.20	10.71	9.48
T value	0.11		0.01		-0.44		0.44	
Z value	1.35		1.06		0.41		1.33	
4 year growth	9.22	8.39	9.69	8.07	8.88	8.65	9.20	8.44
T value	0.38		0.74		0.10		0.35	
Z value	1.14		1.40		0.71		1.07	
5 year growth	9.80	6.40	10.13	6.63	8.76	7.05	8.36	7.36
T value	1.41		1.25		0.68		0.42	
Z value	1.48		1.20		0.29		0.43	
Companies	22	22	22	22	18	26	16	22

The table indicates the comparison of mean employee growth rates in the first five years. Mean growth for a certain year is calculated as the number of employees at the end of each period divided by the number of years. The last row reveals the number of companies in each group according to the initial differentiation.
T values report the results of a Welch two-sample t test with unequal variances. Z values report the results of a Mann-Whitney test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Clustering the companies in the first two years indicates a positive association between MCS emergence and new venture performance. However, the differences are mostly not significant. When we group the companies in year three and year four, the growth rates are almost the same for firms with high and low system intensity. Again, I use a figure to emphasise the association between early MCS emergence and company growth. Therefore, I show employee development for firms categorised in year two.

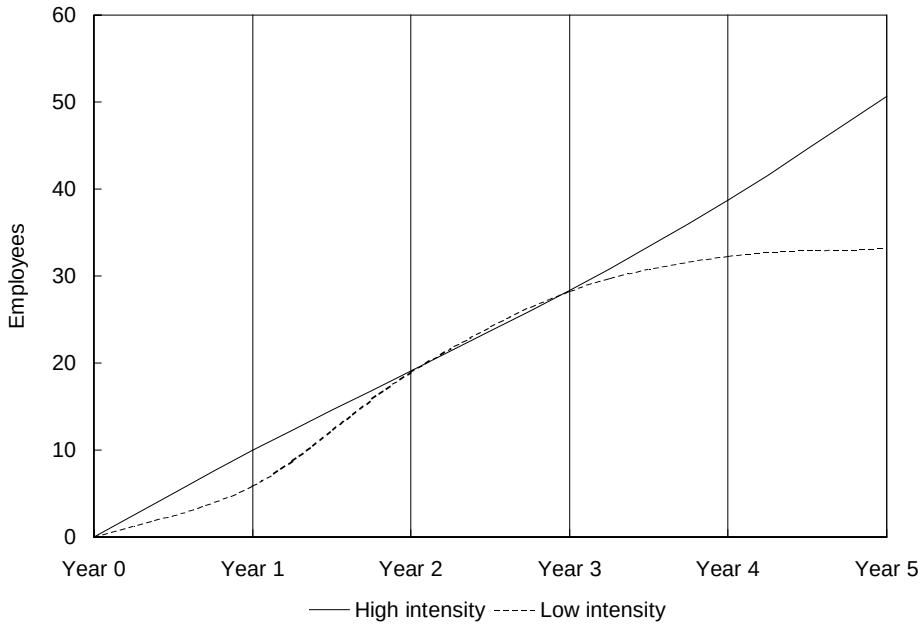

Figure 18 Strategic planning MCS intensity in year two and company growth

The figure above offers results that are similar to the statistical tests. Although there is a difference in terms of company growth for the first five years, the effect for strategic planning systems is not as strong as for financial planning and financial evaluation MCS. In fact, the positive association in the figure is mainly concentrated on years four and five.

After MCS in the area of finance and strategy, I turn to management control systems in the field of human resources. I start with human resource planning before I turn to human resource evaluation. The results of the corresponding statistical tests are given in the following table.

Table 31 Time-dependent human resource planning MCS intensity and company performance

	Year 2		Year 3		Year 4	
Intensity	High	Low	High	Low	High	Low
1 year growth	13.87	4.68	12.43	5.69	10.56	5.96	12.73	4.50
T value	3.10 ***		2.24 **		1.73 *		2.86 **	
Z value	3.01 ***		2.96 ***		2.33 **		3.24 ***	
2 year growth	9.27	9.59	12.82	7.80	13.00	6.83	14.50	6.76
T value	-0.12		1.62		2.31 **		2.57 **	
Z value	0.34		1.86 *		2.74 ***		3.02 ***	
3 year growth	9.02	9.67	11.52	8.39	13.94	6.06	15.09	6.35
T value	-0.28		1.15		3.22 ***		3.12 ***	
Z value	0.36		1.71 *		3.23 ***		3.00 ***	
4 year growth	9.39	8.51	9.66	8.39	12.00	6.57	12.72	6.08
T value	0.35		0.59		2.36 **		2.92 ***	
Z value	0.33		1.07		2.45 **		2.87 ***	
5 year growth	7.90	7.65	11.80	6.96	11.71	6.23	11.60	6.27
T value	0.08		1.34		2.09 *		1.99 *	
Z value	0.00		1.57		2.17 **		2.00 **	
Companies	15	29	14	30	18	26	15	23

The table indicates the comparison of mean employee growth rates in the first five years. Mean growth for a certain year is calculated as the number of employees at the end of each period divided by the number of years. The last row reveals the number of companies in each group according to the initial differentiation.
T values report the results of a Welch two-sample t test with unequal variances. Z values report the results of a Mann-Whitney test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Reflecting on the table above, categorising firms according to system intensity in the field of human resource planning in the first year does not reveal any significant performance implications except for first year growth. The annual mean growth based on firm size in years two and three is even lower for high intensity companies. However, the picture changes with the timing of categorisation. While the grouping in year two reveals a better performance for high intensity companies with a few significances, this effect becomes stronger for the grouping in year three and four. The performance differences between the two groups are highly significant for almost all growth rates applied in the analysis. The

following figure shows the employee numbers for high and low intensity companies clustered in year three.

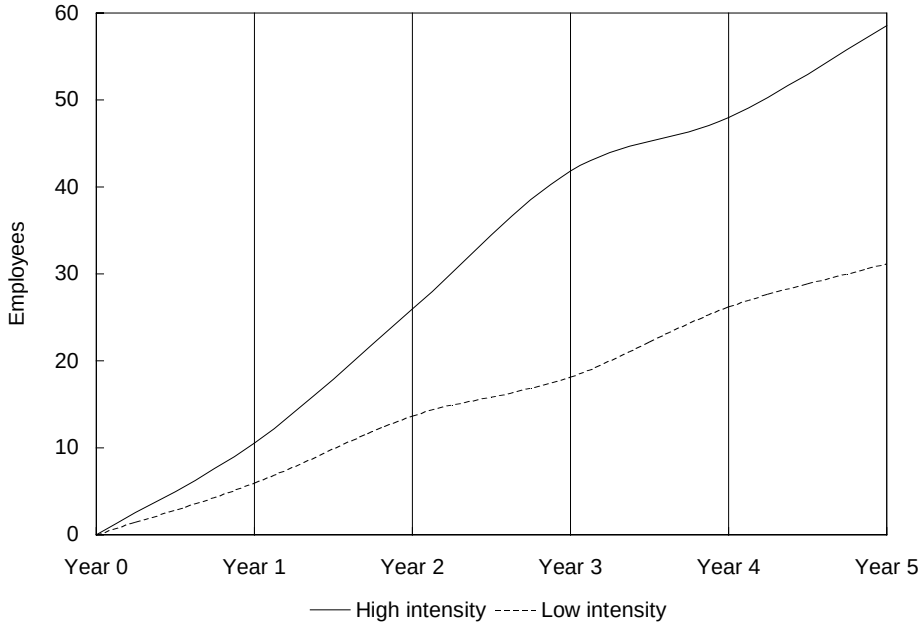

Figure 19 Human resource planning MCS intensity in year three and company growth

The graphs of the two groups of companies in the figure above show substantial differences. While the low intensity group indicates a constant and low growth, firms with high system intensity in year three account for a steep employee curve that flattens in year four to become steeper again in the subsequent year. The next group of human resource MCS covers the field of personnel evaluation. The following table indicates the corresponding results from the statistical tests.

Table 32 Time-dependent human resource evaluation MCS intensity and company performance

	Year 1		Year 2		Year 3		Year 4	
Intensity	High	Low	High	Low	High	Low	High	Low
1 year growth	11.33	7.32	10.62	6.70	10.72	5.84	9.11	6.50
T value	0.86		1.13		1.79 *		0.96	
Z value	0.62		0.74		1.52		0.87	
2 year growth	6.58	9.96	11.46	8.59	11.64	7.85	12.13	7.59
F value	-1.20		0.87		1.36		1.51	
F value	-0.83		0.64		1.57		1.79	
3 year growth	5.39	10.11	10.59	8.92	10.57	8.58	12.67	7.00
T value	-1.84		0.54		0.77		2.08 **	
Z value	-1.55		0.29		1.04		2.01 **	
4 year growth	6.56	9.04	9.06	8.68	8.90	8.70	10.79	6.64
T value	-0.51		0.13		0.09		1.96 *	
Z value	-1.42		-0.25		0.21		1.54	
5 year growth	3.00	8.32	6.20	8.07	5.83	8.27	9.51	6.75
T value	-3.13 ***		-0.76		-1.11		1.06	
Z value	-1.65 *		-0.52		-0.76		0.92	
Companies	6	38	13	31	18	26	19	19

The table indicates the comparison of mean employee growth rates in the first five years. Mean growth for a certain year is calculated as the number of employees at the end of each period divided by the number of years. The last row reveals the number of companies in each group according to the initial differentiation.
T values report the results of a Welch two-sample t test with unequal variances. Z values report the results of a Mann-Whitney test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The results show that high system intensity in the field of human resource evaluation in the first three years is not associated with extraordinary growth rates. On the contrary, several performance measures report a negative association between the two groups of companies clustered in years one, two, and three. For the five-year growth rate for firms categorised in year one, this result is highly significant. Focusing on the grouping in year four, the picture changes substantially. The association between system intensity and company performance is positive throughout the analysis. For the three- and four-year growth rates, the results are also significant. The next figure shows the corresponding graphs.

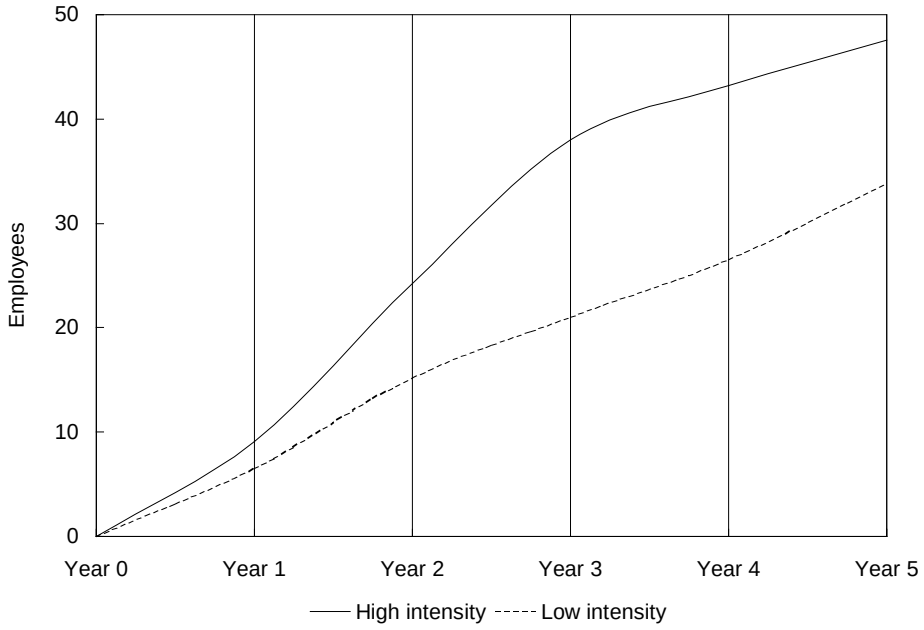

Figure 20 Human resource evaluation MCS intensity in year four and company growth

The graph emphasises the results of the parametric and non-parametric tests. From the first year, the difference between the two groups increases until the end of year three. From that point on, the gap almost remains constant.

5.2.1.3 Sequencing of MCS Emergence

In this section, I reflect on different hypotheses derived in chapter 2.4.4.1. All of them address the timing of different groups of dynamic capabilities in technology-based new ventures. According to the initial propositions, I assume that the adoption of product development, marketing and sales, as well as partnership management capabilities, follows the emergence of specific skills in the field of finance, strategy, and human resources.

To test these initial hypotheses, the time of emergence for each group of MCS has to be determined first. Since every capability is a construct of several management control systems which incorporate different adoption times, I have to determine a way to calculate a representative time for each capability. Using the first or last system adopted in each group seems not to be a reasonable operationalisation. Adopting one system from

a certain group does not indicate the emergence of the specific capability. On the other hand, most firms do not adopt all MCS of one group, although they developed this particular skill to a reasonable degree. In order to mitigate this problem, I consider a group of MCS as adopted if the number of systems exceeds half the median of the total number of MCS in this group. Then I count the years until the occurrence of this event.

To test whether a certain group of systems emerged before another one, I apply two different approaches. First, I compare the mean adoption times for the two groups, regardless of the number of firms adopting the particular system. Therefore, I use an unpaired t test. In addition, I compare the time of emergence of firms that adopted both systems under study. To test the time difference for significance, I apply a paired Welch parametric t test as well as a Wilcoxon matched-pairs signed-rank test. The latter is a non-parametric test. The following table reports the results for product development MCS.

