Entrepreneurial Networks of University Spin-offs

How Social Networks Affect the Growth of Firms

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"The value of a social network is defined not only by who's on it, but by who's excluded"

Paul Saffo
in The Economist

Chapter 1

INTRODUCTION

1.1 Introduction

Since the beginning of this century, those developing regional policies in many countries have pursued, among other things, the goal of attracting and supporting knowledge-based industries. Attention for supporting growth of technology-based firms fits into the policy belief that future regional growth is driven by new knowledge and innovation (OECD, 2001). In this policy framework, universities are seen as an important actor as they take part in the creation of university spin-offs (Shane, 2004). Although the size of the impact of university spin-offs is small in terms of aggregate employment, university spin-offs may significantly contribute to the creation of high-skilled jobs through sub contracting relations, and to the transfer of knowledge from university to market (Rothwell and Zegveld, 1985; Mansfield, 1998; Martinelli et al., 2008). University spin-offs which have technology as the core of their business can, if they are clustered in space, increase the competitive edge of development regions (Keeble and Wilkinson, 1999; Knie and Lengwiler, 2008; Mustar et al., 2008).

Despite the propagation of university spin-offs, progress in finding effective ways to support growth of these spin-offs has been relatively slow and there are few success stories (Colombo and Grilli, 2006; Shane, 2004). Mustar et al. (2007) observe that university spin-offs in Europe do not show high job growth, although, more than 75% of spin-offs in European countries were still extant six years after establishment. By and large, there is one common theme in these studies and that is that failing to acquire critical resources may prevent the growth of university spin-offs. Even though resources are strongly required, unfortunately, university spin-offs generally do not have the capability to generate resources internally. Furthermore, finding external resources is also difficult since being a new venture, university spin-offs often lack legitimacy among potential resource providers (Aldrich, 1999). Therefore, university spin-offs may seek support through their (previous) networks such as friends, family, and former colleagues. Additionally many spin-off founders form relationships with other entrepreneurs and business people in their environment which allow them to learn and adopt best practices for running a new venture.

Although social networks can be used as a way of accessing resources for growth, it is still not clear how social networks influence the growth of university spin-offs. The fact that access to diverse knowledge and endorsement are often acquired through social networks, and since access to such resources may influence the growth (Stuart et al., 1999; Burt, 2000, 2005), means that it is important from an academic and policy perspective to examine the role of social networks in the growth of university spin-offs (Gübeli and Doloreux, 2005). Based on this argument, the influence of four characteristics of social networks, i.e. structural characteristics, relational characteristics, heterogeneity in the background of

partners and spatial orientation, and other factors, i.e. risk profile of strategy, level of capabilities, resources deficiency and added value support, on the growth of university spin-offs were examined in this study.

1.2 Theoretical perspectives in understanding growth

Two theories, i.e. Resource-Based View (RBV) and Social Networks Theory (SNT), were selected in this study because they complement each other in explaining the growth of university spin-offs. Literature in strategic management shows that many theories, such as knowledge-based theories, dynamic capability, and strategic alliance have been developed over the years to help understand the growth of firms (Gilbert et al., 2006). Basically, all of these theories are rooted in the RBV theory introduced by Penrose (1959). Penrose's seminal work has been instrumental to the on-going development of RBV theory and it is applied in many fields such as strategic management, organization studies and marketing (Priem and Butler, 2001). According to RBV theory, firms can be conceptualized as a heterogeneous bundle of assets or resources tied to the management of firms (Barney and Clark, 2007). Firms search for and acquire resources as inputs and convert them into products or services for which revenue can be obtained. Resources such as capital and access to research facilities are needed while the capability to identify market opportunities, skills in managing a new firm, and networking skills are also important.

As RBV theory mainly focuses on internal capabilities that are generated and controlled by firms, the process of acquiring external resources cannot be understood solely by using RBV theory. SNT theory offers an explanation for the way university spin-offs acquire external resources. There are many studies that can be found in the literature about the role of social networks as a source of firm's competitive advantage (Gulati et al., 2000; Stuart and Sorensen, 2008). The locus of innovation is no longer the firm but, increasingly, the networks in which the firm is embedded in (Powell et al., 1996; Baldwin and Clark, 2000). Nicolaou and Birley (2003) found that family, friends and colleagues supply information, advice and provide opportunities for new firms regarding their business ventures. Johannisson (1990) and Nicolaou and Birley (2003) found that social networks provide access to financial resources and help new firms solve technical and operational problems. This allows new firms realize the increasing need for effective networks, and to acquire information and knowledge required for growth.

1.3 Characteristics of social networks and the growth of university spin-offs

The network approach is not new, but recently studies that focus on networks and relationship between individual and organization have increased drastically (Hoang and Antoncic, 2003; Parkhe et al., 2006). Yet, despite the pervasion of network concept and its increasing popularity, there is still a considerable disagreement and confusion concerning the roles of the particular characteristics of the social networks (Steir and Greenwood, 2000; Hite and Hesterly, 2001). In addition, scholars, e.g. Gargiulo and Benassi (2000a) and Hansen (2002), have started to recognize the 'dark side' of networks which may result in, for example, significant costs, risks, and lock-in effects, that may overshadow the benefits

associated with social networks. From the review of the current literature on social networks, there are at least four subjects of debate found which will be discussed in the following section.

The first subject of the debate is concerned with the spatial orientation of social networks. Social networks may be perceived as a concept of 'thickness' which is frequently discussed under the theme of agglomeration (Amin and Thrift, 2002; Oinas and Malecki, 2002; van Oort, 2004). 'Thickness' is represented by social cohesion and seen to encourage trust, cooperation, intense information exchange and sharing among local actors in city or regions. A strong orientation on local partners can generate positive effects, which may underpin innovation and growth of firms (Löfsten and Lindelöf, 2005), however, scholars have recently reemphasize that an external orientation may also be necessary to support growth (Bathelt et al., 2004). New information and knowledge that leads to opportunities are often delivered from non-local partners. In the case of university spin-offs, an external orientation, indicated by the presence of non-local partners in networks, appears to be important. Spin-offs which develop innovative products and services, sometimes need to develop global networks as a way to transfer state-of-the-art knowledge. In some cases, university spin-offs receive benefits from their global networks in terms of opening new opportunities and achieving significant competitive advantages in countries around the world (McDougall et al., 1994; Rasmussen et al., 2002). Interaction with non-local/global partners is no longer difficult. Modern transportation and high-speed telecommunication facilitate interactions with partners in other parts of the world, teleconference technology may substitute a part of face-to-face interactions while email exchanges are frequently used to manage project teams whose members are geographically separated (Malecki, 2002; Loane, 2005). Increasingly research collaborations are conducted at a distance, as shown by the slight decrease in importance of local networks on the basis of publications and patent citations (Ponds and Van Oort, 2006).

The literature also witnesses the debate concerning specific characteristics of social networks, namely structural and relational characteristics that create benefits for firms (Adler and Kwon, 2002). Some scholars, e.g. Burt (2000, 2005) and Baum et al. (2000), propose that benefits are created based on the structural characteristics of networks. Other scholars, e.g. Podolny and Baron (1997) and Granovetter (2005), argue that the relational characteristics of networks can also provide benefits. While the debate among scholars about whether the structural or relational characteristics have a positive influence on growth has not reached a conclusion, certain aspects within the structural and relational characteristics that influence growth are also not clear. For instance, the question arises as to which structural characteristics of networks such as tight or loose networks, have a positive influence on growth. Coleman (1988, 1990) suggests that tight networks can reduce the risks of uncertainty, create trust and efficiency when transferring information and knowledge. Loose networks enable the discovery of opportunities because they serve as a bridge to new and different information (McEvily and Zaheer, 1999). Some scholars, however, think that relational characteristics are more beneficial for supporting growth. Yet, scholars still differ on whether strong or weak relationships are more important. Granovetter (2005), for instance, argues that new information is obtained through weak ties

rather than through strong ties. Since strongly connected actors are likely to interact frequently, much of the information that circulates in the social system is redundant. Other scholars, e.g. Coleman (1990), favor strong ties because they can facilitate trust, commitment, transfer tacit knowledge and facilitate willingness of actors to support each other reciprocally.

Aside from the structural and relational characteristics of social networks, the literature shows general agreement regarding the positive impact of heterogeneity in partners' backgrounds on growth. Although, managing and maintaining networks of partners that consist of people from different background may create costs that surpass benefits, many studies emphasize the benefits of heterogeneous partners for growth, e.g. Beckman and Haunschild (2002). Steir and Greenwood (2000) suggests that to overcome the liability of newness, firms should develop a network that is diverse rather than uniform. Firms with partners from different backgrounds enjoy a variety of partners' resources, including experience, information and knowledge. Summarizing this, it seems that the different ideas among scholars point to the need for further studies to deepen the knowledge about the influence of social networks for stimulating growth.