Table 33 Timing of product development MCS emergence

	Time to adoption (unpaired analysis)				
	Test variable		Product development		
	Time	N	Time	N	T value
Financial planning	1.66	44	2.53	38	2.03 **
Financial evaluation	2.10	41			0.99
Strategic planning	1.72	43			1.92 *
HR planning	2.92	37			-0.78
HR evaluation	2.89	36			-0.77

	Time to adoption (paired analysis)				
	Test variable	Product development	N	T value	Z value
Financial planning	1.68	2.53	38	2.59 **	3.12 ***
Financial evaluation	2.06	2.57	35	1.77 *	1.88 *
Strategic planning	1.65	2.57	37	3.08 ***	3.53 ***
HR planning	2.91	2.63	32	-0.76	-0.51
HR evaluation	2.81	2.72	17	-0.26	-0.71

Table indicates the comparison of mean adoption times of different groups of MCS with one reference group. The first part of the table comprises an unpaired analysis reporting the different adoption times and the results of a corresponding unpaired t test. The second part of the table comprises the corresponding paired analysis indicating the different adoption times and the results of a paired t test with unequal variances as well as a Wilcoxon signed-rank test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The unpaired test reveals that the adoption time of financial planning and strategic planning MCS is significantly smaller than for product development MCS. The time until adoption for financial evaluation systems is shorter as well; however, the results do not indicate any significance. The parametric and non-parametric paired tests support the outcome. In addition, they indicate a significance for financial evaluation MCS.

While these results are in line with the initial hypothesis, the picture looks different when we turn to human resource planning and evaluation MCS. For both groups, the analysis reports a longer adoption time than for product development systems. However, the results are not significant. The next group that I consider in terms of adoption time is marketing and sales. Again, I apply the same statistical tests. The following table comprises the corresponding results.

Table 34 Timing of marketing and sales MCS emergence

	Time to adoption (unpaired analysis)				
	Test variable		Marketing and sales		
	Time	N	Time	N	T value
Financial planning	1.66	44	3.38	26	3.21 ***
Financial evaluation	2.10	41			2.37 **
Strategic planning	1.72	43			3.13 ***
HR planning	2.92	37			0.78
HR evaluation	2.89	36			0.86

	Time to adoption (paired analysis)				
	Test variable	Marketing and sales	N	T value	Z value
Financial planning	2.08	3.38	26	4.18 ***	3.28 ***
Financial evaluation	2.28	3.36	25	2.55 **	2.31 **
Strategic planning	1.85	3.38	26	4.89 ***	3.64 ***
HR planning	3.41	3.50	22	0.29	0.15
HR evaluation	2.84	3.36	25	1.19	0.77

Table indicates the comparison of mean adoption times of different groups of MCS with one reference group. The first part of the table comprises an unpaired analysis reporting the different adoption times and the results of a corresponding unpaired t test. The second part of the table comprises the corresponding paired analysis indicating the different adoption times and the results of a paired t test with unequal variances as well as a Wilcoxon signed-rank test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The results for marketing and sales MCS are different from product development MCS. Here, the unpaired as well as the paired analysis indicates a significantly lower time up to adoption for financial and strategic planning as well as for financial evaluation. In addition, the unpaired analysis reveals that both groups of human resource MCS emerge earlier than marketing and sales MCS. However, the results are not significant.

On the other hand, the paired analysis reports almost the same time for the adoption of human resource planning MCS and marketing and sales MCS. Human resource evaluation MCS instead emerge prior to systems in the area of marketing and sales. Again, the results are not significant. The last group of systems I compare to MCS in the area of finance, strategy, and human resources focuses on the capability of the entrepreneurial firm to manage partnerships. The results of the unpaired and paired mean adoption times and the corresponding statistical tests are given in the next table.

Table 35 Timing of partnership MCS emergence

	Time to adoption (unpaired analysis)				
	Test variable		Partnership		
	Time	N	Time	N	T value
Financial planning	1.66	44	3.05	20	2.25 **
Financial evaluation	2.10	41			1.53
Strategic planning	1.72	43			2.17 **
HR planning	2.92	37			0.85
HR evaluation	2.89	36			0.81

	Time to adoption (paired analysis)				
	Test variable	Partnership	N	T value	Z value
Financial planning	1.85	3.05	20	3.40 ***	2.83 ***
Financial evaluation	2.17	3.11	18	2.52 **	2.26 **
Strategic planning	1.85	3.05	20	3.09 ***	3.02 ***
HR planning	3.00	3.16	19	0.31	0.47
HR evaluation	2.65	3.17	17	0.92	0.43

Table indicates the comparison of mean adoption times of different groups of MCS with one reference group. The first part of the table comprises an unpaired analysis reporting the different adoption times and the results of a corresponding unpaired t test. The second part of the table comprises the corresponding paired analysis indicating the different adoption times and the results of a paired t test with unequal variances as well as a Wilcoxon signed-rank test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

For partnership MCS, the mean adoption time in the paired, as well as in the unpaired analysis, is longer than the time to adoption for financial planning and evaluation, strategic planning, and human resource planning and evaluation systems. However, not all the reported differences are significant. The unpaired statistics indicate significances for financial and strategic planning MCS. The paired tests reveal significant differences for the time to adoption for financial planning and evaluation as well as strategic planning MCS. The results for human resource planning and evaluation are again not significant.

5.2.1.4 CEO Replacement and New Venture Performance

We have already derived from theory that the replacement of the CEO is an important event in the history of a technology-based new venture and is seen as a substantial driver for second order learning in entrepreneurial firms. However, CEO replacement has not shown significant influence on the emergence of management control systems in general.

In chapter 2.4.4.3, I have reflected on the replacement of the CEO as a substantial challenge within the organisation. To understand this event, I compare the employee growth of companies that replaced the CEO with those that kept their general manager during the observation period. In the following figure, I show the employee development of both groups for the first four years of existence.

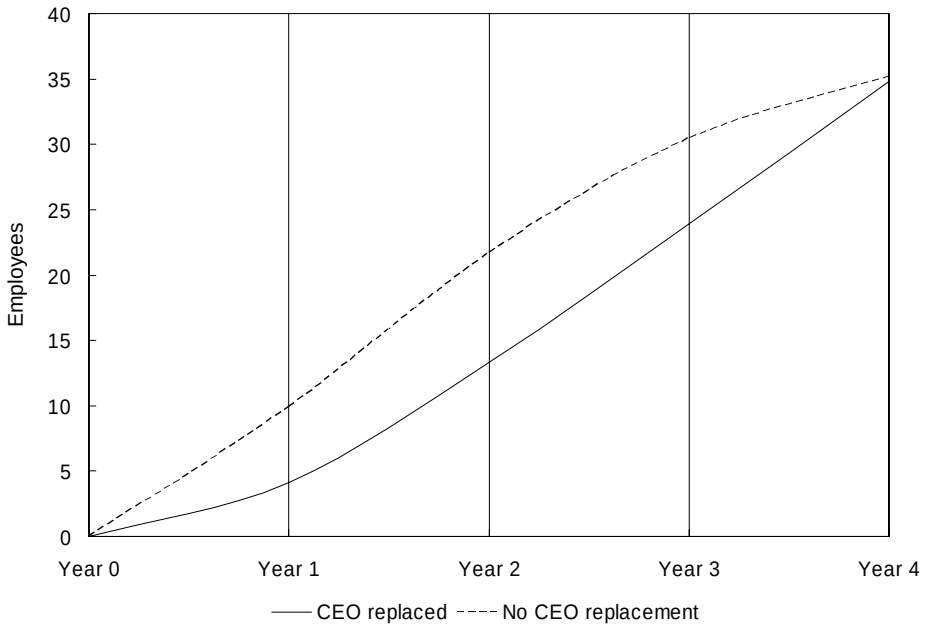

Figure 21 Comparison of firms that replaced the CEO with firms that did not

Although firms which replaced the CEO lag slightly behind firms that did not follow this practice, the graph does not reveal a substantial difference between the two groups regarding growth in the first four years of existence. In chapter 2.4.4.3., I have hypothesised that the years prior to and after the succession of the CEO do not show a significant positive association with employee growth. On the contrary, the association in the years surrounding this crisis should be positive and significant. To test this hypothesis I chose an event study design. I define employee growth as a function of the increase of the demand, the economic situation, the quality of the investors, the increase in financial reserves, the three years prior to the replacement of the CEO, the three years after the replacement of the CEO and the year of actual CEO succession.

The increase of employees is usually associated with a demand increase of the firm's products or services on the market. The economic situation is reported to have a major influence on the performance of start-up firms. Especially after the burst of the bubble many small start-up firms vanished from one day to the other due to the dramatic change of the economic situation. Financial reserves enable organisations to increase the number of employees. The quality of the investor is assumed to have a positive association with

the growth of the organisation as well. We have already learned that VCs may offer services to their portfolio companies that go beyond the provision of pure funds. However, not all investors actually provide these benefits to their investments. Thus, better venture capital firms should provide services that are more valuable to their portfolio companies. There is another important aspect that determines the quality of the VC firm. Investors with a and strong and long-standing track record have obviously been able to predict the success of start-ups better than VCs with a weaker performance history.

The quality differences in the venture capital industry are especially high in Germany. This may be due to the rapid rise and fall of the country's own venture capital industry. In the early 1990s, Germany adopted a position far behind France and UK in terms of financial resources for entrepreneurial firms. Only a few professional equity investors existed in these days. During the internet hype, the country caught up and in 1999, the amount of external funding for start-ups in Germany exceeded both France and UK by the factor of two (Lehrer 2000). Nevertheless, most German venture capital firms still did not have much experience in technology investment. Consequently, I expect some VCs to have much higher quality than most of the players in the market and I assume this quality to have a substantial impact on growth.

The economic situation is a time-varying binary variable that adopts one for the years before the "burst of the bubble" and zero for the years after. Revenue growth as an explanatory variable is used as a proxy for a change in market demand. The financial reserves of the organisation are modelled with the amount of funding the new venture receives from its investors in the respective year. For the quality of the investor, a time-invariant binary variable is applied that adopts the value of one for high-quality investors and zero for other VCs. The corresponding information is obtained from a survey among limited partners, conducted and published by AltAssets Research (2002). In addition, I add two Munich-based venture capital firms, which were recently able to raise new funds (Red Herring 2005; Schuermann 2005). Finally, the years before and after the replacement of the CEO are coded with dummy variables that assume the value of one if the event occurs. Otherwise, the binary variables are zero.

In order to define an appropriate model for the regression I control for the applicability of a random-effects model. The Hausman test does not reject a random-effects specification. In addition, I test the panel data for heteroskedasticity and autocorrelation. The data shows heteroskedasticity across panels but no autocorrelation within panels. To account for the characteristics I apply a cross-sectional time-series linear model using feasible generalized least squares (FGLS). The model has the following specification.

$$\begin{aligned} \textit{Employee growth} = {} & \alpha_0 + \alpha_1 \textit{revenue growth} + \alpha_1 \textit{economic situation} + \\ & \alpha_2 \textit{quality of the investor} + \alpha_3 \textit{amount of funding} + \\ & \alpha_4 \textit{CEO replacement}^{t-3} + \alpha_5 \textit{CEO replacement}^{t-2} + \\ & \alpha_6 \textit{CEO replacement}^{t-1} + \alpha_7 \textit{CEO replacement}^{t} + \\ & \alpha_8 \textit{CEO replacement}^{t+1} + \alpha_9 \textit{CEO replacement}^{t+2} + \\ & \alpha_{10} \textit{CEO replacement}^{t+3} + \varepsilon \end{aligned} \tag{1.3}$$

Table 36 Employee growth and the replacement of the CEO

	Employee growth	
	Coefficient	Z statistic
Revenue growth	0.0029	4.94 ***
Economic situation	7.0087	3.50 ***
Quality of the investor	1.5908	0.93
Amount of funding	0.0005	3.57 ***
3 years before CEO replacement	0.9622	0.29
2 years before CEO replacement	5.4383	1.83 *
1 year before CEO replacement	3.6357	1.25
Year of CEO replacement	4.4833	1.55
1 year after CEO replacement	0.4181	0.14
2 years after CEO replacement	6.0325	1.67 *
3 years after CEO replacement	6.9010	1.73 *
Observations	97	
Companies	15	
Wald χ^2	53.80	

Table reports the results of a cross-sectional time-series random-effects linear regression model using feasible generalised least squares (FGLS) and accounting for heteroskedastic panels.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The event study indicates a positive and highly significant association between employee growth and the increase in revenues, the economic situation, and the amount of funding in the actual year. The year before the replacement of the CEO, the actual year of succession and the year after do not have a positive and significant association with employee growth. However, the annual period two years before the replacement, as well as the periods two and three years after the CEO succession, are positively and significantly associated with the increase in employees. Although the significances are only reported at the 10% level, an observable effect cannot be disregarded. To denote the effect of CEO replacement I provide the following figure. It indicates the employee development around the succession. Therefore, I consider two periods before and after the actual replacement. The year of succession is shaded.

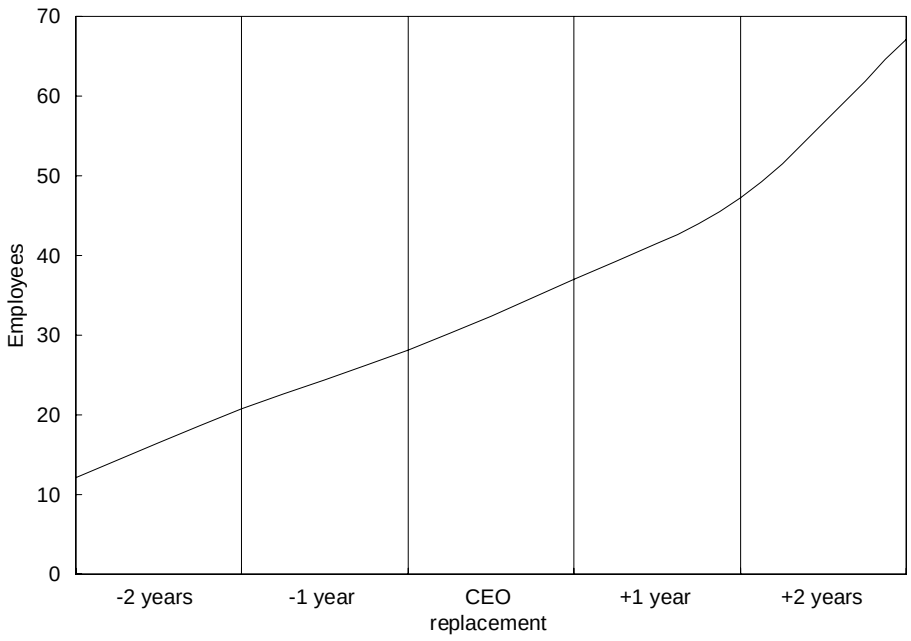

Figure 22 Company size around the replacement of the CEO

The figure shows that the growth in employees is slightly steeper two years before and two years after the replacement of the CEO. However, the effect on growth is much stronger after the CEO has been replaced. In the year of succession, as well as in the period before and after the event, no significant increase in employees can be noticed.