Reviewing the current state of networks studies give rise to several reasons that are relevant and may be the cause of the lack of knowledge on this subject. First, studies on this subject suffer from a lack of solid empirical studies of university spin-offs. Although various authors see networking as a key feature in explaining the nature of newly established firms and in predicting their future success, i.e. Larson and Starr (1992), very few studies focus on social networks of university spin-offs, except for Perez and Sanchez (2003), Markman et al. (2005), and Scholten (2006). The fact that university spin-offs have distinctive characteristics compared to other startups and face relatively high obstacles may indicate an important role for social networks when a firm is gathering resources. Secondly, the studies that have been conducted focus mainly on a single characteristic of networks and few studies have analyzed the combined effects of these network characteristics on the growth of university spin-offs. Previous studies have emphasized one particular dimension and ignore the others. The fact that social networks can be described using some different characteristics is barely touched in the literature. Thirdly, a relatively few empirical studies have been conducted to analyze the role of networks in different social and economic conditions, such as the location of spin-offs or the development stage of spin-offs. Given the differences on the argument among scholars, it may be the case that firm's network will impact differently in different conditions (Gilsing et al., 2008; Jack, 2008).

1.4 Research questions

Given the above discussion, the aim of the study was to clarify the debate concerning the importance of the different characteristics of social networks in the growth of university spin-offs. Thus, the following main research question was posed:

How do social networks influence the growth of university spin-offs?

The main research question consists of two components, social networks and growth of university spin-offs. In order to answer the main research question, two sets of questions were formulated. The first set consisted of the following questions:

> What is the growth of university spin-offs, in particular, how does the pattern of obstacles faced by university spin-offs change overtime?

Growth is a multidimensional phenomenon and it can be measured in many different ways, however, there is little agreement among scholars concerning the best indicator to use to measure growth in entrepreneurship studies (Murphy et al., 1996; Weinzimmer et al., 1998). An indicator such as increase in employment, i.e. job growth, is frequently used, however, solely using this indicator may not be enough to describe the growth of university spin-offs. A new trend of growth emerges in the form of business networking activities such as sub-contract agreements and outsourcing activities (Davidsson et al., 2007). Moreover, growth can also be described as a process of acquiring resources. Growth can get stuck if firms fail to acquire the necessary resources. Based on the above explanation, growth is explored in three ways. One, growth in this study was measured using job growth. Two, growth was also measured in terms of spin-offs' activities in building and expanding business networks as suggested in the current trend. Three, an attempt was made to understand growth by exploring the obstacles experienced by university spin-offs over time. The latter measurement was aimed at understanding growth as a process of reducing obstacles to gain resources for growth.

The second set of questions was aimed at improving the understanding of the characteristics of social networks that effectively support growth. The following set of questions was formulated.

> What are the characteristics of social networks of university spin-offs, to what extent, and under what conditions, are the characteristics of social networks beneficial for growth?

The aim of these questions was to reveal the characteristics of the social networks that are developed and maintained by university spin-offs. The importance of network characteristics on growth is addressed in this study and four characteristics of social networks are identified. The conditions under which social networks and other factors provide positive benefits to growth are also explored (Mehra et al., 2006; Oh et al., 2004). Spin-offs may operate in a different condition and potentially, not all network characteristics will be equally beneficial for spin-offs (Peng and Luo, 2000; Zaheer and Bell, 2005). In this study, there were two conditions that were argued to shape the characteristics of networks and their influence on growth: the level of urbanization where spin-offs are located and the development stages of spin-offs. Regarding the level of urbanization, it was assumed that social networks of spin-offs in metropolitan areas have different characteristics and offer different benefits compared to those in non-metropolitan areas. Spin-offs in metropolitan areas have larger opportunities for networking compared to those in non-metropolitan areas. In addition, the social networks of spin-offs in the early stages may be different

compared to those in later stages. Spin-offs in the early stages may rely on their close networks such as friends and colleagues from university to solve problems such as difficulty in penetrating the market, a lack of entrepreneurial knowledge and technical problems in product development. Spin-offs in the early stages may still in the process of developing networks while spin-offs in later stages have experience on networking and able to establish effective networks for supporting their growth.

1.5 Contribution of the study

The purpose of this study was to make a contribution to the theory of university spin-offs' growth and practice of supporting spin-offs. At the theoretical level, the contribution of this study was aimed at three fields, namely social networks, the concept of agglomeration (metropolitan and non-metropolitan areas) and studies on the growth of university spin-offs.

The first theoretical contribution was to deepen the knowledge on the role of social networks in growth given different conditions. This study tried to extend recent efforts in clarifying the different arguments in social network theory, e.g. tight versus loose networks, strong versus weak ties, and internal versus external orientation of networks by analyzing the impact of various social network characteristics under different conditions. Secondly, the classic argument in the literature about the advantages of being located in metropolitan areas was challenged. Focusing on the characteristics of social networks, a strong suggestion that metropolitan areas do not offer advantages to growth was found. Alternatively, it was found that networks developed by spin-offs and university incubators can be used to overcome the disadvantages of being located in a non- metropolitan area. The differences in characteristics and the importance of social networks in the growth of spin-offs in metropolitan and non-metropolitan areas were revealed by this study. The third theoretical contribution was to improve the empirical knowledge on the growth and the time-patterns of obstacles faced by university spin-offs. University spin-offs are believed to face a great number of obstacles, but the nature and trends of these obstacles are not yet understood clearly in the literature. The aim of this study was to improve the understanding of the growth of university spin-offs by clarifying particular problematic stages in the growth of university spin-offs and exploring trends in obstacles to growth using both cross-sectional and longitudinal data. The findings of the analysis may also give an additional explanation on the difference between social network characteristics of spin-offs at different development stages.

The overall findings of this study can be used to improve the practice of supporting university spin-offs (Wright et al., 2006). This is particularly important since there is a strong need to improve support to university spin-offs (Lockett et al., 2005; Fini et al., 2009). Studies on the growth of spin-offs to date have primarily discussed the incubation process in terms of organization, process and financial aspects and only a limited number of studies have examined the aspect of added value support such as improving the quality of social networks related to growth (Totterman and Stern, 2005; Hughes et al., 2007). Exploring the influence of social networks can be used as a basis for suggestions to improve the network support provided for university spin-offs through incubation programs.

1.6 Research approach

In this study, social networks are defined as personal networks of important partners that potentially provide knowledge and information beneficial for growth. Scholars, e.g. Larson (1992) and Nicolaou and Birley (2003), have found that the most important ties of new firms are generally dominated by social networks, and these networks are defined on the level of spin-offs consisting of personal ties between entrepreneurs and their partners. Social means that these networks initially develop through social relationships but overtime the networks are used to discuss business matters. Conversely, networks may first start as business networks, e.g. relationship with business angel and investor, but later gain a strong social and informal component. This study is focused on network partners such as family, friends, colleagues, and former professors, through whom university spin-offs attempt to get essential knowledge or information on gaining access to critical resources. In other words, the networks of university spin-offs in the form of knowledge networks were explored in which knowledge or information is the content that is transferred.

The research approach of this study starts with a review of the relevant literature to determine the current state of research in the field and to build the theoretical construct used as the foundation of this research. To enrich the understanding of the subject, interviews were conducted with experts and policy makers. As a result, several hypotheses concerning the growth of university spin-offs were developed. Before conducting an empirical study to test the hypotheses, a framework for a case study selection of university incubators was developed and two potential candidates were selected for further fieldwork. The empirical study on networks and growth of university spin-offs was performed following the selection process. Besides interviews, other data sources, e.g. spin-offs' website, discussion with incubator managers and faculty officers, were used to increase the quality of the data. The hypotheses were tested in the analysis using several models of regression analysis (Aiken and West, 1991).

1.7 Outline of the thesis

This study is organized into 8 chapters. The elaboration of two theories used in the study is presented in chapter 2. Following the theoretical discussion, factors that hypothetically influence the growth of university spin-offs are presented in chapter 3. In total, there were nine hypotheses constructed and tested in this study. The research design is presented in chapter 4. In this chapter, the two steps of the research design are presented, including a discussion of the sampling methods, variables and method of analysis that were employed. The framework of the case study selection of incubators is presented in chapter 5. A meta-analysis study on the incubation process was conducted and two university incubators were selected based on two factors, i.e. model of stakeholder involvement and level of urbanization. The growth of university spin-offs is examined in chapter 6 in terms of pattern of obstacles, job growth and growth in business networks. A critical year in the growth of university spin-offs was identified as a result of the analysis of pattern of obstacles. This result underpins the division of university spin-offs into those in an early stage and those in a

later stage. The descriptive analysis of the characteristics of social networks profile in two conditions, namely a different level of urbanization resulting from the analysis in chapter 5 and development stages resulting from the analysis in chapter 6, are presented in chapter 7. Six linear regression models were developed to test the influence of social networks on growth. In addition, several models were developed to explore the interaction effect and non-linear relationship of several factors on growth. Finally, the conclusion and recommendation of the study are presented in chapter 8.