5.2.1.5 International Sales and New Venture Performance

We have already learned that the internationalisation of sales is an important event in the growth process of technology-based new ventures. The positive and significant association with the emergence of different groups of MCS has been revealed in chapter 5.2.1.1. One category of systems that is substantially influenced by the internationalisation of revenues is marketing and sales. In order to gain further understanding of the relationship between this event and the group of marketing and sales MCS, I conduct an event study that controls for the increase in marketing and sales systems in the years prior and subsequent to the first international sales. The explanatory variables are equal to the set used in chapter 5.2.1.1, except the addition of the years around the event of internationalisation.

The model used for this regression is a cross-sectional time-series random-effects count model with the dependent variable following a negative binomial distribution in order to account for overdispersion in the response vector. The control period considers three years before and after the first international sales. The years are coded as dummy variables that assume the value of one if the corresponding event occurs. Otherwise, the binary variables are zero.

$$\begin{aligned} Sales\ MCS = {} & \alpha_0 + \alpha_1 age + \alpha_2 employees + \\ & \alpha_3 venture\ capital + \alpha_4 CEO\ replacement + \\ & \alpha_5 CEO\ experience + \alpha_6 introduction\ of\ a\ CFO + \\ & \alpha_7 biotech\ industry + \alpha_8 software\ industry + \\ & \alpha_9 international\ sales^{t-3} + \alpha_{10} international\ sales^{t-2} + \\ & \alpha_{11} international\ sales^{t-1} \alpha_{12} international\ sales^{t} + \\ & \alpha_{13} international\ sales^{t+1} \alpha_{14} international\ sales^{t+2} + \\ & \alpha_{15} international\ sales^{t+3} + \varepsilon \end{aligned} \tag{1.4}$$

The next table indicates the results of the event study. In fact, the third year prior to the internationalisation of sales shows a negative and significant association with the number of marketing and sales MCS. The first and second years before internationalisation indicate a marginal negative association.

On the other hand, the first, second, and third annual periods after the first international revenues are positively and significantly associated with the number of management control systems in the field of marketing and sales. In addition, company age and the introduction of a CFO are reported to have had a positive and highly significant relationship with marketing and sales MCS. As expected, the biotechnology industry segment is negatively associated with the emergence of MCS and the influence is highly significant.

Table 37 Timing of international sales and the emergence of marketing and sales MCS

	Marketing and sales MCS	
	Coefficient	Z statistic
Organisational age	0.1722	3.24 ***
Organisational size	0.0842	0.72
Venture capital	0.2704	0.94
Replacement of CEO	0.0823	0.33
CEO experience	-0.0121	-0.62
Introduction of a CFO	1.1483	5.28 ***
Biotech industry	-1.8939	-3.65 ***
Software industry	0.4993	1.47
3 years before international sales	-2.0228	-1.94 *
2 years before international sales	-0.6965	-1.30
1 year before international sales	-0.0119	-0.04
Year of international sales	0.3508	1.40
1 year after international sales	0.4329	1.94 *
2 years after international sales	0.4628	2.32 **
3 years after international sales	0.3991	2.12 **
Overdispersion (α)	0.8535	
Observations	245	
Companies	44	
Wald χ^2	155.56	

Table reports the results cross-sectional time-series random-effects count data regression model applying a negative binomial distribution for the dependent variable.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The generation of international revenues is not solely expected to drive the emergence of marketing and sales MCS, but is also assumed to have a positive impact on sales growth. In order to verify this hypothesis, I formulate another regression model. Similar to the event study in chapter 5.2.1.4, I apply the economic situation, the quality of the investor, the annual amount of funding and dummy variables for the three years before and after the internationalisation of sales, as well as for the year of internationalisation as explanatory variables.

In order to define an appropriate model for the regression I control for the applicability of a random-effects model. The Hausman test does not reject a random-effects specification. In addition, I test the panel data for heteroskedasticity and autocorrelation. The data shows heteroskedasticity across panels but no autocorrelation within panels. To account for the characteristics I apply a cross-sectional time-series linear regression model using feasible generalized least squares (FGLS). The following equation denotes the regression model.

$$\begin{aligned} Sales\ growth = {} & \alpha_0 + \alpha_1 economic\ situation + \alpha_1 quality\ of\ the\ investor + \\ & \alpha_2 amount\ of\ \ funding + \alpha_3 international\ sales^{t-3} + \\ & \alpha_4 international\ sales^{t-2} + \alpha_5 international\ sales^{t-1} + \\ & \alpha_6 international\ sales^{t} + \alpha_7 international\ sales^{t+1} + \\ & \alpha_8 international\ sales^{t+2} + \alpha_9 international\ sales^{t+3} + \varepsilon \end{aligned} \qquad (1.5)$$

The results of the regression are given in the following table. In fact, the internationalisation of sales has an important influence on the growth of revenue streams for technology-based new ventures.

Table 38 Revenue growth and the timing of international sales

	Revenue growth	
	Coefficient	Z statistic
Economic situation	-170.2306	-1.40
Quality of the investor	160.7764	1.45
Amount of funding	-0.0058	-0.76
3 years before international sales	-91.1286	-0.44
2 years before international sales	169.2217	0.91
1 year before international sales	80.9280	0.50
Year of international sales	438.5383	2.74 ***
1 year after international sales	545.3080	3.09 ***
2 years after international sales	524.8880	2.45 **
3 years after international sales	507.9927	2.12 **
Observations	234	
Companies	41	
Wald χ^2	33.48	

Table reports the results of a cross-sectional time-series random-effects linear regression model using feasible generalised least squares (FGLS) and accounting for heteroskedastic panels.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

While the years before the internationalisation of sales are not significantly associated with revenue growth, the year of going international, and the years after, shows a positive and highly significant association with the annual increase in revenues. To elaborate further on this topic, I consider the revenue development of new ventures before and after the internationalisation of sales. The following figure shows the results.

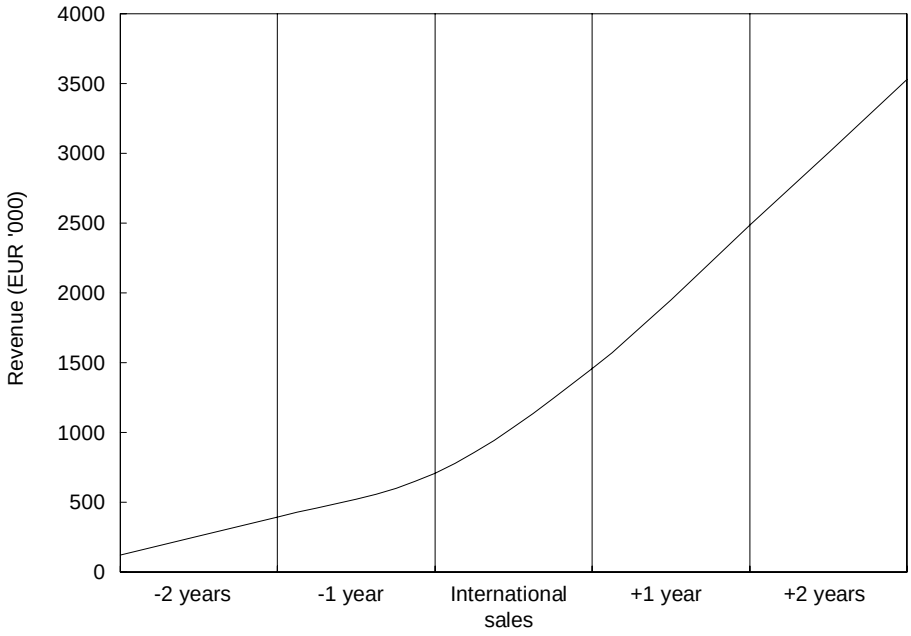

Figure 23 Revenue around the internationalisation of sales

The impact of international sales on the revenues of technology-based new ventures becomes highly transparent in the figure above. While the turnover curve is rather flat in the years prior to the internationalisation of sales, the curve indicates a steep and constant increase of revenues at the time the new venture starts to sell internationally.

5.2.2 Additional Findings

In addition to the various hypotheses, I have formulated different exploratory questions in chapter 3.3 of this dissertation. In the following sections, I conduct several statistical analyses to gain insights into these specific aspects of organisational learning and the emergence of dynamic capabilities in technology-based new ventures. Therefore, I discuss the drivers influencing the adoption of the different groups of MCS. In addition, I focus on the endogeneity of company size and MCS emergence. Finally, I focus on different paths of system adoption in entrepreneurial firms and the corresponding impact on new venture performance.

In addition to the explorative questions, I further elaborate on the relationship between early MCS adoption and new venture performance. In chapter 5.2.1.2, I have tested different types of MCS in this direction. However, other systems are not expected to have a positive impact on growth if adopted early. Thus, I dedicate the last section of this chapter to these groups of management control systems.

5.2.2.1 Drivers for the Emergence of Different Groups of MCS

In chapter 5.2.1.1, I have analysed different drivers for the adoption of management control systems in general as well as for product development and marketing and sales. The drivers have been identified in chapter 2.3.4 as positive influences on double-loop learning in entrepreneurial firms. In the following, I carry out the same analysis for the remaining MCS which have not been considered in chapter 5.2.1.1, i.e. systems in the area of financial planning and evaluation, strategic planning, human resource planning and evaluation as well as partnerships and alliances. The two regression models applied for each MCS are equal to the models used for the statistical analysis carried out in chapter 5.2.1.1. I start with the emergence of financial planning systems. The results of the regression models are given in the following table.

Table 39 Drivers for the emergence of financial planning MCS

	Model 1		Model 2	
	Coefficient	Z statistic	Coefficient	Z statistic
Organisational age	0.0367	1.49	0.0046	0.16
Organisational size	0.1831	3.05 ***	0.1265	1.93 *
Venture capital	0.7377	4.19 ***	0.7072	3.87 ***
Replacement of CEO	0.0102	0.08	0.1319	0.90
CEO experience	0.0121	1.58	0.0114	1.35
Introduction of a CFO			0.3578	2.73 ***
International sales			0.1775	1.42
Biotech industry			-0.1451	-0.75
Software industry			0.0832	0.59
Overdispersion (α)	0[(a)]		0[(a)]	
Observations	245		245	
Companies	44		45	
Wald χ^2	70.46		76.54	

Model 1 and model 2 are cross-sectional time-series random-effects count data regression models. A Poisson distribution is adopted for the dependent variable and tested for overdispersion. If the null hypotheses of no overdispersion must be rejected the model adopts a negative binomial distribution for the dependent variable.
(a) The null hypothesis of no overdispersion is not rejected and α is constrained to zero. The table reports the results of a Poisson regression model.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The first model only indicates size and venture capital funding as positively associated with the emergence of financial planning systems. In the second model, size loses some of its explanatory power. Instead, the introduction of a CFO turns out to be highly significant. In both models, organisational age, CEO replacement, and CEO experience have no significant association with the adoption of financial planning MCS in technology-based new ventures. In the second model, the same is true for the internationalisation of sales as well as the biotech and the software sector. The next two models address the emergence of financial evaluation MCS.

Table 40 Drivers for the emergence of financial evaluation MCS

	Model 1		Model 2	
	Coefficient	Z statistic	Coefficient	Z statistic
Organisational age	0.0977	3.58 ***	0.0531	1.71 *
Organisational size	0.2082	3.09 ***	0.1171	1.70 *
Venture capital	0.4124	2.32 **	0.3486	1.97 **
Replacement of CEO	0.0618	0.39	0.1636	1.01
CEO experience	0.0152	1.55	0.0119	1.09
Introduction of a CFO			0.6226	4.30 ***
International sales			0.2912	2.13 **
Biotech industry			-0.1409	-0.55
Software industry			0.0126	0.07
Overdispersion (α)	0.1297		0.1905	
Observations	245		245	
Companies	44		44	
Wald χ^2	94.64		126.92	

Model 1 and model 2 are cross-sectional time-series random-effects count data regression models. A Poisson distribution is adopted for the dependent variable and tested for overdispersion. If the null hypotheses of no overdispersion must be rejected the model adopts a negative binomial distribution for the dependent variable.
*, **, and *** indicate significance at the 10%, 5%, and 1% level respectively.

In the first model, size, age, and venture capital funding are significantly and positively associated with the emergence of management control systems in the field of financial evaluation. In the second model, age and size are still significant, but not to the same extent as in the first model. Again, venture capital is reported to have a positive and significant influence on the adoption of financial evaluation MCS. In addition, introducing a CFO and internationalising sales operations show a positive and significant association with system adoption in this particular field. The next category includes management control systems that support strategy formulation in entrepreneurial firms. The following table indicates the results of the corresponding statistical analyses.

Table 41 Drivers for the emergence of strategic planning MCS

	Model 1		Model 2	
	Coefficient	Z statistic	Coefficient	Z statistic
Organisational age	0.0691	2.32 **	0.0216	0.66
Organisational size	0.0429	0.68	-0.0249	-0.39
Venture capital	0.8039	4.85 ***	0.7472	4.33 ***
Replacement of CEO	0.0834	0.57	0.1051	0.69
CEO experience	0.0172	1.90 *	0.0203	2.09 **
Introduction of a CFO			0.5763	4.43 ***
International sales			0.2787	2.16 **
Biotech industry			0.1177	0.50
Software industry			0.2793	1.55
Overdispersion (α)	0.1576		0.1772	
Observations	245		245	
Companies	44		44	
Wald χ^2	82.81		101.53	

Model 1 and model 2 are cross-sectional time-series random-effects count data regression models. A Poisson distribution is adopted for the dependent variable and tested for overdispersion. If the null hypotheses of no overdispersion must be rejected the model adopts a negative binomial distribution for the dependent variable.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The first model indicates a positive and significant influence of organisational age and venture capital funding on the adoption of strategy MCS. In addition, the experience of the CEO has a positive and significant association with MCS emergence. In the second model, age shows no significance any more. However, venture capital funding and CEO experience are still positively and significantly associated with strategic planning MCS emergence. The introduction of a CFO and international sales expansion are significant as well. The next functional area is human resource management in the entrepreneurial firm. I start with human resource planning. The next table provides the results of the corresponding statistical analyses.