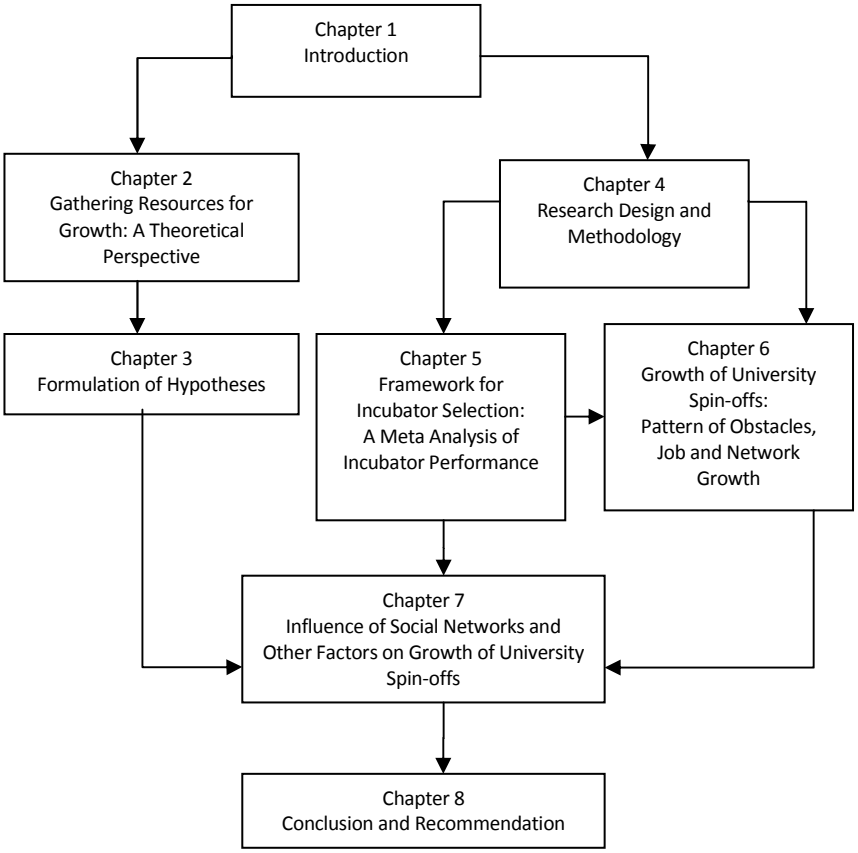

Figure 1.1 Structure of the thesis

Chapter 2

GATHERING RESOURCES FOR GROWTH: A THEORETICAL PERSPECTIVE

2.1 Introduction

The two theories, Resource-Based View (RBV) and Social Network Theory (SNT), that were employed to develop hypotheses are discussed in this chapter. RBV was used because it argues that the growth of university spin-offs is determined by the spin-offs' ability to access critical resources while SNT was employed to understand the nature of interactions between university spin-offs and their partners (social networks) in getting access to resources. This chapter starts with a discussion of the conceptualization of university spin-offs in section 2.2. It is followed by a discussion of RBV in section 2.3 and SNT in section 2.4. A summary of the discussion is given in section 2.5.

2.2 Conceptualization of university spin-offs

The conceptualization of university spin-offs used in this study is discussed in this section. A clear conceptualization is important since this will determine the results and interpretations of the study. The different forms of conceptualization of university spin-offs found in the literature are shown in table 2.1. It appears that there are many different concepts of university spin-offs, although a detailed examination reveals some similarities (Pirnay et al., 2003). There are three dimensions, namely (1) spin-off creation processes, (2) status of founders and (3) types of technological content, commonly used to develop the conceptualization of university spin-offs.

Concerning the spin-off creation process, most of the concepts agree that to be a university spin-off, knowledge must be transferred from the university or research center to the new firm. In other words, university spin-offs are trying to commercialize research and innovations that were developed within a university and/or a research center. While most authors have a common understanding regarding the process of creation, there are different arguments concerning the status of founders. Some authors define university spin-offs as firms founded by academic staff members, e.g. Steffensen et al. (2000) and Crayannis et al. (1998), while others, being less strict, include students as founders, e.g. Smilor et al. (1990) and Bellini et al. (1999). Others have not considered the status of the founders as long as the knowledge that is commercially exploited comes from the university, e.g. Klofsten (2005) and Roberts and Malone (1996). Moreover, the creation of spin-offs can be seen as a process in which founders have to leave the university or research institute to manage their own firms, e.g. Carayannis et al. (1998) and Steffensen et al. (2000), or founders may have a parallel job at university and at spin-offs, e.g. Smilor et al. (1990). In several countries, the civil servant status of academic staff prevents them from taking part in the creation of

university spin-offs to transfer their research results. However, there are some recent developments in countries such as France, Italy and Belgium. In France, this status has been amended, so that academic staff can now establish a firm and leave their laboratory without losing their status. They even have a possibility of returning to their institution in case of failure (Wright et al., 2007).

Table 2.1 The conceptualization of university spin-offs in the literature[a)]

Authors	Conceptualization of university spin-offs
Smilor et al. (1990)	A company founded by a faculty member, staff member, or student who leaves the university to start a company or who starts the company while still being affiliated with the university; and/or around technology or technology-based ideas developed within the university.
Carayannis et al. (1998)	A new company formed by individuals who are former employees of a parent organization (the university), around a core technology that originates at the parent organization and that is transferred to the new company.
Bellini et al. (1999)	Companies founded by university teachers, researchers, or students and graduates to exploit commercially results of research in which they might have been involved at university, the commercial exploitation of scientific and technological knowledge is realized by university scientists, i.e. teachers or researchers, students and graduates.
Clarysse et al. (2005)	A new company set up by a host institute, i.e. university, technical school, public/private R&D department, to transfer and commercialize inventions resulted from the R&D efforts of departments.
Klofsten (2005)	A new firm or organization exploiting research results produced by universities.
Steffensen et al. (2000)	A new company formed by individuals who are former employees of a parent organization that has a core technology that is transferred from the parent organization.
Roberts and Malone (1996)	A company formed with the involvement of four principal parties: technology originator, entrepreneur, R&D organization and venture investor.
Nicolaou and Birley (2003)	A company formed by three different scenarios involving academic inventors. An orthodox spinout involving both the academic inventor(s) and the technology spinning out from the institution. A hybrid spinout involving the technology spinning out and the academic(s) retaining his or her university position, but holding a directorship, membership of scientific advisory board or other part time position(s) within a company. A technology spinout involving the technology spinning out, but the academic(s) maintain no connection with the newly established firm.
Perez and Sanchez (2003)	A company arising when an entrepreneur leaves a university to start a firm of her/his own.
Pirnay et al. (2003)	New firms created to exploit commercially some knowledge, technology or research results developed within a university

a) Source: partly retrieved from Pirnay et al. (2003)

Looking at types of technological content, Steffensen et al. (2000) argue that university spin-offs are companies with an objective to commercialize core technological ideas based on patents and licenses. Defining rather broadly, Smilor et al. (1990) consider not only technology based on patents and licenses but also scientific know-how or non-patented technology generated at a university and/or research institute.

Following the analysis by Pirnay et al. (2003), university spin-offs in this study are conceptualized as independent technology-based firms founded by academic entrepreneurs with the objective to commercialize knowledge developed at university or research institute. Concerning the origin of founders, university spin-offs in this study are defined as firms established by academic staff members, students, and graduates or in a team of founders.

Firms whose founders are external entrepreneurs, without any links with the university, that just buy patents from the university are excluded. In establishing university spin-offs, the founders may retain their position at university while at the same time pursuing commercial opportunities. Regarding the knowledge that is commercialized, this study covers a relatively broad area, i.e. patented technology and knowledge accumulated by the founder(s) during their academic activities, nevertheless service companies without technological content such as management consultants and trading companies are excluded in this study. Making a strict conceptualization based on types of technology is difficult as spin-offs can simultaneously have different business models (Stankiewizc, 1994). University spin-offs often start with developing products based on patented technology and at the same time use consultancy work as a means to generate income.

2.3 Resource-Based View (RBV)

The relevance of the Resource-Based View as a means to explain the growth of university spin-offs is discussed in this section. The question of why some firms survive and grow better than other firms has been the subject of study among scholars for many years (Dierickx and Cool, 1989; Amit and Schoemaker, 1993; Collis and Montgomery, 1995). Despite the fact that this subject has been studied from many different perspectives, it seems that there is no clear answer. In understanding the growth of firms, most studies have returned to Penrose's Theory of the Growth of The Firm, which first appeared in 1959. Penrose (1959) conceptualizes firms as a collection of productive resources, tangible and intangible, tied to the firm's management. Accordingly, she provides explanations that clearly define the links between resources and competitive advantages. Firms acquire or search for resources as inputs and convert these into products or services for which revenue can be obtained. Although the RBV has been mainly applied to large and multi-business organizations, many recent studies in entrepreneurship and small business have started to use RBV as a framework to understand growth (e.g. Alvarez and Busenitz, 2007).

In the elaboration of this perspective, two scholars have expanded the original ideas of Penrose into two fundamental schools of thought, that is Wernerfelt (1984, 1995) and Barney (1991). Wernerfelt (1984) emphasizes the relationship between resources and diversification in the strategy of firms, while Barney (1991) extends the understanding of firms' resources from the perspective of competitive advantage. Overall, the RBV has a significant contribution on how competitive advantage can be achieved and how that advantage can be sustained over time (Prahalad and Hamel, 1990). The focus is therefore on the internal organization of the firm and resources are broadly defined as tangible, human, organization and intangible assets. In this view, the notion of resource idiosyncrasy plays a prominent role. Firms which possess resources that are valuable, rare and inimitable and non substitutable can achieve sustained competitive advantages because these resources enable them to implement value-creating strategy that cannot easily be duplicated by competitors (Barney and Clark, 2007). Over the years, the RBV has become popular in the field of management and many empirical studies have been conducted to support the ideas. Barney and Arikan (2001) find that only four percent results (from 166 empirical articles) are partially inconsistent with the RBV. Recently, some debate has emerging in the literature on

the RBV. The debate is concerned with the validity of studies in measuring the core idea of the RBV. The key test of empirical studies' findings is the extent to which these findings can be generalized, hence there is a paradox in the concept of the RBV. Competitive advantages can be achieved based on firm's idiosyncratic resources, yet they, by definition, cannot be generalized (Gibbert, 2006; Newber, 2007). Given this difficulty, this study does not aim to specifically measure the firm-idiosyncratic resources that contribute to growth. In fact, in this study the profiles of the social networks are described using broad categories of networks, just to enable a comparative analysis.

Search for resources: development stages

To understand the growth of firms, different models have been developed over the years. One of the first models was proposed by Kazanjian (1988) who identifies growth as a linear process. The basic assumption of this model is that growth is characterized by regularities, and these regularities can be segmented into discrete stages (Dodge and Robbins, 1992). Each growth stage is described as a period of relatively stable growth, followed by a crisis or obstacles. If spin-offs have overcome these obstacles, they can go to the next stage. Scott and Bruce (1987) improve the early models by arguing that firms do not move through their development at the same rate of time. Instead, firms can stay in the same stage for a considerable period of time. Recently, Vohora et al. (2003) have proposed that each stage of growth involves an iterative or non-linear process of development in which there may be a need to move back to earlier stages.

Looking at those models, it can be seen that most of the early models lack a solid theoretical foundation. The models are not built on a conceptual common ground that integrates them into the growth theory of the firm. The only model that is based on existing theory of the firm was developed by Garnsey (1998) and Reid and Garnsey (1998). They propose a stage model of firm growth based on the Resource-Based View and see growth as a series of different development stages in which resources are acquired (Figure 2.1). These development stages include resources access, resources mobilization, resources generation, growth reinforcement and growth reversal. The key assumption is that different needs for resources and the capability to access critical resources from the external environment lead to different growth paths and degrees of success. A lack of this capability can cause a stop in growth, either by the firm entering a relatively steady phase or by it falling back to a previous stage. To be able to progress through different phases of development, newly established firms need to organize access to resources, such as new knowledge, laboratory room and equipment, investment capital, qualified employees, etc. At the same time they need to acquire particular capabilities through learning. Indeed, growth paths may be full of iterations. For instance, failure in the phase of resources generation may imply a return to the mobilization of resources phases.

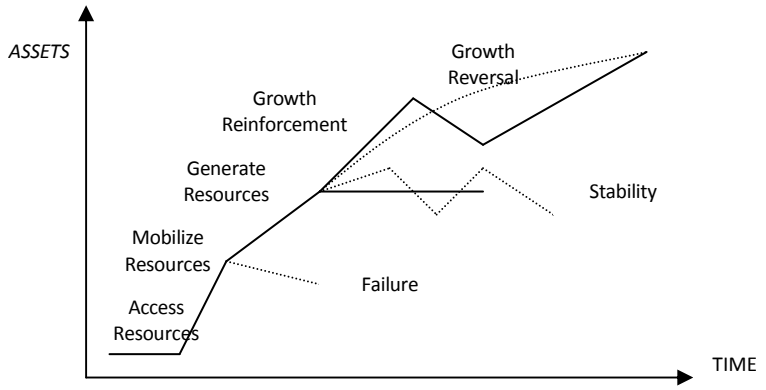

Figure 2.1 Growth paths of new high-technology firms (Reid and Garnsey, 1998)

Types of obstacles

Regarding the growth of spin-offs, many studies show that newly established technology-based firms often experience similar obstacles (Groen et al., 2005; Reid and Garnsey, 1998; Roberts, 1991; Stuart and Sorenson, 2003; Kirwan et al., 2006). In the remaining section, the following obstacles, such as the liability of newness, lack of financial capital, lack of human capital and a lack of entrepreneurial knowledge, will be discussed.

The first obstacle encountered by spin-offs is a lack of reputation, this is known as the liability of newness. Scholars, e.g. Stinchcombe (1965), Chorev and Anderson (2006), find that young firms have a greater propensity to fail than mature organizations because of this obstacle. As a new firm, spin-offs have not yet established relationships with customers and suppliers. Accordingly, spin-offs that are able to persuade potential customers and secure a stable supplier have more possibilities to succeed in a new market. Secondly, spin-offs may lack an adequate supply of capital (Miller and Garnsey, 2000; Stuart and Sorenson, 2003). To develop an innovative product, spin-offs need relatively large investments for research and development activities. Some findings in the Netherlands, e.g. van Geenhuizen and Soetanto (2003), reveal that although spin-offs realize that lack of capital may hinder growth, they are also reluctant to gain support from venture capitalists. Spin-offs do not want to loose control of their firms. Alternatively, these spin-offs try to generate income from other activities, such as consultation, but this diversification in activities may also introduce them to another new obstacle such as difficulties with managing their spin-offs, lack of time or a loss of focus on research and development of their new product. Thirdly, a later obstacle experienced by spin-offs is finding employees with the knowledge, skills and expertise, often highly specialized, required to deal with their product. Prahalad and Hamel (1990) argue that knowledge acquired by high-skilled employees is one of the important sources of competitive advantages in technology-based firms. Using knowledge, firms are able to innovate continuously (Nonaka et al., 2000). The last obstacle faced by spin-offs is related to a lack of entrepreneurial knowledge on behalf of the founders (Soetanto and van Geenhuizen, 2006). As spin-offs intended to bring new technology and innovation to market, practical knowledge such as understanding market conditions and how to manage a firm is

important. This kind of knowledge is often lacking by founders of university spin-offs who mostly have a technical or engineering educational background.

Factors influencing growth

While in the previous section, types of obstacles that may be faced by spin-offs were exposed, in this section factors that help spin-offs in overcoming the obstacles are explained. The first factor that may influence the growth of university spin-offs is the risk profile of the spin-offs' strategy (Finney et al. 2008). There are two types of strategy here, a risk-taking strategy and risk-avoiding strategy. Spin-offs with risk-taking strategies put a high investment into research and development and try to be first in the market, i.e. first mover strategy. By being the first, spin-offs expect to gain advantage over their actual and potential competitors. The risk is high as spin-offs need relatively huge resources and competitors may imitate the product very quickly. In addition, spin-offs that manufacture their products take higher risks than spin-offs in the service industries. In manufacturing products, spin-offs need to arrange production processes such as dealing with suppliers, setting up production facilities, etc. As spin-offs often start their business with limited resources, investing resources in these activities may increase their risk, have potential high shifting costs and make spin-offs very vulnerable in the early years. In contrast, spin-offs that are risk-avoiding such as those providing services have more chance to grow, especially in the early years, as they need relatively fewer resources. Moreover, they experience lower costs and take less time to develop products and process innovations than spin-offs with a risk-taking strategy.

The second factor is the level of capability. This factor refers to the quantity and quality of human capital owned by a university spin-off (Schneider et al., 2007). The amount of human capital varies with the quantity of the founders. Despite the potential for disagreement and conflicts between founders (Shaver and Scott, 1991; Casson, 1982), firms established by a team of founders enjoy better conditions for growth compared to firms with a single founder. Several empirical studies have revealed that having a team of founders facilitates a division of labor, specialization of capabilities/knowledge and allows firms to benefit from extensive networks (Westhead et al., 1995; Timmons, 1999; Rosa and Scott, 1999; Lechler, 2001). The latter is important as the more extensive network developed by spin-offs, the more chance to access various resources (Grandi and Grimaldi, 2003). Moreover, the quality of human capital varies with the previous experience of the founders (Shane, 2000; Murray, 2004). Chandler and Hanks (1994) find that founders with prior managerial experience are better at solving obstacles faced by new firms. Having prior experience of starting a new business, entrepreneurs have more knowledge of how to deal with the liabilities of newness and smallness (Eisenhardt and Schoonhoven, 1990). Spin-offs with prior experience may already have partners from their old developed networks. These old partners can be contacted to help solve obstacles faced by spin-offs. Overall, resources can be gained more effectively as spin-offs already have known partners that they can contact to provide extra resources.