Table 42 Drivers for the emergence of human resource planning MCS

	Model 1		Model 2	
	Coefficient	Z statistic	Coefficient	Z statistic
Organisational age	0.0882	2.96 ***	0.0661	2.04 **
Organisational size	0.3592	5.16 ***	0.3301	4.63 ***
Venture capital	0.1599	0.90	0.1056	0.58
Replacement of CEO	0.0459	0.29	0.3885	0.24
CEO experience	0.0047	0.45	0.0046	0.42
Introduction of a CFO			0.1906	1.47
International sales			0.2065	1.52
Biotech industry			0.2271	0.89
Software industry			0.0165	0.08
Overdispersion (α)	0.2017		0.2108	
Observations	245		245	
Companies	44		44	
Wald χ^2	116.20		120.09	

Model 1 and model 2 are cross-sectional time-series random-effects count data regression models. A Poisson distribution is adopted for the dependent variable and tested for overdispersion. If the null hypotheses of no overdispersion must be rejected the model adopts a negative binomial distribution for the dependent variable.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

According to our first regression model, size and age have a significant positive influence on the adoption of management control systems in the field of human resource planning. Extending the model by considering additional covariates has no reasonable impact on age and size, although the significance of the former variable slightly decreases. Other explanatory variables are still not reported as significant influences. In the next two models, I focus on human resource evaluation. The following table shows the results of the corresponding regressions.

Table 43 Drivers for the emergence of human resource evaluation MCS

	Model 1		Model 2	
	Coefficient	Z statistic	Coefficient	Z statistic
Organisational age	0.1547	3.99 ***	0.1337	3.12 ***
Organisational size	0.3586	3.21 ***	0.2469	2.11 **
Venture capital	-0.0766	-0.28	-0.2439	-0.89
Replacement of CEO	0.0755	0.33	-0.0837	-0.31
CEO experience	-0.0064	-0.40	0.0018	0.11
Introduction of a CFO			0.5453	2.70 ***
International sales			0.4698	2.26 **
Biotech industry			0.7945	2.27 **
Software industry			0.4922	2.00 **
Overdispersion (α)	0.4068		0.3689	
Observations	245		245	
Companies	44		44	
Wald χ^2	79.84		94.56	

Model 1 and model 2 are cross-sectional time-series random-effects count data regression models. A Poisson distribution is adopted for the dependent variable and tested for overdispersion. If the null hypotheses of no overdispersion must be rejected the model adopts a negative binomial distribution for the dependent variable.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The first model shows the same results as the regressions carried out for human resource planning, i.e. age and size have a positive and significant association with MCS adoption in this particular field. However, turning to the second model, the outcome is different. Although organisational age and size are still positive and significant, introducing a CFO, selling internationally, biotechnology and software are also positively and significantly associated with MCS emergence. The last functional area I consider in the analysis is related to partnership and alliance management in entrepreneurial firms. The results are given in the following table.

Table 44 Drivers for the emergence of partnership MCS

	Model 1		Model 2	
	Coefficient	Z statistic	Coefficient	Z statistic
Organisational age	0.2800	4.25 ***	0.1852	2.65 ***
Organisational size	-0.0362	-0.25	-0.1173	-0.79
Venture capital	-0.4042	-1.19	-0.2903	-0.81
Replacement of CEO	1.2836	3.10 ***	1.1592	2.83 ***
CEO experience	-0.0374	-1.18	-0.0315	-0.99
Introduction of a CFO			0.9174	3.09 ***
International sales			0.5210	1.98 **
Biotech industry			1.2321	1.76 *
Software industry			1.0961	2.16 **
Overdispersion (α)	1.9448		1.7002	
Observations	245		245	
Companies	44		44	
Wald χ^2	51.46		63.93	

Model 1 and model 2 are cross-sectional time-series random-effects count data regression models. A Poisson distribution is adopted for the dependent variable and tested for overdispersion. If the null hypotheses of no overdispersion must be rejected the model adopts a negative binomial distribution for the dependent variable.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The first model indicates that age and the replacement of the CEO have a positive and highly significant influence on the adoption of MCS in the area of partnerships and alliances. The second model provides the same results for organisational age and CEO replacement. Again, these covariates are reported as positive and highly significant. In addition, the introduction of a CFO indicates a highly significant and positive association with the adoption of partnership MCS. The international expansion of sales operations, as well as the biotechnology and the software segment, are positively and significantly associated with system adoption in this particular field.

5.2.2.2 Organisational Size and MCS Emergence

In order to elaborate on the second explorative question formulated in chapter 3.3, I apply simultaneous-equations models introduced in chapter 4.2.3. Thus, I am able to shed light on the association between size and MCS emergence. For the first equation, I define the

size of the company as a function of market demand, financial reserves, quality of the investor, and MCS intensity. Usually the number of employees is correlated with demand on the market. Financial resources enable firms to recruit and retain employees. In general, high quality investors provide valuable services to their portfolio companies, which enable the firms to grow to a substantial size. Finally, the emergence of MCS as an effect of dynamic capability evolution is expected to have a positive influence on organisational size.

Market demand is coded as absolute revenue recognised by the new venture in each year of observation. Cumulative funding represents the cumulated amount of financial resources granted by investors during the observation period. MCS intensity and quality of the investor are coded as in chapter 5.2.1.2 and chapter 5.2.1.4 respectively.

In order to define an appropriate model for the regression I control for the applicability of a random-effects model. The Hausman test does not reject a random-effects specification. In addition, I test the panel data for heteroskedasticity and autocorrelation. The specification shows serial correlation within the panels and heteroskedasticity across panels. Consequently, I model the error term by using a first order auto-correlation model and considering heteroskedasticity. The regression is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity. The model has the following specification.

$$\begin{aligned} Employees = {} & \alpha_0 + \alpha_1 MCS\ intensity + \alpha_2 revenues + \\ & \alpha_3 cumulative\ \ funding + \alpha_4 investor\ quality + \varepsilon\left(AR1\right) \end{aligned} \tag{1.6}$$

The second equation of the simultaneous-equations model is similar to the regression applied in chapter 5.2.1.1. Consequently, the independent variables are identical. However, this time, I use a linear model instead of a count model. Instead of counting the number of MCS in each year, I calculate the MCS intensity, which has already been introduced in chapter 5.2.1.2. The Hausman test rejects the efficient random-effects model. Thus, I apply a generalised estimating equation (GEE) model introduced in chapter 4.2.3 to be able to use time-invariant independent variables. Again, the error

terms show serial correlation. Consequently, I apply a first order auto-correlation model. The specification is as follows.

$$\begin{aligned} MCS\ intensity = {} & \beta_0 + \beta_1 employees + \beta_2 venture\ capital + \\ & \beta_3 CEO\ replacement + \beta_4 CEO\ experience + \\ & \beta_5 introduction\ of\ a\ CFO + \beta_6 international\ sales + \\ & \beta_7 biotech\ industry + \beta_8 software\ industry + \varepsilon\,(AR1) \end{aligned} \tag{1.7}$$

The following table shows the results of the simultaneous-equations model, considering all management control systems for the MCS intensity variable. In general, the system of two regression models indicates that organisational size has a positive influence on the size of the organisation. On the other hand, size as the number of employees can be considered a significant driver for the emergence of management control systems in technology-based new ventures.

Table 45 Organisational size and MCS intensity

	Organisational size	
	Coefficient	Z statistic
MCS intensity	4.8389	3.54 ***
Revenues	0.0040	10.68 ***
Cumulated funding	0.0008	6.88 ***
Quality of the investor	3.8189	1.83 *
Wald χ^2	437.54	
	MCS intensity	
Organisational size	0.0136	5.24 ***
Venture capital	0.3405	3.05 ***
Replacement of CEO	0.2759	2.18 **
CEO experience	0.0048	0.42
Introduction of a CFO	0.5373	5.43 ***
International sales	0.2975	3.08 ***
Biotech industry	0.0096	0.04
Software industry	0.2149	1.10
Wald χ^2	196.91	
Observations	234	
Companies	41	

Model 1 is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity.
Model 2 is a linear cross-sectional time-series generalised estimating equation (GEE) population-averaged regression model. The models control for autocorrelation of error terms for observations from the same technology-based new venture.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

cross-sectional time-series random-effects linear regression model using feasible generalised least squares (FGLS)

In addition to MCS intensity, the demand, as well as the received funds, is highly significant in terms of their influence on organisational size. The quality of the investor shows a positive significant association with the number of employees in entrepreneurial firms. In the second equation, venture capital funding, the replacement of the CEO, the

introduction of a CFO, and the internationalisation of sales are all significantly associated with the intensity of management control systems.

The next table reports a similar simultaneous equations model. However, instead of all management control systems, I focus on financial planning. The following table indicates the respective results.

Table 46 Organisational size and financial planning MCS intensity

	Organisational size	
	Coefficient	Z statistic
Financial planning MCS intensity	2.8884	2.81 ***
Revenues	0.0043	12.34 ***
Cumulated funding	0.0008	7.79 ***
Quality of the investor	3.8577	1.98 **
Wald χ^2	425.43	
	Financial planning MCS intensity	
Organisational size	0.0047	1.69 *
Venture capital	0.6936	5.49 ***
Replacement of CEO	0.4159	2.94 ***
CEO experience	0.0188	1.53
Introduction of a CFO	0.7650	6.91 ***
International sales	0.1022	0.94
Biotech industry	-0.3791	-1.52
Software industry	0.1281	0.64
Wald χ^2	183.04	
Observations	234	
Companies	41	

Model 1 is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity.
Model 2 is a linear cross-sectional time-series generalised estimating equation (GEE) population-averaged regression model. The models control for autocorrelation of error terms for observations from the same technology-based new venture.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

In both equations, financial planning MCS intensity and organisational size are positively and significantly associated. In the first equation revenues, cumulated funding, and the

quality of the investor show a positive and significant association with organisational size. The second equation indicates the significance of the influence of venture capital funding, CEO replacement, and the recruitment of a CFO on financial planning MCS intensity. The next group of systems focuses on financial evaluation. The following table provides the results of the simultaneous-equations model.

Table 47 Organisational size and the emergence of financial evaluation MCS

	Organisational size	
	Coefficient	Z statistic
Financial evaluation MCS intensity	5.6516	3.21 ***
Revenues	0.0040	10.72 ***
Cumulated funding	0.0008	7.16 ***
Quality of the investor	4.4546	2.30 **
Wald χ^2	439.26	
	Financial evaluation MCS intensity	
Organisational size	0.0100	3.26 ***
Venture capital	0.2921	2.19 **
Replacement of CEO	0.3654	2.41 **
CEO experience	0.0038	0.28
Introduction of a CFO	0.3068	2.62 ***
International sales	0.2649	2.30 **
Biotech industry	-0.3008	-1.05
Software industry	-0.1278	-0.56
Wald χ^2	85.95	
Observations	234	
Companies	41	

Model 1 is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity.
Model 2 is a linear cross-sectional time-series generalised estimating equation (GEE) population-averaged regression model. The models control for autocorrelation of error terms for observations from the same technology-based new venture.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

System intensity is a highly significant driver for organisational size, and the influence of size on the emergence of MCS is highly significant as well. In the first equation, revenues, cumulated funding, and the quality of the investor are also significant.

According to the second regression size, VC funding, CEO replacement, CFO installation, and the internationalisation of sales are all significantly associated with financial evaluation system intensity. The next group of systems focuses on strategic planning. The results of the corresponding regressions are given in the following table.

Table 48 Organisational size and the emergence of strategic planning MCS

	Organisational size	
	Coefficient	Z statistic
Strategic planning MCS intensity	4.2605	3.28 ***
Revenues	0.0043	12.25 ***
Cumulated funding	0.0008	7.78 ***
Quality of the investor	3.4637	1.78 *
Wald χ^2	432.17	
	Strategic planning MCS intensity	
Organisational size	0.0029	1.01
Venture capital	0.5070	4.10 ***
Replacement of CEO	0.2475	1.76 *
CEO experience	0.0080	0.62
Introduction of a CFO	0.6222	5.68 ***
International sales	0.2071	1.95 *
Biotech industry	0.0279	0.10
Software industry	0.1441	0.63
Wald χ^2	112.28	
Observations	234	
Companies	41	

Model 1 is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity.
Model 2 is a linear cross-sectional time-series generalised estimating equation (GEE) population-averaged regression model. The models control for autocorrelation of error terms for observations from the same technology-based new venture.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

In this system of equations, MCS intensity has a highly significant positive influence on the size of a technology-based new venture. The influences of revenues and cumulated funding are similar. In addition, the quality of the investor is positively and significantly associated with organisational size. Turning to the second equation, the results are

different from the previous groups of systems. Here, organisational size is not reported to have a positive and significant influence on MCS intensity. On the other hand, venture capital funding, CEO replacement, the introduction of a CFO, and the internationalisation of sales are all significantly associated with system adoption. The next group of MCS I consider focuses on human resource planning. The following table shows the results.

Table 49 Organisational size and the emergence of HR planning MCS

	Organisational size	
	Coefficient	Z statistic
HR planning MCS intensity	8.5067	3.68 ***
Revenues	0.0037	8.91 ***
Cumulated funding	0.0007	5.74 ***
Quality of the investor	2.4204	1.22
Wald χ^2	437.39	
	HR planning MCS intensity	
Organisational size	0.0166	5.34 ***
Venture capital	0.2411	1.83 *
Replacement of CEO	0.0866	0.58
CEO experience	0.0010	0.07
Introduction of a CFO	0.2555	2.19 **
International sales	0.1847	1.62
Biotech industry	0.2279	0.77
Software industry	0.0035	0.01
Wald χ^2	90.35	
Observations	234	
Companies	41	

Model 1 is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity.
Model 2 is a linear cross-sectional time-series generalised estimating equation (GEE) population-averaged regression model. The models control for autocorrelation of error terms for observations from the same technology-based new venture.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

In contrast to the previous group of systems, the table reports positive and highly significant associations between size and MCS intensity in both equations. In the first regression model, revenues and cumulated funding are both positively and significantly

associated with organisational size. For the second equation, venture capital funding and the introduction of a CFO have a positive and significant association with system intensity in the field of human resource planning. The next group of MCS I consider for this analysis focuses on HR evaluation. The corresponding results are given in the next table.

Table 50 Organisational size and the emergence of HR evaluation MCS

	Organisational size	
	Coefficient	Z statistic
HR evaluation MCS intensity	9.3843	3.51 ***
Revenues	0.0037	9.02 ***
Cumulated funding	0.0007	5.53 ***
Quality of the investor	1.5524	0.75
Wald χ^2	432.11	
	HR evaluation MCS intensity	
Organisational size	0.0168	5.05 ***
Venture capital	0.0809	0.53
Replacement of CEO	0.1787	1.05
CEO experience	-0.0003	-0.02
Introduction of a CFO	0.2295	1.72 *
International sales	0.0864	0.65
Biotech industry	0.4270	1.59
Software industry	0.3102	1.46
Wald χ^2	65.24	
Observations	234	
Companies	41	

Model 1 is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity.
Model 2 is a linear cross-sectional time-series generalised estimating equation (GEE) population-averaged regression model. The models control for autocorrelation of error terms for observations from the same technology-based new venture.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Again, organisational size and MCS intensity show a positive and highly significant association in both equations. The results of the first regression model are almost identical to the outcome for human resource planning systems. Revenues and cumulated

funding are highly significant, while the quality of the investor indicates no significance. In the second equation, only the introduction of a CFO is significant in addition to organisational size. The next group of systems covers product development. The results are indicated in the table below.

Table 51 Organisational size and the emergence of product development MCS

	Organisational size	
	Coefficient	Z statistic
Product development MCS intensity	6.4138	3.77 ***
Revenues	0.0040	10.78 ***
Cumulated funding	0.0008	6.94 ***
Quality of the investor	2.9016	1.49
Wald χ^2	441.56	
	Product development MCS intensity	
Organisational size	0.0103	3.09 ***
Venture capital	0.1838	1.22
Replacement of CEO	0.0782	0.47
CEO experience	0.0067	0.48
Introduction of a CFO	0.3913	2.96 ***
International sales	0.4142	3.14 ***
Biotech industry	0.3139	1.17
Software industry	0.1598	0.75
Wald χ^2	73.05	
Observations	234	
Companies	41	

Model 1 is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity.
Model 2 is a linear cross-sectional time-series generalised estimating equation (GEE) population-averaged regression model. The models control for autocorrelation of error terms for observations from the same technology-based new venture.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Regarding the field of product development, size and system intensity have a positive and highly significant association in both equations of the model. In addition, the influence of cumulated funding and revenues on organisational size is reported to be highly significant. In the second equation, the introduction of a CFO and the internationalisation

of sales have a positive and highly significant association with system intensity. The next group of MCS covers marketing and sales. The results of the corresponding simultaneous-equations model are given in the next table.

Table 52 Organisational size and the emergence of marketing and sales MCS

	Organisational size	
	Coefficient	Z statistic
Marketing and sales MCS intensity	4.5641	2.42 **
Revenues	0.0042	10.60 ***
Cumulated funding	0.0009	8.17 ***
Quality of the investor	4.7098	2.39 **
Wald χ^2	426.78	
	Marketing and sales MCS intensity	
Organisational size	0.0118	4.43 ***
Venture capital	0.1577	1.31
Replacement of CEO	-0.0799	-0.59
CEO experience	0.0078	0.62
Introduction of a CFO	0.2897	2.73 ***
International sales	0.3602	3.45 ***
Biotech industry	-0.6239	-2.34 **
Software industry	0.2785	1.30
Wald χ^2	96.85	
Observations	234	
Companies	41	

Model 1 is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity.
Model 2 is a linear cross-sectional time-series generalised estimating equation (GEE) population-averaged regression model. The models control for autocorrelation of error terms for observations from the same technology-based new venture.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

For marketing and sales, the association between size and MCS intensity is positive and significant in both equations of the model. In the first equation, revenues, cumulated funding, and the quality of the investor also have a positive and significant influence on organisational size. Regarding the second regression model, the introduction of a CFO and the internationalisation of sales operations are positively and significantly associated

with system intensity. In addition, the biotech industry is reported to have a negative and significant influence on MCS intensity in this particular field. The last group of systems focuses on the management of partnerships in technology-based new ventures. The results are indicated in the following table.

Table 53 Organisational size and the emergence of partnership MCS

	Organisational size	
	Coefficient	Z statistic
MCS intensity	7.7741	3.47 ***
Revenues	0.0041	11.53 ***
Cumulated funding	0.0008	7.92 ***
Quality of the investor	2.8709	1.50
Wald χ^2	430.90	
	MCS intensity	
Organisational size	0.0060	1.74 *
Venture capital	-0.1603	-1.06
Replacement of CEO	0.3189	1.84 *
CEO experience	-0.0202	-1.34
Introduction of a CFO	0.3561	2.63 ***
International sales	0.2947	2.21 **
Biotech industry	0.3564	1.18
Software industry	0.3309	1.37
Wald χ^2	36.62	
Observations	234	
Companies	41	

Model 1 is a cross-sectional time-series linear model using feasible generalized least squares (FGLS) considering autocorrelation within panels and heteroskedasticity.
Model 2 is a linear cross-sectional time-series generalised estimating equation (GEE) population-averaged regression model. The models control for autocorrelation of error terms for observations from the same technology-based new venture.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

In both equations size and system intensity are positively and significantly associated. However, the significance is much stronger in the first equation. As in many other groups of MCS, revenues and cumulated funding show a highly significant positive influence on the size of entrepreneurial firms. The impact of the investor's quality is not significant.

Regarding the second equation the replacement of the CEO as well as the introduction of a CFO and the internationalisation of sales have a positive and significant association with MCS intensity.

5.2.2.3 Paths of MCS Emergence and New Venture Performance

In chapter 2.4.4 I have formulated different hypotheses, addressing the path dependency of dynamic capabilities and thus of company growth. Therefore, I have already hypothesised the sequencing of management control systems and the performance implications of early system adoption. However, the derived propositions are broad or only compare groups of systems with respect to MCS emergence. To gain further insights on the sequencing of MCS emergence and its impact on growth, I choose an explorative design. I cluster the sample firms into three groups, according to the adoption times of the eight groups of management control systems. To determine the time to adoption for each group, I apply the same methodology as in chapter 5.2.1.3. A group of MCS is considered as adopted if the number of observed systems exceeds the median of all management control systems in this particular group. Given the adoption times of all eight groups, I use Ward's agglomerative hierarchical clustering (Voß 2000) to form three groups of companies. For the three clusters, I determine the median rank for each management control system according to the adoption time. Thus, I obtain a specific sequence of MCS emergence for the different groups. The following table reports the characteristics of the three clusters comprising the median system ranks and the number of companies in each group.

Table 54 Sequence of MCS emergence in three different clusters

	Ranking of MCS emergence		
	Cluster 1	Cluster 2	Cluster 3
Financial planning	1	1	1
Financial evaluation	3	4	4
Strategic planning	1	2	1
Human resource planning	6	3	6
Human resource evaluation	6	5	1
Product development	3	5	5
Marketing and sales	5	5	6
Partnerships and alliances	6	8	6
Companies	17	14	13

Table indicates the median ranking of the time to emergence of the eight different categories of management control systems. Clusters were determined according to Ward's agglomerative hierarchical clustering procedure.

Reflecting on the results of the ranking, the first group starts with strategic and financial planning. Afterwards, the companies studied engage in the adoption of product development and financial evaluation MCS followed by marketing and sales systems. The last systems adopted are human resource planning and evaluation, as well as partnership MCS. The second cluster of firms starts with financial planning, followed by strategic planning. The third group of management control systems adopted focuses on human resource planning. Afterwards, financial evaluation MCS emerge. The next systems being adopted are human resource evaluation, product development, and marketing and sales. The last group of MCS that emerges in this cluster focuses on partnership and alliance management. According to the median rank, companies from the third cluster start with financial and strategic planning as well as human resource evaluation. Afterwards, they implement financial evaluation systems, followed by product development systems. The last MCS which emerge address human resource planning, marketing and sales, and partnerships.

To analyse the performance implications of MCS sequencing in technology-based new ventures, I apply different growth measures; i.e. I compare the three clusters in terms of employee growth during the first four years. I limit the analysis to four years to keep the number of observations per cluster at a minimum level. To control for the significances of

the differences between the three groups, I apply the non-parametric Kruskal-Wallis equality of populations rank test. The results are laid out in the following table.

Table 55 Time-dependent MCS intensity and company performance

	Employee growth			
	Cluster 1	Cluster 2	Cluster 3	χ^2 with 2 d. f.
1 year growth	5.56	11.00	7.38	7.291 **
2 year growth	6.63	12.46	9.79	5.848 *
3 year growth	6.81	12.64	9.19	6.490 **
4 year growth	6.57	12.37	7.24	6.664 **

Table indicates the mean employee growth rates for the first 4 years of the new ventures for the three clusters. Z values report the results of a Kruskal-Wallis equality of populations rank test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

For the one-, two-, three-, and four-year growth rates, the Kruskal-Wallis test indicates a significant difference between the three clusters. While cluster one and three are somehow comparable in terms of growth, the second group of new ventures shows a much higher increase in employees. To elaborate further on these findings, I plot the mean employee size of all three clusters for the first four years. The following figure shows the results.

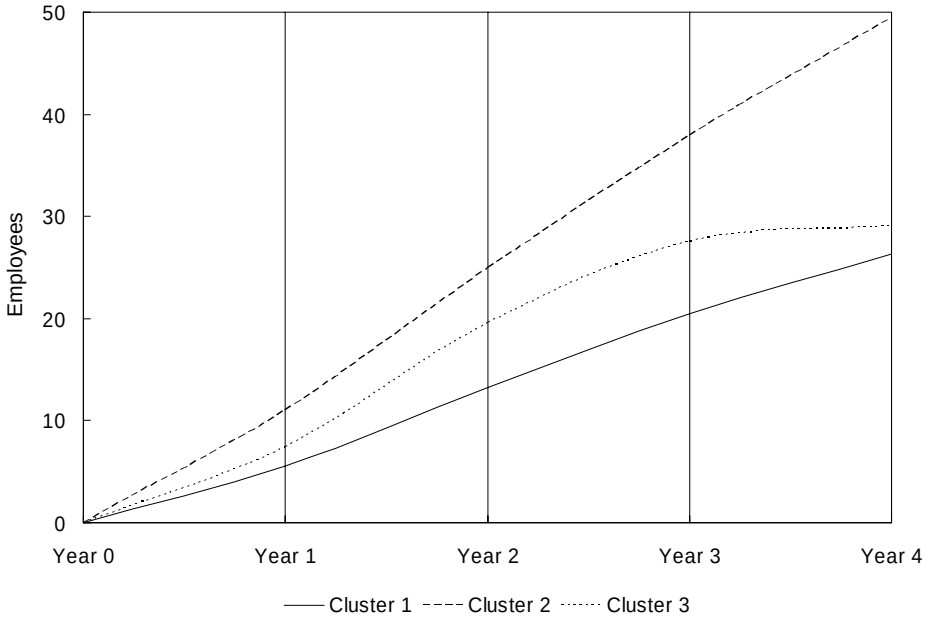

Figure 24 Employee development of clustered entrepreneurial firms

The size of cluster one firms increases steadily but also rather slowly. Firms from cluster two and three grow much faster in the first two years. The employee curve of the third group flattens in year four and thus, clusters one and three show almost identical employee numbers in year four. Only the second group grows fast and constantly. To analyse this outcome further, I draw the same curves for revenues instead of employees. The following figure shows the results.

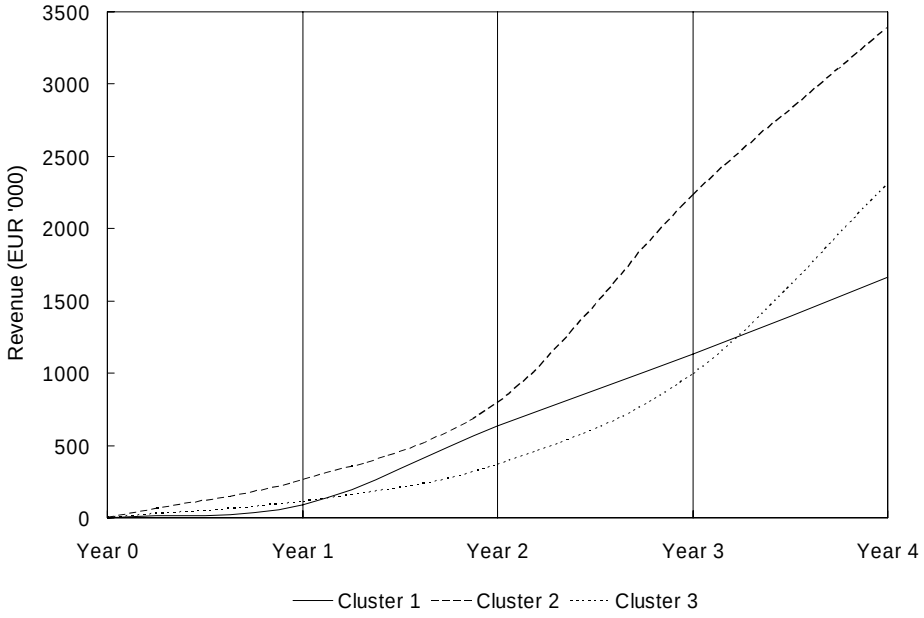

Figure 25 Revenue development of clustered entrepreneurial firms

Again, cluster two shows the highest growth during the first four years of existence. Firms from the first group grow constantly but slowly. Companies from clusters two and three show limited growth in the first two years but strong growth in years three and four. However, the growth of cluster two is much stronger.