The third factor is the capability of entrepreneurs to prevent and overcome a lack of resources (Heirman and Clarysse, 2004). This factor is crucial for growth and it is frequently discussed with early work on entrepreneurship studies begin in the 1930s (Schumpeter,

1934). Entrepreneurs have a special intuition and skills that they use to recognize opportunities and manage resources in the early years of firms' establishment. Young firms lack a solid customer base, experience, and reputation, and gaining critical resources in the early years of establishment is one of the most difficult tasks for entrepreneurs (McGrath, 1999; Brush et al., 2001). Spin-offs that are able to acquire resources in the early years of establishment have a chance to survive and grow.

The last factor is the capability of entrepreneurs to access resources through support from incubator organizations. While there are many different types and characteristics of incubator organizations, incubator organization is defined rather broadly in this study. Incubator organizations aim to support the growth of (university) spin-offs. Regarding the type of support, incubator organizations provide a range of support spanning from conventional to added value support. Conventional support is oriented towards the provision of tangible assets, e.g. flexible working space, laboratory facilities and financial support. In contrast, added value support aims to connect start-ups to various networks, provide new methods in business mentoring and entrepreneurial training (Hanson et al., 2005). Concerning the fact that most university spin-offs have to deal with a lack of entrepreneurial knowledge and skills, it is believed that this value added support is more effective than conventional support in encouraging the growth of university spin-offs (Hannon and Chaplin, 2003; Bøllingtoft and Ulhøi, 2005).

2.4 Social Network Theory (SNT)

In this section, various factors that influence the growth of university spin-offs based on SNT are addressed. The literature indicates that many studies link social networks to firms' performance. Social networks can provide social support, increase self-esteem and reference (Cohen and Syme, 1985). Apparently, social networks are an essential component of 'social capital' (Lin et al., 2001). According to Coleman (1990), social capital is defined as 'some aspects of social structure, facilitating certain actions in individuals who are within the structure'. Similarly, Putnam (1995) defines social capital as 'the features of social organization, such as networks, norms and social trust that facilitate coordination and cooperation for mutual benefit'. A definition proposed by Bourdieu (1985) states that 'social capital is the sum of the resources, actual or virtual, that accrue to an individual or group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition'. Napahiet and Ghosal (1998) define social capital as 'some of the actual and potential resources embedded within, available through and derived from the network of relationships possessed by individual or social units'. In general, there is a wide consensus that social capital is a valuable asset whose value emerges from the access gained to resources through the social relationships of an actor (Granovetter, 1983; Liao and Welsch, 2003).

The concept of social capital has provided a solid explanation in different streams of research (Nahapiet and Goshal, 1998; Adler and Kwon, 2002). At the level of individuals, the concept of social capital provides insights into how people enhance their career success (Burt, 1992), how people find jobs (Granovetter, 1974), and how entrepreneurship is

facilitated (Chong and Gibbons, 1997; Anderson et al., 2007). At a more higher level, the concept of social capital gives an additional explanation of the performance of firms (Lee et al., 2001) and the emergence process of new firms (Steier and Greenwood, 2000; Shane, 2004). More specifically, Kogut and Zander (1996) argue that the source of advantages of firms over competitors arises from their superior capacity to create and transfer knowledge. In this case, learning through social networks allows firms to accumulate knowledge.

Despite the broad consensus on the importance of social networks in creating social capital (Anderson et al. 2007), there is a debate concerning the characteristics and the mechanism through which social networks impact on growth (Moran, 2005). In a slightly different angle of perspective, field of economic geography offers a detailed insight into social capital based on the exploration of different dimensions of proximity (Boschma, 2005). In this perspective, proximity is concerned with more than just spatial proximity (distance) between actors. Another type of proximity is organizational proximity which covers the extent to which actors interact with their partners. Besides, proximity also includes aspects covering cognitive, social and institutional dimensions. For example, actors need cognitive proximity in order to communicate, absorb and process new information due to the tacit and idiosyncratic nature of knowledge. While social proximity is defined as socially embedded relations between actors based on friendship, kinship and past experience, institutional proximity is associated with sets of habits, routines, practices, rules or laws that regulate the relations and interactions between actors. Although the multidimensional concept of proximity can help in understanding networks, using the different types of proximity would introduce a too detailed level of analysis which cannot be covered in this study. Given the above explanations, in this study, four characteristics of social networks, namely structural, relational, heterogeneity of partners' background and spatial orientation are assumed to influence growth and will be discussed in the remaining part of this section.

Structural characteristics, i.e. tightness of networks

The first characteristic discussed here is known as structural characteristics. Apparently, scholars have different ideas about the importance of social networks as far as structural characteristics are concerned. Basically, there are two opposing opinions: namely that based on network closure versus the structural holes argument. Network closure argument (Coleman, 1988) proposes that tight networks offer positive impacts on the growth of firms. In tight networks, information known to one person is rapidly diffused to other people and interpreted in similar ways (Granovetter, 1974, 1995). Members of tight networks trust each other and can therefore diminish the uncertainty of their interaction and enhance their ability to cooperate. The reputation of one member can be recognized easily by other members while the norms and behavior in the networks are well-known to all members. In tight networks it is less risky for people to trust one another. Granovetter (1983) uses the same argument in a rather different form, he argues that the positive effects of networks facilitate trust between people and reduce risks of strategic behavior. Actors linked to such networks are more likely to conform to the norm of reciprocity (Raub and Weesie, 1990). Failure to reciprocate in behavior may result in strong sanctions and cause serious damage to a reputation (Gulati, 1995). Moreover, tight networks may improve the communication of tacit knowledge (Hansen, 1999). When someone interacts with other people in a group in

which everyone knows each other, the fine tuning of activities is easier, more efficient, and thus less costly. Tight networks also have some disadvantages. In this kind of networks, the autonomy of members is heavily restricted, since each decision taken by them is subject to the acceptance and influence of all inter-connected contacts (Burt, 1992; Gargiulo and Benassi, 2000a).

Some scholars, e.g. Burt (1992), argue that loose networks offer more advantages, i.e. the structural hole argument. In a loose network, there are opportunities to be exploited as a result of brokering connections between disconnected segments (Lechner and Leyronas, 2007). If spin-off A is connected with partner B and partner C, but partner B and partner C are not connected, then partner A occupies a structural hole. In other words, spin-off A possesses two non-redundant ties (Figure 2.2). The structural hole argument claims that benefits result from the diversity of information and brokerage opportunities created by the lack of connections between separate ties or clusters of ties in a social network. The advantages of such networks can increase the range of networks in covering more new information about opportunities, e.g. potential markets, investors and business ideas.

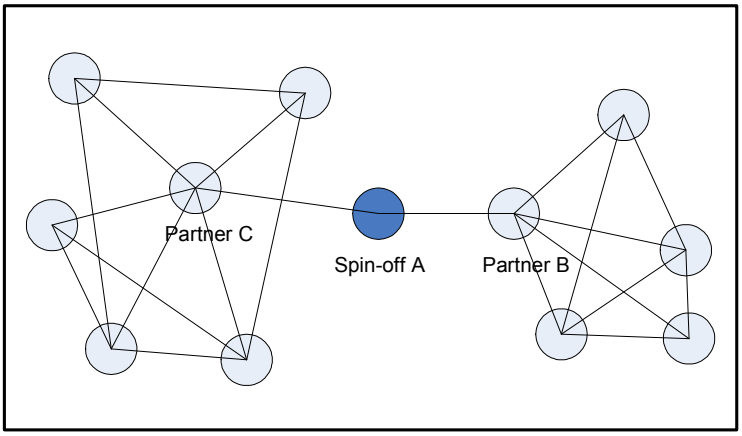

Figure 2.2 Spin-off A in the structural hole position

Overall, there are two divergent arguments concerning the structural characteristics of social networks. In short, the closure argument stresses that the contacts of tight networks can facilitate smooth communication, build a strong reputation and secure continuity in getting access to external resources. The structural hole argument claims that loose networks that are rich in non-redundant contacts provide access to more information about unique resources, opportunities and referrals to a wider scope of potential business partners. Thus, the general understanding on the importance of structural characteristics of networks on growth is largely unsettled as to whether the closure argument (Coleman, 1990; Steier and Greenwood, 2000) or the structural hole argument (Burt, 1992; Baum et al., 2000) is more relevant in explaining the growth of firms.

Relational characteristics, i.e. strength of ties

While structural characteristics determine the extent and range of resources that are within a firm's reach, relational characteristics determine the mechanism of how the resources are acquired. In other words, relational characteristics deal with the quality of networks (Moran, 2005). In the literature, the relational characteristics refer to a dyadic relationship between spin-offs and their partners, commonly denoted strength of ties. There are two types of ties between spin-offs and their partners, strong and weak ties.

Strong ties require fairly frequent contacts that are usually long-term, reciprocal and involve a strong degree of trust and emotional closeness (Granovetter, 1995; Marsden and Campbell, 1984). Scholars, e.g. Hansen (1999) and Podolny (2001), who support the importance of strong ties argue that this type of relationship benefits from the transfer of complex information. People in close and emotional contacts are generally more willing to spend time to explain or listen to complex ideas (Grannovetter, 1985; Uzzi, 1996). Nohria (1992) suggests that partners in close contact are also more willing to support and encourage innovative ideas that give entrepreneurs the energy to turn an idea into a business. Newly established firms can rely on strong ties for (personal) advice and support. Strong ties shape the willingness of partners in the networks to provide resources because people are more likely to offer information, know-how or support to persons who are close, than to those who are more distant, however, strong ties may constrain the search for new and novel information. In contrast, entrepreneurs can gain new perspectives and insights through communication and exchanges of ideas with people they do not meet very often, i.e. via weak ties. A weak tie can be described both as temporary and as transient, and normally it involves little emotional investment. Weak ties can provide information and resources beyond what is available in a close social circle (Granovetter, 1983). Moreover, weak ties can be a source of unique opportunities and resources (Hansen, 1999).

From the above explanation, it is obvious that scholars have not reached consensus regarding which ties are more effective in influencing the growth of university spin-offs. In short, the current research is still inconclusive as to whether strong relationships (Gulati, 1995; Larson, 1992) or weak relationships (Mitsuhashi, 2003) are more effective in influencing the growth of firms. In some of the recent literature, e.g. Hite and Hesterly (2001), Elfrink and Hulsink (2003) and Gilsing and Duyster (2008), a new perspective is proposed based on an argument that both types of ties may provide benefits to firms. In more details, Larson and Starr (1993) claim that over time, networks reflect increasing density and interdependence of actors. In addition, Hite and Histerly (2001) argue that networks change from being identity-based to being more calculative and networks shift from being dominated by socially embedded ties to having a balance of embedded ties.

To illustrate those tow arguments, the characteristics of the networks of two spin-offs, A and B are shown in figure 2.3. Spin-off A has six partners of which four are connected through relatively strong ties. Likewise, spin-off B has six partners. However, spin-off B and its partners are connected through relatively weak ties due to the distance to some partners outside the region. Most of the partners of spin-off A are mutually connected and know each

other. Accordingly, spin-off A is connected in a tight network with strong ties. Spin-off B has loose networks and weak ties with few partner connections.

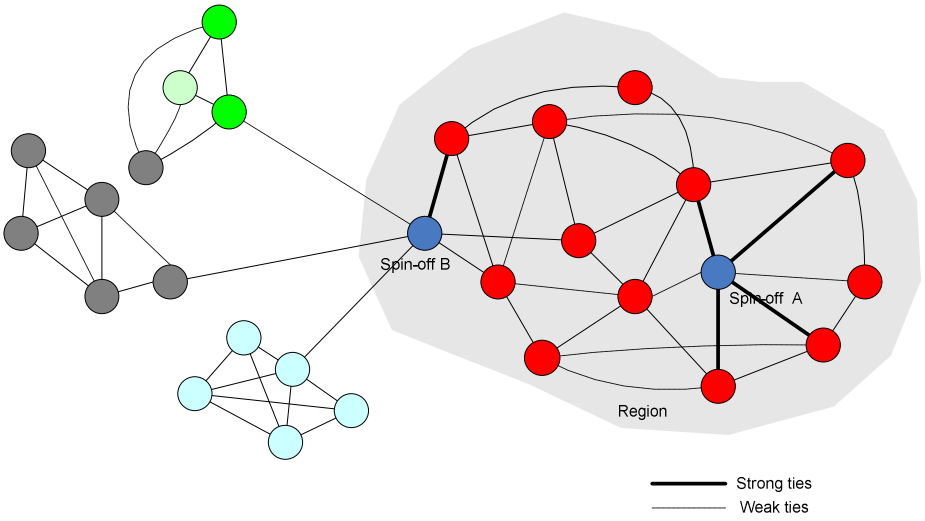

Figure 2.3 Illustration of social network characteristics

Heterogeneity in the background of partners

Larson and Starr (1992) posit that in the formation of new firms, networks follow a three-stage sequence of development. In the first stage, entrepreneurs connect with those partners that will provide critical resources, particularly ties with family, friends, and colleagues. In this stage, partners usually come from the same background as the entrepreneurs. In later stages, the content becomes more complex as it involves many aspects, including those dealing with technology and business purposes. The network becomes more crystallized and is characterized by a high quality of information exchange between partners. In the last stage, networks may consist of specialized partners that come from different backgrounds (Figure 2.4). Marsden (1987) argues that partners from diverse backgrounds, integrating several spheres of society, facilitate more beneficial actions to individuals than partners from similar backgrounds (Uchino et al., 2001). Networks consisting of diverse partners provide firms with more diverse samples of experience from which the firm can learn (Rodan and Galunic, 2004). Another advantage of diverse partners is the variety of information flowing through the networks (McPherson et al., 2001). Accordingly, in the context of university spin-offs, a set of partners that originate from different environments would bring about a wider variety in perceptions, ideas, strategies and give access to a wider range of resources for a spin-off, than a set of partners with a common origin.

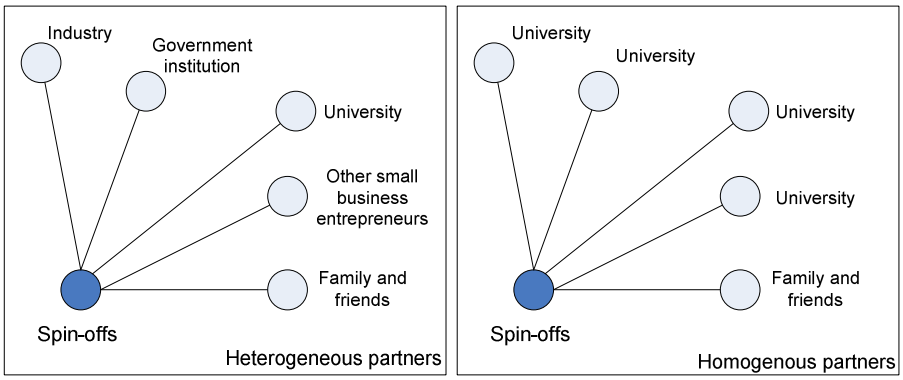

Figure 2.4 Heterogeneous and homogeneous partners in terms of social background

Spatial orientation of networks

Much attention in regional studies is devoted to regional aspects that stimulate innovation activity and the competitiveness of firms (Porter, 1998). The key argument about the ability of regions to stimulate firms' innovation activity is rooted in the view of innovation as a systemic and interactive process across several firms and organizations, i.e. university and research centers, in close spatial proximity (Asheim and Isaksen, 1997; Cooke et al., 2005). An internal orientation using interaction with partners located in close proximity is important for firms because it produces positive impacts of external economies, e.g. labor, supply of intermediary goods, localized knowledge spillovers. In addition, empirical studies tend to confirm that in terms of knowledge utilization, interacting with partners in close proximity has a positive impact on learning. Firms that are spatially concentrated benefit from knowledge externalities. Close proximity literally brings firms together, favors information contacts, develops trust and facilitates the exchange of tacit knowledge through face-to-face interactions (Harrison, 1992; Grossetti, 2008). In contrast, Bathelt et al. (2004) argue that the dynamics of regional growth also include an important impact of linkages with markets and technologies from outside regions. Some studies, e.g. Amin and Thrift (2002), MacKinnon et al. (2002), argue for the benefit from both an internal and an external orientation by pointing to the danger of 'lock-in' with close proximity partners, giving raise to inflexibility and obstacles to innovation. If firms act in local networks that are too close and too rigid (Grabher 1993), then they may receive less diverse information and knowledge. Since relationships with local players may be 'over-embedded', non-local networks can play an important role in bringing in new ideas and knowledge. Bathelt et al. (2004) suggest that firms need to build 'pipelines' to bodies of knowledge outside regional boundaries to overcome shortcomings in the firms' knowledge and in the local knowledge base. A valuable situation can be created when locally embedded knowledge is combined in novel ways with external knowledge. In the case of university spin-offs, it seems that both an internal and an external orientation in firms' networks provide a positive influence on growth. Spin-offs need to rely on their close proximity partners for developing ideas and product development while they also need to get access for new information and opportunity from their distant proximity partners.

The characteristics of social networks in different conditions

The social network is extremely important in the early years of a spin-off establishment. In this stage, spin-offs use networks to fulfill their needs for resources. It may be the case that different conditions, namely level of urbanization and development stages, may create a special need for resources, and therefore, spin-offs need certain network characteristics to access resource.