5.2.2.4 MCS Emergence and New Venture Performance

In chapter 5.2.1.2 I have tested the association between early system adoption and new venture performance for strategic planning, financial management, and human resource management. The analysis reflects on the three hypotheses derived in chapter 2.4.4.1. However, it might also be interesting to control for a potential association between early emergence and start-up growth for the other groups of systems, as well as for all MCS at once. I start with all eight groups of MCS. Therefore, I calculate the total system intensity as the standardised average of all group intensities. The statistical tests are the same as in chapter 5.2.1.2. The following table indicates the corresponding results.

Table 56 Time-dependent MCS intensity and company performance

	Year 1		Year 2		Year 3		Year 4	
	High	Low	High	Low	High	Low	High	Low
1 year growth	9.90	5.95	10.86	5.05	10.55	5.09	9.42	6.17
T value	1.59		2.40 **		2.31 **		1.22	
Z value	2.20 **		2.30 **		1.61		0.81	
2 year growth	10.95	8.00	11.64	7.31	11.16	7.63	11.76	8.00
T value	1.10		1.64		1.33		1.24	
Z value	1.11		1.63		1.70 *		1.40	
3 year growth	10.21	8.67	10.37	8.51	11.12	7.58	12.39	7.31
T value	0.61		0.73		1.42		1.83 *	
Z value	1.07		1.41		2.23 **		2.11 **	
4 year growth	8.84	8.71	10.03	7.81	9.85	7.85	9.71	7.78
T value	0.06		1.02		0.91		0.86	
Z value	0.52		1.72 *		1.34		1.23	
5 year growth	9.32	6.70	10.33	6.54	11.14	6.44	10.42	6.27
T value	1.04		1.38		1.61		1.63	
Z value	0.40		1.48		1.74 *		1.57	
Companies	22	22	22	22	22	22	19	19

The table indicates the comparison of mean employee growth rates in the first five years. Mean growth for a certain year is calculated as the number of employees at the end of each period divided by the number of years. The last row reveals the number of companies in each group according to the initial differentiation.
T values report the results of a Welch two-sample t test with unequal variances. Z values report the results of a Mann-Whitney test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

The results indicate that, for each year of categorisation, firms with high system intensity show better performance with respect to company growth. However, grouping in the first two years, the differences are mostly not significant. Clustering the companies in year three and comparing their growth rates shows a different picture. Now, at least one of both tests indicates a significant difference in growth between firms with high and low system intensity for years one, two, three and five. The following figure denotes the development of employees for both groups for the first five years. The groups were clustered according to their system intensity in year three.

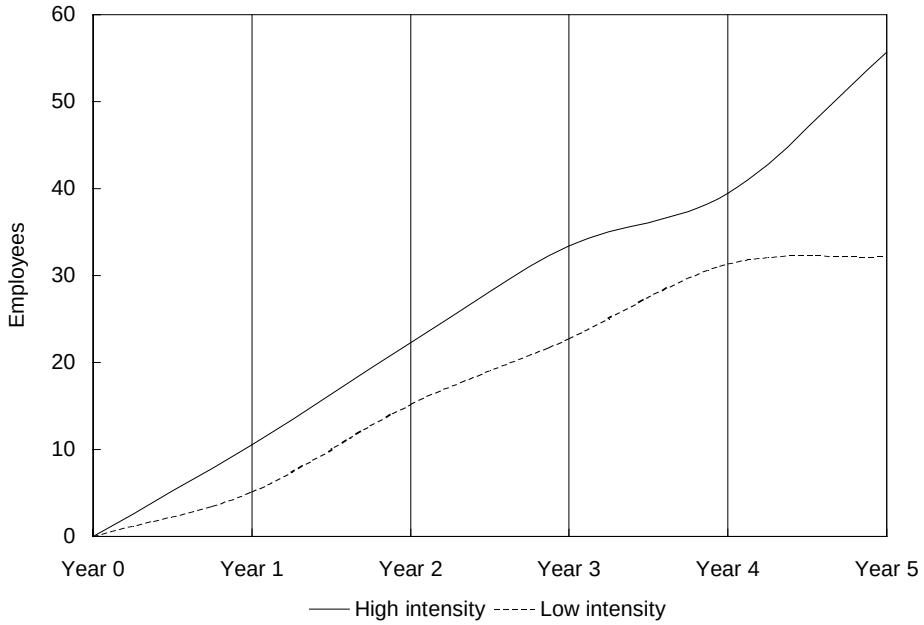

Figure 26 MCS intensity in year three and company growth

The results from the statistical tests are clearly observable in the figure above. From the beginning to year three, the curve for the high intensity group is slightly steeper than for companies with low system intensity. While the latter group catches up slightly in the fourth year of existence, the spread between the two curves increases substantially in the subsequent year. The next group of systems I address in this chapter covers product development. The statistical tests are given in the following table.

Table 57 Time-dependent product development MCS intensity and company performance

	Year 1		Year 2		Year 3		Year 4	
Intensity	High	Low	High	Low	High	Low	High	Low
1 year growth	9.39	6.80	9.82	6.62	10.43	5.45	10.73	5.86
T value	1.01		1.13		2.01 *		1.58	
Z value	1.44		0.91		1.73 *		1.57	
2 year growth	10.17	8.96	12.29	7.56	11.31	7.64	11.90	8.61
F value	0.44		1.63		1.37		1.00	
F value	0.83		1.30		1.22		0.95	
3 year growth	8.87	9.86	9.88	9.13	9.40	9.48	10.98	9.29
T value	-0.39		0.28		-0.03		0.56	
Z value	-0.48		0.22		0.26		0.84	
4 year growth	7.63	9.64	8.71	8.80	8.16	9.29	9.12	8.53
T value	-0.92		-0.04		-0.51		0.26	
Z value	-0.78		0.30		-0.11		0.57	
5 year growth	6.40	8.67	5.71	8.44	5.23	8.81	8.51	7.41
T value	-1.08		-1.33		-1.82 *		0.39	
Z value	-0.31		-0.93		-1.64		0.23	
Companies	19	25	18	26	22	22	15	23

The table indicates the comparison of mean employee growth rates in the first five years. Mean growth for a certain year is calculated as the number of employees at the end of each period divided by the number of years. The last row reveals the number of companies in each group according to the initial differentiation.
T values report the results of a Welch two-sample t test with unequal variances. Z values report the results of a Mann-Whitney test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

In general, the analysis reveals no substantial positive association between MCS intensity and company growth. The only exception is the one-year growth for companies categorised in year three. The companies with low system intensity often show higher growth rates than those with high MCS intensity. This effect is significant with respect to the five-year growth of groups that are formed according to their intensity in year three. To support the statistical tests, the following figure shows employee development for groups clustered in year four.

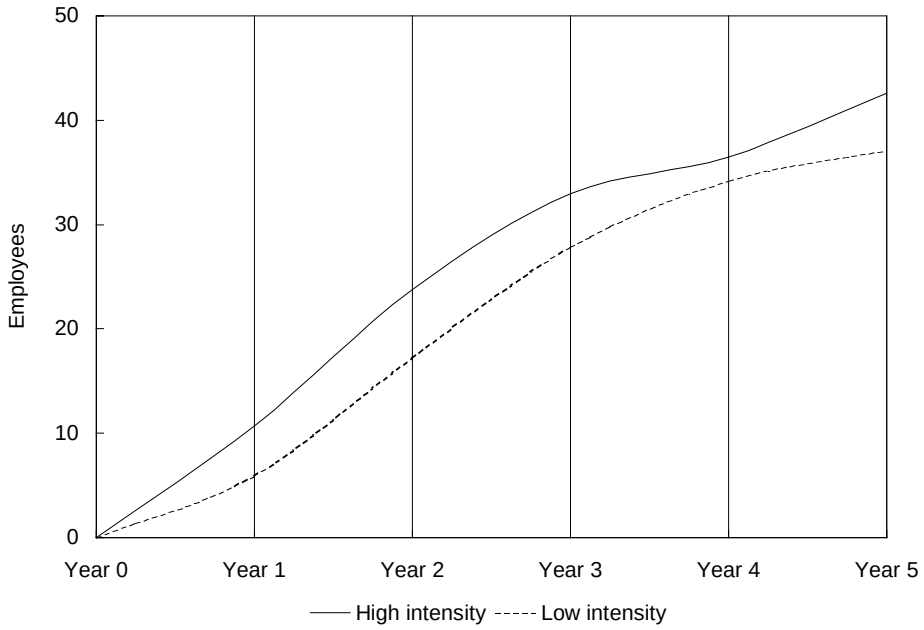

Figure 27 Product development MCS intensity in year four and company growth

The figure shows that there is no substantial difference between firms with high and low intensity in terms of product development systems. Although the employee curve for companies with high system intensity is slightly above the curve for low intensity firms, the effect is too small to draw any conclusions. The next group of MCS covers marketing and sales. The statistical tests are given in the following table.

Table 58 Time-dependent marketing and sales MCS intensity and company performance

	Year 1		Year 2		Year 3		Year 4	
Intensity	High	Low	High	Low	High	Low	High	Low
1 year growth	17.43	6.03	10.11	6.28	10.68	5.67	9.54	6.92
T value	2.25 *		1.41		1.93 *		0.78	
Z value	2.65 ***		1.44		2.04 **		0.54	
2 year growth	17.36	7.90	12.47	7.22	12.03	7.37	14.77	7.28
F value	2.10 *		1.88 *		1.70 *		2.28 **	
F value	2.28 **		1.85 *		1.75 *		2.43 **	
3 year growth	13.62	8.60	11.69	7.75	11.72	7.55	15.26	7.01
T value	1.14		1.57		1.68		2.79 **	
Z value	1.22		2.28 **		2.34 **		3.07 ***	
4 year growth	11.75	8.19	10.02	7.82	10.17	7.45	11.88	7.08
T value	1.15		1.02		1.24		2.29 **	
Z value	1.36		1.66 *		2.01 **		2.63 ***	
5 year growth	7.50	7.73	9.71	6.65	9.72	6.45	11.70	6.51
T value	-0.08		1.19		1.36		2.14 *	
Z value	0.29		1.30		1.40		2.16 **	
Companies	7	37	19	25	20	24	13	25

The table indicates the comparison of mean employee growth rates in the first five years. Mean growth for a certain year is calculated as the number of employees at the end of each period divided by the number of years. The last row reveals the number of companies in each group according to the initial differentiation.
T values report the results of a Welch two-sample t test with unequal variances. Z values report the results of a Mann-Whitney test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Firms that are clustered in the first year show a significant and positive association between growth and system intensity for one- and two-year growth. However, the three-, four-, and five-year growth rates are not significant in terms of system intensity. With respect to five-year growth, the relationship is even negative. Companies that are clustered in the second, third, and fourth year indicate a positive association between system intensity and company growth for all measures applied. Most of the tests for the different growth rates are significant. The significance of the tests increases with the timing of categorisation. The following figure denotes the development of organisational size for companies that are categorised in the fourth year of existence.

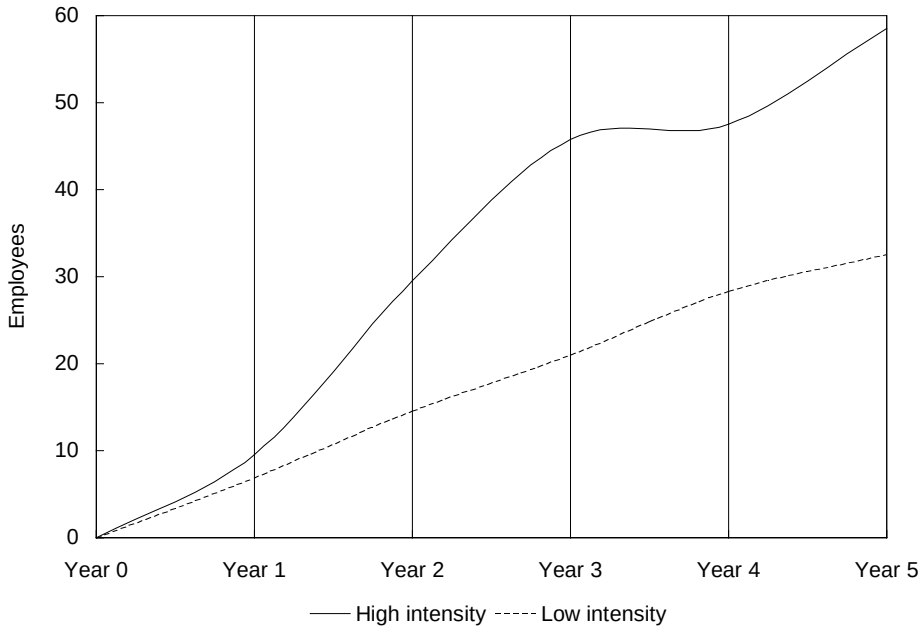

Figure 28 Marketing and sales MCS intensity in year four and company growth

While the two curves are almost identical for the first year, the spread between both lines increases substantially in the second and third year of existence. Afterwards, the distance decreases slightly to become larger again in the last period of observation. The last group of management control systems I consider in this analysis focuses on partnerships and alliances. The results of the corresponding statistical tests are indicated in the following table.

Table 59 Time-dependent partnership MCS intensity and company performance

	Year 1		Year 2		Year 3		Year 4	
Intensity	High	Low	High	Low	High	Low	High	Low
1 year growth	5.50	8.13	8.17	7.84	9.00	7.40	8.19	7.57
T value	-1.56		0.09		0.58		0.23	
Z value	0.11		0.23		0.98		0.83	
2 year growth	11.38	9.28	11.75	9.10	10.12	9.19	10.56	9.53
F value	0.26		0.50		0.29		0.33	
F value	-0.34		0.41		0.31		0.69	
3 year growth	12.42	9.12	11.83	9.04	7.85	10.15	10.31	9.73
T value	0.42		0.54		-0.80		0.19	
Z value	-0.17		0.27		-1.28		0.00	
4 year growth	7.56	8.93	10.20	8.55	7.06	9.59	8.28	9.19
T value	-0.46		0.47		-1.16		-0.41	
Z value	-0.27		0.51		-1.09		-0.44	
5 year growth	6.00	7.93	6.00	7.93	5.44	8.25	8.08	7.54
T value	-0.80		-0.80		-1.57		0.20	
Z value	-0.44		-0.44		-0.75		0.00	
Companies	5	39	7	37	14	30	17	21

The table indicates the comparison of mean employee growth rates in the first five years. Mean growth for a certain year is calculated as the number of employees at the end of each period divided by the number of years. The last row reveals the number of companies in each group according to the initial differentiation.
T values report the results of a Welch two-sample t test with unequal variances. Z values report the results of a Mann-Whitney test.
*, **, and *** indicate significance at the 10%, 5%, and 1% levels respectively.

Reflecting on the statistical tests, a large percentage of the indicated measures reveal a negative association between system intensity in the field of partnerships and alliances and company performance. However, none of the tests is significant. The relationship between partnership MCS intensity and company growth is further emphasised in the following figure, which indicates the development of high and low intensity firms clustered in year four.

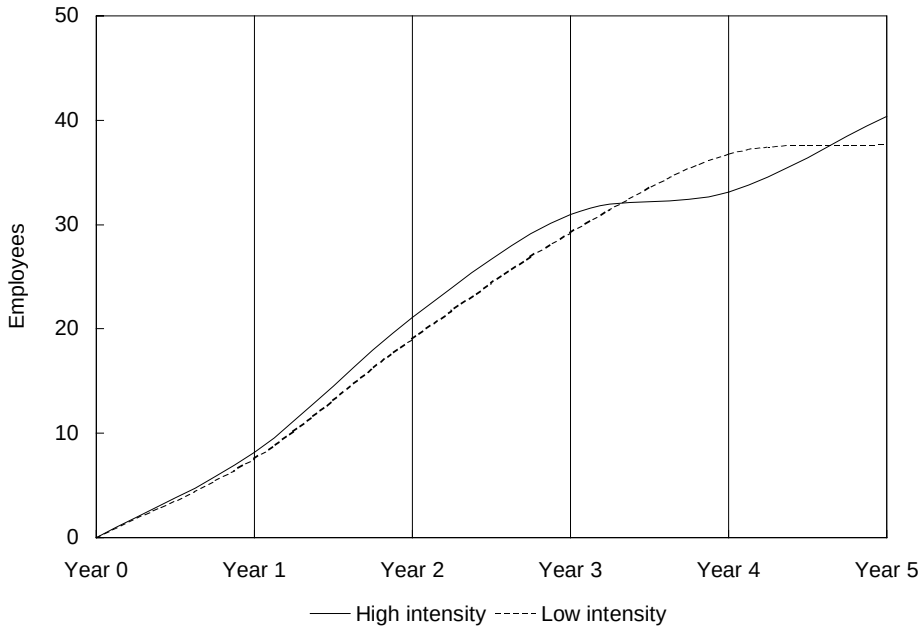

Figure 29 Partnership MCS intensity in year four and company growth

In fact, there is almost no noticeable difference between companies with high and low system intensity in the field of partnerships and alliances. While the curve for new ventures with high MCS intensity is slightly above the low intensity curve for the first three years, the picture changes in the fourth year. In year five, the high intensity group is again slightly ahead in terms of number of employees. However, the differences are minimal.

6 DISCUSSION OF RESULTS

6.1 TEST OF HYPOTHESES

In the second chapter of this dissertation, I have derived various hypotheses that have been used to approach the emergence of dynamic capabilities in technology-based new ventures and their influence on growth. In the previous sections, I have carried out various statistical analyses that are related to the initial hypotheses. In this section, I reflect on the results of the corresponding survey research.

In chapter 2.3.4, I have identified various drivers for learning in entrepreneurial firms. These factors have been tested in chapter 5.2.1.1. Contrary to the initial hypotheses, not all the drivers have a positive and significant association with the emergence of management control systems and thus, dynamic capabilities in technology-based new ventures. According to the regressions, the replacement of the CEO and the experience of the CEO do not significantly influence MCS adoption.

The fact that the replacement of the founder has no significant influence on the implementation of most MCS contradicts the findings of previous studies on the adoption of human resource management control systems (Davila 2005) and MCS in the area of finance and accounting (Davila and Foster 2005) in U.S. ventures. However, there are two potential reasons for this outcome. First, not many CEOs have been replaced in the sample firms of this study. This could be due to the German labour law, which makes it much harder to replace a founder as CEO than in the United States. In addition, German managers are highly attached to their companies. Thus, they might consider a replacement as a personal mistake and hold on to their position as long as possible, while ignoring the fact that the company actually suffers a leadership crisis and needs a new CEO.

It is surprising that CEO experience has no significant influence on MCS adoption in entrepreneurial firms. This outcome also contradicts previous findings (Davila 2005). Experience is usually considered as a major driver for learning and it is therefore expected to have a positive influence on the development of dynamic capabilities within

organisations. However, the explanatory variable deployed in this study does not differentiate between related and unrelated experiences. Instead, the driver simply refers to previous work experience and does not take into consideration whether the manager has gained experience in a similar industry or a start-up company. It may still be possible that the CEOs in place have a positive influence on the development of certain capabilities but these skills do not match the actual requirements of a young growing firm. Consequently, a more differentiated analysis regarding this aspect should be carried out in order to ascertain the experience relevant to the emergence of capabilities necessary in technology-based new ventures. This outcome is in-line with the considerations in chapter 1.1. Here I mentioned a lack of capable managers in Germany who are able to grow small start-ups to a reasonable size within a relatively short timeframe.

An interesting aspect of the first analysis is the positive and significant association between the emergence of dynamic capabilities and the software industry. The analysis proposes that software start-ups show more skills at an earlier stage than new ventures in other industries. A reason for this outcome may be found in the higher cycle times in the software sector compared to other industries. While life science ventures develop their pharmaceutical products over many years, software firms usually release their products much earlier to compete successfully on the market. Thus, they may require a broader set of capabilities much faster than other start-ups.

In my initial hypotheses, I propose that the biotechnology segment is negatively associated with marketing and sales capabilities and has a positive association with management control systems in the field of product development. While the first hypothesis is fully supported by the panel data regressions, the second one is not reflected in the statistical models. I initially hypothesise the association between life science and product development MCS, due to regulations imposed by government authorities. However, in Germany, companies in different industry sectors are certified and thus more firms may have high system intensity in the field of product development. An example is the quality certification from the International Standards Organization (ISO), which is held by many different firms, especially in the high technology and engineering areas. This may be a reason for the lack of significance in the life science sector.

In chapter 5.2.1.2, I focus on the association between early emergence of groups of MCS and thus dynamic capabilities and new venture performance. According to theoretical considerations and the corresponding hypotheses, the early adoption of financial and human resource planning and evaluation skills, as well as strategic planning capabilities, should be positively associated with company growth. Regarding the various statistical tests, the hypotheses are generally supported for the different groups of capabilities in the areas of finance and human resources. However, the tests do not support the hypotheses for strategic planning capabilities. Although the provided figure indicates a better performance for companies that develop strategic planning skills in the second year, the statistical tests do not report any significance. A reason for this outcome could be the fact that strategic planning capabilities emerge in almost all the sample firms in a very short time. Thus, it may be difficult to ascertain any differences with respect to performance based on the underlying observation.

The statistical tests in chapter 5.2.1.3 focus on the sequencing of capability evolution in technology-based new ventures. Here, I expect entrepreneurial firms to develop skills in the fields of strategy, finance, and human resources earlier than for product development, marketing and sales, as well as partnership and alliance management. Reflecting on the statistical tests, the hypotheses hold true for strategic planning as well as for financial planning and evaluation. However, the applied mean comparison tests do not support an earlier emergence of HR management skill. Assuming that the theoretical considerations are valid, start-ups develop either HR capabilities too late or the other three groups of specific skills too early. In any case, the results indicate that human resource management is not a top priority in the sample firms. Reasons can be found in the nature of HR management. First, it is resource consumptive. Managers have to allocate a substantial amount of time to further develop, motivate, and retain their employees. In addition, training programmes for the organisational members are expensive. A second reason for the low priority of HRM is the long-term orientation. Unlike marketing and sales, efforts in this field do not immediately translate into measurable results. However, reflecting on the results of the previous analysis, an early emergence of HR management skills has a positive association with new venture performance.

Turning to the replacement of the CEO, the statistical tests in chapter 5.2.1.4 provide limited support for the initial hypotheses that CEO succession impedes growth. The years before, during, and after the replacement of the founder as CEO show no negative and significant association with organisational growth. However, the growth rates two years before and two and three years after the succession are positively and significantly associated with growth in employees. The indicated significances are not very strong; however, the results cannot be neglected. Consequently, I gain some support for the proposed crisis around the replacement of the CEO in German technology-based start-up firms, which at least does not fuel growth.

The last group of hypotheses focuses on the internationalisation of sales in technology-based new ventures. In this case, I expect international expansion to have a significant influence on the development of marketing and sales capabilities as well as on revenue growth. The regression models provided in chapter 5.2.1.5 support the initial hypotheses. In fact, the years after going international are positively and significantly associated with the emergence of capabilities in the field of marketing and sales. This is in line with the results of the regressions for marketing and sales skills carried out in chapter 5.2.1.1, which report a positive and significant influence of international sales on system adoption and thus on capability emergence. Reflecting on the second hypothesis in this field, the year of international sales expansion and the years thereafter show a highly significant and positive association with revenue growth.

6.2 EXPLORATIVE ELEMENTS OF THE STUDY

In chapter 3.3, I formulated three explorative questions to elaborate further on the emergence of dynamic capabilities and their association with new venture performance. The first question addresses the drivers for capability emergence in different functional areas. The results of the regression models are very different for the eight groups of skills arrived at earlier in this study. In the following, I will comment further on the drivers and their influence on MCS adoption and thus the development of dynamic capabilities in technology-based new ventures.

The first driver is organisational age. Age has a positive and significant association with most functional capabilities. However, for financial planning and strategic planning, age has no significant influence on skill development in technology-based new ventures. A reason for this outcome can be found in the adoption patterns of both groups. Reflecting on chapter 5.1, most of the financial planning and strategic planning systems are adopted very early in the lifetime of the sample firms. In addition, these MCS are adopted by most of the start-ups that were subject to this research effort. Therefore, the intensity will not substantially increase when firms become older. According to the initial hypotheses and the results of the statistical tests in chapter 5.2.1.2, the early emergence of financial and strategic planning capabilities also has a positive influence on new venture performance.

The next explanatory variable for the regression models is organisational size. In the same way as age, the size of the firm is significantly and positively associated with almost all functional capabilities. However, size has no significant influence on the development of strategic planning, marketing and sales, and partnership management skills. For strategic planning, we can use the same explanation as for organisational age. Most sample firms implement these systems very early and thus develop strategic planning capabilities in the early days. For marketing and sales, and partnership management capabilities, the results are surprising. For these skills, it is in fact more a question of age and not of size, whether they emerge in technology-based new ventures.

Venture capital funding has been identified as an important driver for the adoption of capabilities in general. In fact, VC funding is significantly and positively associated with the emergence of financial planning and evaluation skills as well as strategic planning capabilities. For all other capabilities, venture capital is not reported to have a significant influence. The results seem to be quite compelling. First, venture capitalists usually monitor their portfolio companies regularly and therefore focus mainly on accounting information. Thus, they drive the development of capabilities in the area of financial planning and evaluation. In addition, VCs usually grant their investments according to the fulfilment of strategic milestones. They are also highly interested in investment budgets and the venture's human resources development plans, since this is an initial part of organisational development. Thus, they may drive the development of strategic planning capabilities.

Another covariate that has no significant influence on the development of dynamic capabilities in general as well as on most functional skills is the replacement of the CEO. However, regarding partnership management skills, the replacement of the CEO is positively and significantly associated. When the founder is replaced, the new CEO is usually an experienced manager, mostly from a larger company. Although start-up firms engage in partnerships, they are usually not able to manage these alliances effectively due to their minor position, the scarcity of resources, and the purpose of most partnerships. Thus, they usually lack partnership management capabilities. On the other hand, managers leaving a larger enterprise may bring those skills to a start-up firm.

Although CEO experience does not show a significant positive association with capability evolution in general, the influence is significant for strategic planning. The reason may be that experienced managers are generally more used to the planning procedures and routines since they often worked for mature companies before they joined start-up firms. In larger organisations, the planning procedures in general are more sophisticated and more formalised. Thus, experienced managers as CEO tend to deploy these tools in the new organisation as well. Inexperienced young business founders on the other hand may lack planning expertise.

The introduction of a CFO has a positive influence on all groups of dynamic capabilities except for human resource planning. A possible reason for this outcome can be found in the role of the head of finance in a start-up firm. While the CFO often takes care of HR evaluation, human resource planning is usually not part of these competencies. Specific elements such as a mission statement, an organisational chart, or company values are important ingredients of the firm and in most cases developed by the CEO.

The next driver for the emergence of dynamic capabilities is the internationalisation of sales operations. While being associated positively and significantly with most functional capabilities, the regressions do not report any significance for financial planning and human resource planning. In general, we can assume that these capabilities are necessary in any case and are not especially driven by efforts of internationalisation. An operational budget or sales projections are required in any new venture, no matter whether the company operates internationally or not. The same is true for human resource planning. On the other hand, the development of capabilities such as marketing and sales or

partnership management can be driven or substantially influenced by the internationalisation of the business.

The influence of the life science and the software industry is significant for human resource evaluation and the management of partnerships and alliances. The reason for the impact on human resource evaluation skills may be due to the professionalisation of the software and biotech segment compared to other industry sectors. Both sectors are global rather than national industries. In general, these companies have to compete with firms across different countries, sometimes even across continents. This competition is not only focused on customers but also on key personnel. To succeed in this field and attract exceptional people, start-ups have to show professional structures and processes. An important aspect therefore is the evaluation and adequate compensation of human resources. In addition, companies competing in the software or life science industries rely heavily on partnerships. Many software companies need to collaborate with large incumbents such as Microsoft and Oracle to obtain basic resources or to receive legitimisation for their products. Biotech ventures, on the other hand, often engage in product development partnerships that need guidance and alignment from the start due to the high complexity.