The first condition is related to level of urbanization where spin-offs are located. Firms and industry activity in general, tend to be spatially concentrated in certain locations with a high level of agglomeration. Firms generate benefit from knowledge spillover processes, by closely connecting with local actors in that region. The importance of local proximity for the transmission of knowledge spillovers is reported in the literature for many different contexts. According to Jacobs (1969), it is the exchange of complementary knowledge across diverse firms and economic agents which yield a greater return on new economic knowledge. She develops a theory that emphasizes that the variety of industries promotes knowledge externalities and ultimately innovative activity and economic growth. The level of urbanization of a region may form the characteristics of networks that influence growth, for instance Saxenian (1994) found certain characteristics of networks are important in the agglomeration region of the Silicon Valley (California, United States). In Silicon Valley, informal contact between individuals is important, mutually beneficial and widely observed. With a culture that supports informal relationships and a variety of regional institutions that provide network services, e.g. trade fairs, conferences, seminars, and social activities, firms meet often, which results in the formation of an open network and strong relationships. In the case of other regions, the characteristics of networks that bring benefits to firms may be different, however, there is little empirical evidence in the literature to explain the relationship among different level of urbanization, the characteristics of social networks and growth.

The second condition is the development stage of firms. In a detailed review of network research in entrepreneurship, Hoang and Antoncic (2003) and Slotte-Kock and Coviello (2009) identified the need to examine networks using longitudinal research to understand how the different characteristics of social networks affect the outcomes of firms in the different stage of a firm's development. In this stream of research, there are still different findings concerning the role of certain network characteristics on growth. Larson and Starr (1993) argue that networks become increasingly tight and complex, leading to the creation of an organization. In comparison, Hite and Histerly (2001) argue that networks change from being established to indentify to be more calculative, and the network shifts from being dominated by strong ties to having a balance of strong and weak ties. As a firm develops, the initial tight networks are expected to become more sparse or to form a loose network. Research, e.g. Elfring and Hulsink (2003), shows that a mix of strong and weak ties influences how startups discover opportunities, secure resources and obtain legitimacy. They emphasize that for startups in a radical innovation, strong ties are important for securing resources while weak ties help to obtain legitimacy. Overall, understanding of the role of

social networks in the growth of spin-offs especially at different development stages is still unclear. If certain types of social networks provide strong support for certain aspects of growth, then the different development stage may require different network characteristics.

2.5 Conclusion

A basis for understanding the growth of university spin-offs by drawing on Resource-Based View and Social Network Theory is given in this chapter. The Resource-Based View is used to understand the role of internal resources in the growth of university spin-offs. With regard to network characteristics, Social Network Theory provides a clear differentiation concerning the characteristics of networks and produces some controversy concerning the role of a network profile in growth. The controversy centers on several different arguments on the role of several types of network profile, such as tight versus loose network, weak versus strong ties and an internal versus external orientation, in influencing the growth of spin-offs. To summarize this chapter, the factors that are assumed to influence the growth of university spin-offs and are used in the development of hypotheses in the next chapter are presented in figure 2.5.

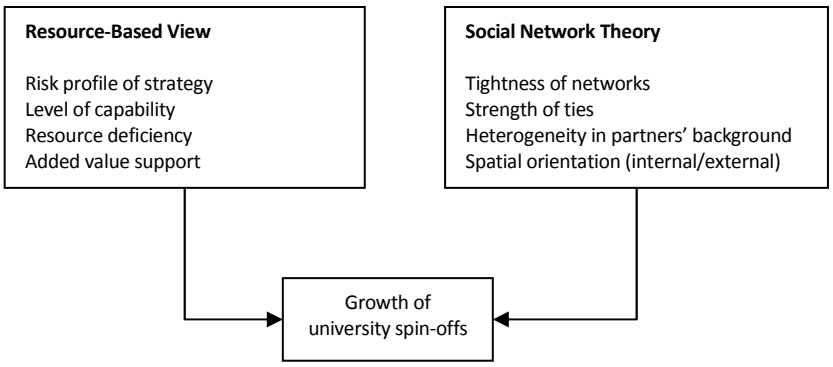

Figure 2.5 Factors influencing the growth of university spin-offs

C H A P T E R 3

FORMULATION OF HYPOTHESES

3.1 Introduction

The relevance of Resource-Based View and Social Networks Theory in explaining growth of university spin-offs was discussed in the previous chapter. Based on these theories, several hypotheses are presented in this chapter. The chapter starts with the hypotheses developed using the Resource-Based View (section 3.2) followed by the hypotheses developed using Social Network Theory (section 3.3).

3.2 Hypotheses based on the Resource-Based View

Four hypotheses are constructed using the Resource-Based View, taking into account one, the risk profile of strategy, two, the level of capability, three, resource deficiency and four, added value support. These factors are assumed to have an impact on growth through their influence on the process of resource acquisition.

Risk profile of strategy

A firms' strategy when entering new market can be divided into two approaches, namely a risk-taking strategy, i.e. *first movers,* and a risk-avoiding strategy, i.e. *late movers* (Brittain and Freeman, 1980; Miles and Snow, 1978). Firms that make the risk-taking strategy invest most of their resources and try to be the first in a newly developed market. They invest strongly in R&D to create a new innovative product that is new to the market (Lieberman and Montgomery, 1998). Firms with the risk-taking strategy may acquire superior initial resources and capabilities, such as a technology protected by patents. They expect to get a monopoly in the early market and establish product specificities that cause 'shifting costs' for customers. Late movers or firms that select the risk-avoiding strategy face a lower risk than first movers. Late movers experience lower costs and take less time to develop products and process innovations than early movers (Levin et al. 1987). In addition, late movers may also gain some 'free-riding' advantages (Lieberman and Montgomery, 1998; Fleury and Fleury, 2009). First movers face a high risk, as they need to go through a long process from the initial ideas, to building a prototype, to product launching. They may not be efficient in managing resources due to technological and market uncertainties. Late movers may sell their products/services relatively faster than first movers and the risk is lower for late movers than for first movers.

In the early years of a firm's establishment when the availability of resources is critical, it is assumed that the more resources are needed, the higher the risk faced by firms that growth could be hindered. In the case of university spin-offs, spin-offs with a large investment in R&D face a higher risk and may have slower growth particularly in early years. Some spin-

offs take risks by developing and manufacturing a new product/service that requires a large amount of resources (Berger and Dick, 2007; Usero and Fernándex, 2008). As university spin-offs have a constraint in resources, it is assumed that the level of risks taken by spin-offs influences their growth. This argument can be formulated in the first hypothesis as follows.

> The growth of university spin-offs is positively influenced by a strategy that is risk-avoiding (1).

Level of capability

Spin-offs need to gather resources including knowledge and skills, that are necessary for growth. In this endeavor, the capability of the founders may determine whether or not they are able to obtain critical resources (Wright et al., 2007). Several studies, e.g. Larson (1992), Aldrich (1999) and Klofsten (2005), find that capability of founders can lead firms to resources such as business advice, reference and customer relationships that are important for growth. Starr and MacMillan (1990) find that firm's capability in capitalizing on social relationships allows them to create a positive image and to obtain resources below market prices. While the capabilities of firms may allow them to obtain resources, firms may differ in level of capabilities due to, for example, differences in the pre-start experience of founders and the different modes used to start a firm, e.g. single start versus team start. For instance, firms that are established by a team of founders and have previous experience are likely to face strong growth. Overall, the literature finds a consistent relationship between the level of capability and the growth of firms (Vissa and Chacar, 2009). Hence, this argument leads to the second hypothesis.

> The growth of university spin-offs is positively influenced by a high level of spin-offs' capability (2).

Resource deficiency

According to Barney and Clark (2007), firms must possess critical resources to exploit market opportunities. Firms search and convert resources into products or services for which revenue can be obtained. University spin-offs may have distinctive resources in technological knowledge and skills, however, they frequently suffer from a lack of other resources. Of the needed resources, entrepreneurial knowledge and skills appear to be the most problematic (van Geenhuizen and Soetanto, 2004). The need for entrepreneurial knowledge is coupled with various needs for management skills and difficulty in dealing with uncertainty as well as in coping with many different management tasks simultaneously (overload). In addition, university spin-offs may be short of financial resources, such as initial investment and cash flow. Failing to overcome these obstacles will hamper growth of university spin-offs. Therefore, this argument leads to the third hypothesis.

> The growth of university spin-offs is positively influenced by a low level of resources deficiency (3).

Added value support

Incubator organizations play an important role in the growth of university spin-offs as they provide resources without the spin-offs incurring substantial costs (Rothaermel and Thursby, 2005; Hannon and Chaplin, 2000; Aguirre et al., 2006). There are two main types of support, conventional and added value support. Conventional support is oriented towards the provision of basic resources, e.g. cheap accommodation, administrative services and financial assistance. It is assumed that conventional support only fulfills the basic needs of university spin-offs, helping them to overcome first obstacles in terms of initial investment and accommodation. As recent studies have found university spin-offs often face a lack of entrepreneurial knowledge and skills (e.g. Soetanto and van Geenhuizen, 2006), support provided by incubator organizations needs to be improved, by including added value support. Added value support encompasses entrepreneurial courses for enhancing business skills, business mentoring and networking services (Smilor and Matthews, 2004; Hughes et al., 2007). It is believed that these types of support are more effective in helping spin-offs to overcome obstacles and at the end, will enhance their growth (Helm and Mauroner, 2007). Therefore, the next hypothesis proposed is as follows:

> The growth of university spin-offs is positively influenced by a high level of added value support (4).