The second explorative question addresses the endogeneity of organisational size and dynamic capabilities. While some scholars may argue that size automatically involves the development of certain skills, others may propose that dynamic capabilities actually drive the increase in employees. Reflecting on the results of the simultaneous-equations models in chapter 5.2.2.2, the intensity of management control systems and organisational size develops simultaneously; i.e. it is not possible to differentiate between cause and effect. Applying the derived operationalisation of the concept, the same is true for dynamic capabilities and size. The results are almost identical for capabilities in general and the different functional areas. Only strategic planning indicates a different result. In this case, the emergence of the capability drives the increase in size but not vice versa. This outcome is an indication that the development of dynamic capabilities and an increase in size is heavily intertwined.

The last explorative question focuses on the paths of capability evolution. Here, I intended to identify certain sequences of skill development and link these paths to new

venture performance. According to the analysis carried out in chapter 5.2.2.3, the sequence has a substantial influence on the growth of start-up firms. Companies following a path that matches the resource requirements of new ventures show growth rates that are significantly higher than those firms which apply a different sequence. In fact, start-ups in the best performing group start with financial, strategic, and human resource planning before they focus on financial evaluation. Afterwards, they concentrate on human resource evaluation, marketing and sales, and product development. The last skill set these companies develop is focusing on partnerships and alliances. Unlike the other clusters of firms, this sequence follows a clear logic. In their sequence, the companies in this group acknowledge that the most important resources in the beginning are financial and human resources as well as the foundational technology and the business idea. In addition, they plan for resources before they start evaluating the corresponding results. Consequently, financial and HR evaluation follows planning in the area of finance and human resources. Interestingly, not all companies in the sample by any means follow this almost natural logic, although they all develop certain skills. The reason for this outcome could be due to a lack of entrepreneurial education. Managerial needs of start-up firms represent a topic that has not been covered in most German academic curricula so far.

In addition to the three explorative questions, I reflect on the results of the statistical tests carried out in chapter 5.2.2.4. In this chapter, I analyse the influence of MCS emergence on new venture performance for dynamic capabilities in general, as well as for product development, marketing and sales, and partnership and alliance management skills. Reflecting on all the capabilities, we can see a certain association between skill development and company growth. Thus, the early development of certain capabilities seems to be beneficial for technology-based new ventures. However, to understand further which skills are necessary, we need to discuss the functional areas that have not been subject to the analysis in chapter 5.2.1.2, focusing on financial and human resource management as well as on strategic planning.

Regarding product development, the test does not reveal a significant association between early evolution and growth. Before entrepreneurial firms are able to develop new products and services, they have to invest heavily in the development of a foundational

technology. This task is characterised by high levels of uncertainty and incorporates multiple iterations and product tests as well as various failures. Thus, it takes a great deal of time before profound product development skills have a noticeable impact. The development of management skills in this field and the corresponding implementation of MCS at this point do not offer any benefits for a new venture. Instead, system adoption implies significant costs and formalism that inhibits experimentation and therefore is not positively associated with performance.

The results for marketing and sales are completely different. The tests indicate that companies with substantial skills in year three and four show significantly higher growth rates than firms which lack these capabilities. There are two reasons for this outcome. First, marketing and sales skills do not only incorporate customer linking but also market sensing. The ability to identify market needs is highly beneficial to the success of technology and product development and thus should emerge rather early. Only with a clear understanding for customer needs technology and product development efforts will head in the right direction. Second, most of the key tasks and activities in marketing and sales are routinised and straightforward. Thus, they can be adopted quickly by organisational members. New ventures do not need much experimentation and failure until a practice is found that can be carried out repeatedly. The process of organisational learning can be passed in a short period and capabilities evolve quickly.

Regarding the ability to manage partnerships, the statistical tests do not reveal any difference between firms with high and low MCS intensity. This outcome could have two reasons. First, many new ventures form initial partnerships in order to gain legitimacy. Therefore, the young firm does not need to invest in learning in order to develop certain capabilities in this field. Second, the establishment of partnerships that require substantial learning to develop profound skills, such as product development partnerships, requires much more time.

7 SUMMARY AND CONCLUSIONS

7.1 REFLECTION ON INITIAL RESEARCH QUESTION

Reflecting on the initial research question, I intended to explain the linkage between the evolution of dynamic capabilities, the growth processes of entrepreneurial firms, and firm performance in terms of growth. By deriving and applying a concrete operationalisation to track the development of specific skills in technology-based new ventures I was able to denote the growth processes of entrepreneurial organisations by observing the evolution of dynamic capabilities in these firms. Therefore, I theoretically derived how an increase in imposed challenges caused by factors such as age, size, or organisational structure generally requires the creation of different capabilities in small growing firms and how other specific drivers could influence the development of these skills. In addition, I provided further insight into this relationship by denoting the simultaneous development of capabilities and increase in size.

How this link affects performance is another important element of this dissertation. I was able to show that the early development of certain capabilities but also important events had an impact on performance. In addition, I demonstrated that the sequence of capability evolution, and thus the growth path of the new venture, has a substantial influence on early performance. Summing up, this dissertation offers many results that help answering the initial research question. However, there is also room for future research in this direction.

7.2 CONTRIBUTION

The contribution of this research effort is two fold. On the one hand, I contribute to theory. On the other hand, the study revealed several insights that are also of interest for practitioners such as founders, venture capitalists, or venture coaches. In the following sections, I reflect on these contributions.

7.2.1 Theoretical Contribution

The theoretical contribution of this research is threefold. The first aspect addresses the research design. In this study, I model the growth processes of entrepreneurial firms. This process has been subject to various research efforts during the past decades. However, this study takes a different perspective on the growth of start-up firms. By choosing a longitudinal research design, I account for the dynamisms of new venture creation and implementation. Thus, I am able to denote the growth processes of technology-based new ventures.

To track the development of the young growing firm, I operationalise an important strategic management framework, namely dynamic capabilities. By conceptualising the development of dynamic capabilities with double-loop learning and the adoption of management control systems, I am able to track the emergence of important skills in entrepreneurial firms over time. Due to the high level of detail, the development of specific capabilities can be observed in all relevant functional areas of the young growing firm. This approach offers new insights into the complex growth processes of technology-based new ventures.

As a third theoretical contribution, this study applies empirical data from a representative sample of organisations to model the growth processes of entrepreneurial firms. Thus, the conducted statistical analyses have predictive power and can serve as a basis for future research efforts in this direction. In addition, the research design reveals interesting influences on the growth of start-up firms. Hence, the study does not only validate the process of venture creation and implementation, but also identifies external and internal linkages of the dynamic evolution of entrepreneurial firms in technology industries.

7.2.2 Practical Contribution

7.2.2.1 Implications for Entrepreneurs

The empirical validation of the growth process of entrepreneurial firms incorporates different valuable implications for business founders as well. First, the study may change the entrepreneur's attitude towards higher-level learning and the development of dynamic

capabilities. As founders are often occupied with various operational tasks, they often lack the time to analyse the situation of their business and determine the next important steps in order to sustain growth. This study sheds light on the evolution of dynamic capabilities and their importance for the young growing firm, and thus may motivate business founders as well as managers to engage actively in the development of specific skills.

This research effort may also increase the understanding of the different priorities and requirements in the various functional areas of start-up firms. An example is the necessity of extensive experimentation in product development, while in other areas repeated practices can be identified fast and implemented accordingly. Other important aspects include the performance implications of international sales expansion and the necessity of fast and professional CEO succession, in case the company needs further management capabilities that cannot be provided by the current management. Finally, management teams may acknowledge the importance of certain resources at specific levels of company evolution and therefore, think about the sequence of skill development in technology-based new ventures.

Entrepreneurs may use the results as indicators for the learning efforts in their own companies. By comparing their level of management control systems with the outcomes of this study, management teams may be triggered to invest in learning efforts in order to develop further valuable dynamic capabilities in different functional areas. Thus, the details on management control systems provided with this document may be applied as checklists for entrepreneurs. On the other hand, founding teams can shift resources when they are about to invest in the development of skills that are not yet needed.

7.2.2.2 Implications for Venture Capitalists and Other Stakeholders

The study reveals the existence and importance of dynamic capabilities in entrepreneurial firms, which are based on organisational learning. Venture capitalists contribute partially to these learning efforts in entrepreneurial firms. The results of the statistical tests indicate that VCs only influence the development of capabilities in the area of finance and strategy in technology-based new ventures. Although the study shows that financial planning and evaluation skills have a significant association with new venture

performance, this result is not very flattering for the German venture capital industry. In fact, this outcome emphasises the assumption that VCs drive learning in those areas where it facilitates their monitoring efforts and investment contract development. In other functional areas, the impact of venture capital funding is not significant. This is especially true for human resource management as well as marketing and sales practices. In these areas, the study reveals that MCS adoption and thus capability development is beneficial in the early years. Unfortunately, many entrepreneurs do not possess these functional skills and must rely on the advice of experienced coaches.

Consequently, not only venture capitalists, but also business angels, consultants, incubators, and science parks, should facilitate the development of these dynamic capabilities in technology-based new ventures. Since dynamic capabilities stem from second order learning, learning support should be considered as a key service for all individuals and entities providing funding and management support to entrepreneurial firms. In addition, entrepreneurial education should prepare future business founders for the establishment of a learning environment and the development of dynamic capabilities in their businesses.

7.3 LIMITATIONS OF THE STUDY

Although this study incorporates various implications for researchers and practitioners, it has some limitations as well. First, I conceptualise the emergence of dynamic capabilities by tracking the adoption of management control systems in technology-based new ventures. I apply resource-based frameworks to link organisational learning and dynamic capabilities with the adoption of management control systems. This construct is theoretical, i.e. the study lacks a direct cause-effect relationship. This gap may incorporate "noise" which cannot be filtered out and the introduced theoretical bridge may thus influence the results in a way that has not been initially intended. In the context of this study, a direct relationship would link new venture performance with the emergence of dynamic capabilities in the entrepreneurial firm.

Second, the possibility of generalising the results for all technology-based new ventures is limited. There are two main reasons for this argument. First, the study focuses on venture

capital backed firms in the Munich region. Although this area shows high entrepreneurial activity, it is not comparable to similar clusters in the UK or especially in the US. The German VC industry does not have a long history and is much smaller than in other European countries or in the US. Compared with large banks or state banks, the importance of venture capital in Germany is rather limited. In addition, the "burst of the bubble" hit Germany much harder than, for example, the US. While in the Silicon Valley, the IPO market for start-up firms has reasonably recovered, the German index for technology firms, the *Neuer Markt* has ceased. A comparable study among technology-based new ventures in Northern California revealed the significant differences between entrepreneurial firms in Germany and the US. The organisations vary significantly in terms of funding volume, CEO succession, size, and performance. A second drawback is due to the relatively small sample size. Although the response rate can be considered as high for a study of this type, the absolute number of participants may still be too low to generalise the results.

7.4 DIRECTIONS FOR FUTURE RESEARCH

Three main directions for future research result from this study on dynamic capabilities and the growth of technology-based new ventures. Although the simultaneous-equations models applied in chapter 5.2.2.2 provide preliminary evidence for the simultaneous evolution of size and capabilities, further research is required regarding the endogeneity of capability emergence and organisational size. There are different requirements for such a study. First, it has to be a longitudinal survey. Second, the design of the research must enable a much more accurate and frequent recording of skill development on the one hand and new venture performance on the other. Only then might the study allow for accurate conclusions towards the impact of dynamic capabilities on growth. However, a more detailed research design is not necessarily sufficient to solve the endogeneity problem. Triangulation may be an appropriate means to develop an understanding of the causes and circumstances of skill development. Therefore, the sampling of the participating firms must be similar to case study research, which increases the research effort tremendously.

A second direction of research could incorporate an international comparison of technology-based new ventures with respect to the emergence of dynamic capabilities. Therefore, entrepreneurial firms in different regional clusters of high entrepreneurial activity must be sampled in the same way. Possible locations might include the Silicon Valley region and Route 128 in the US, as well as Cambridge or London in the UK. A thorough international comparison may shed light on the regional differences between start-up firms and thus the influence of the environment on the dynamic growth processes of technology-based new ventures. This effort could distinguish the findings that can be generalised from those that cannot be applied to every young growing firm regardless of its location.

A third direction for future research might include studies in a similar context but with a different operationalisation of dynamic capabilities in technology-based new ventures. While this study applied second order learning and the adoption of management control systems to conceptualise the development of dynamic capabilities in entrepreneurial firms, future efforts might use different approaches for a similar purpose. A comparison of the results might indicate the appropriateness of the operationalisation that was used in this study.

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CURRICULUM VITAE

Florian Thomas Strehle was born on August 6, 1975 in Munich, Germany. In 1996, he attended Technische Universität München to study mechanical engineering with a focus on construction and development. Florian graduated in 2001 as Dipl.-Ing., which is equivalent to a M.Sc. degree. During his studies, he participated in various research efforts on virtual and augmented reality in the field of production engineering at the Institute for Machine Tools and Industrial Management at Technische Universität München. In 2001, Florian joined McKinsey & Company, an international strategic management consultancy. As a member of their European high tech core group, he participated in various international projects in the private equity, telecom equipment, mobile and fixed line operator, semiconductor, and industrial high tech space.

In 2003, Florian took a sabbatical to join Prof. Bernhard R. Katzy at the Centre for Technology and Innovation Management (CeTIM) at the University BW in Munich, Germany and at Leiden University, the Netherlands as an external researcher. With a special interest in entrepreneurship and the development of technology-based new ventures, he participated in the Stanford Entrepreneurial Management Systems Project (SEMAS) covering the area of Munich in the course of this international research effort. In 2004 and again in 2005, Florian visited the Center for Entrepreneurial Studies at the Stanford Graduate School of Business on invitation of Prof. George Foster.

In 2005, Florian restarted working at McKinsey & Company before joining 3i Group in their global venture capital team where he now focuses on early and late stage investments in the area of clean technologies and IT. In 2006, Florian co-authored several publications with Prof. Bernhard R. Katzy, e.g. a chapter in the forthcoming multi-volume set “The Creative Enterprise” edited by Prof. Antonio Dávila, Prof. Marc J. Epstein, and Robert Shelton.