3.3 Hypotheses based on Social Network Theory

From literatures, it appears that there are two contrasting arguments. One, there is a broad consensus that a social network is a valuable asset enabling spin-offs to access resources through their social relationships (Granovetter, 1995; Westlund, 2005; Walter et al., 2006). Two, there is discrepancy among authors' opinions concerning the role of certain characteristics of social networks that bring benefits. To contribute to the discussion about this subject, several hypotheses concerning structural and relational characteristics, the heterogeneity in the background of partners and spatial orientation are constructed and presented in this section.

Structural characteristics – tightness of networks

In studies on small business development, the importance of tight networks is stressed as being one of the factors that enhances the survival of new and small firms (Simsek et al., 2003). Tight networks are described as networks in which everyone is connected, because people know and interact with each other, they are more likely to convey and reinforce norms of exchange and are more able to enforce sanctions. In business, such networks will reduce risks and enhance the opportunity of building cooperation and getting access to resources from other partners connected to the networks. Members of the networks are familiar with each other's interests, making the transfer of knowledge less difficult. In general, tight networks are beneficial for the transfer of complex and tacit knowledge, development of trust and comfort, legitimacy or reputation, and joint-problem solving (Coleman, 1990; Uzzi, 1996).

In contrast with the above argument, Granovetter (1983) suggests that people who are connected in loose networks will benefit from the diversity of information available and the brokerage opportunities created by the lack of connection between separate clusters in the networks. The persons who occupy brokerage positions between separate clusters have better access to information (Hanaki et al., 2007). Spin-offs face potential advantages in terms of new commercial opportunities, access to resources and references from partners, by being connected to a loose network (Gnyawali and Madhavan, 2001; Ulhøi, 2005). The above discussion shows that studies on the influence of structural characteristics of networks on growth are not yet conclusive (Gargiulo and Benassi, 2000b; Moran, 2005). Therefore, this consideration leads to the construction of the two following hypotheses:

> The growth of university spin-offs is positively influenced by tight networks of partners (5a).
> The growth of university spin-offs is positively influenced by loose networks of partners (5b).

Relational characteristics – Strength of ties

Strength of relationships is based on time and emotions invested in the relationships and reciprocity between partners (Granovetter, 1983). As people know each other more and become emotionally involved, they will develop strong ties that involve trust, commitment and willingness to support each other. In terms of new firm growth, there are a growing number of scholars, e.g. Leana and van Buren (1999) and Adler and Kwon (2002), who view the value of strong ties in organization and firms' performance. These types of ties are important for start-up companies such as spin-offs who try to market an unproven product and have limited resources (Datta and Saad, 2008).

In contrast, Granovetter (1983) argues that new information is obtained through casual acquaintances, i.e. weak ties, rather than through strong ties. Since strongly connected partners are likely to interact frequently, much of the information that circulates in this social system is redundant. Weak ties often include links with partners from other networks. Weak ties tend to serve as a bridge for disconnected networks and become an important source of information about activities, resources, and opportunities in distant parts of the social system (McEvily and Zaheer, 1999). In the case of university spin-offs, it may be that either strong or weak ties have a positive influence on growth (Hite and Hesterly, 2001; Elfring and Hulsink, 2003). Spin-offs need to access knowledge or get references of their product or service through strong ties with their partners while information and opportunity about new market can be obtained through weak ties. Based on these arguments, hypothesis six was formulated in two parts.

> The growth of university spin-offs is positively influenced by strong ties (6a).
> The growth of university spin-offs is positively influenced by weak ties (6b).

Heterogeneity in the background of partners

The next hypothesis is concerned with the social characteristics of networks. Marsden (1987) showed that diverse partners integrating several spheres of society provide more benefits to

individuals than partners from the same sphere. In the context of spin-offs' growth, partners that come from a diverse environment give access to a wider range of resources. The more heterogeneous partners' spin-offs have the more variety of resources such as know-how, information and expertise can be accessed. Therefore hypothesis seven reads as follows.

> The growth of university spin-offs is positively influenced by a heterogeneous background of network partners (7).

Spatial orientation

In studies of network creation, it is assumed that networks do not randomly link individuals (Sorenson, 2005). Rather, people interact most frequently with those in close spatial proximity, and with whom they share common backgrounds, interests and affiliations (Gertler, 2003). Close spatial proximity decreases direct costs associated with frequent and extended interactions necessary for maintaining social relationships (Zipf, 1949; Cooke et al., 2005), particularly personal networks. A network of firms that is clustered in a small area provides a greater opportunity to interact actively, i.e. face-to-face interaction, and to benefit from knowledge spillovers (Audretsch, 1998; Jaffe et al., 1993; Camagni, 1991; Boschma and ter Wal, 2007; Grossetti, 2008). Accordingly, it is argued that having an internal orientation in a network between firms and their partners in close proximity will have a positive influence on growth (Cooke, 2007). In contrast, in some recent studies there is an emphasis on the importance of partners located at a distance, i.e. external orientation of firms. Interactions between firms and their distant partners bring benefits in terms of receiving new information, opportunities and novel knowledge which is also necessary for growth (Bathelt et al., 2004). Based on these arguments, hypothesis eight was constructed in two parts.

> The growth of university spin-offs is positively influenced by the internal orientation of spin-offs (8a).
> The growth of university spin-offs is positively influenced by the external orientation of spin-offs (8b).

3.4 Hypotheses regarding interaction effects

In this section, some hypotheses will be developed based on the assumption that several factors, i.e. age of spin-offs, level of urbanization, spin-offs' capability and spatial orientation of spin-offs, a moderating influence on the relationship between social network characteristics and spin-offs' growth.

Concerning the age of spin-offs, the literature indicates that networks change dynamically over time (Hite and Hesterly, 2001; Cooper, 2002; Lechner et al., 2006). To gain resources, younger spin-offs may depend more heavily on their initial networks than older spin-offs. Younger spin-offs are under pressure to utilize their networks in searching for resources, as the available resources are limited (Schutjens and Stam, 2003). Accordingly, younger spin-offs may prefer to have tight networks, strong ties less heterogeneity in the background of partners and an internal orientation. These characteristics of networks are assumed to have

a positive influence on spin-offs in the early stage of innovation and growth. In contrast, older firms may have loose networks, weak ties, heterogeneous background of partners and an external orientation due to more information and a larger experience in network building coupled with a specific need to achieve a solid market position. Based on this argument, a hypothesis was constructed as follows.

> The age of spin-offs has a moderation effect on the relationship between the profile of social networks and the growth of university spin-offs (9.1).

Another variable that is expected to have a moderating effect on growth is the level of urbanization of the city where spin-offs are located, metropolitan versus non-metropolitan. Due to larger opportunities for networking, the growth of spin-offs in metropolitan areas seems to be influenced by certain characteristics of networks such as loose networks, weak ties, the heterogeneous background of partners and an external orientation. In contrast, certain characteristics such as tight networks, strong ties and an internal orientation may color the networks characteristics of spin-offs located in non-metropolitan areas. Due to the large distance to big cities, non-metropolitan spin-offs have a limited chance to expand networks. The idea that location could determine the characteristics of networks that have an impact on growth will be tested using the following hypothesis.

> The level of urbanization has a moderating effect on the relationship between the profile of social networks and the growth of university spin-offs (9.2).

Further, spin-offs endowed with a high level of capability may develop networks that are more effective in supporting growth compared with spin-offs with a low level of capability. In spin-offs with a high level of capability, the increased experience is able to develop certain network characteristics that positively influence growth (Reagans and Zuckerman, 2001; Reagans et al., 2004; Vissa and Chacar, 2009). Remarkably, the influence of different capability on the relationship between social networks and growth has not yet been the subject of study. Therefore, hypothesis was constructed with the objective to explore this relationship.

> The level of capability of spin-offs has a moderating effect on the relationship between the profile of social networks and the growth of university spin-offs (9.3).

Finally, a hypothesis was constructed to test whether the spatial orientation of spin-offs determines the relationship between other network characteristics and growth. Due to a number of partners that are located in distant proximity, spin-offs with an external orientation may develop loose networks and weak ties. The networks are loose, as those partners may not be connected in the local networks of spin-offs. In addition, spin-offs cannot meet those partners as frequent as with partners in close proximity. Spin-offs with an internal orientation may develop tight networks and strong ties. The networks are tight as partners in close proximity may come from the same networks and as a result they may know each other. Spin-offs can meet those partners regularly and as frequent as possible due to the close proximity. The hypothesis was thus formulated as follows.

The spatial orientation of spin-offs has a moderation effect on the relationship between the characteristics of social networks and the growth of university spin-offs (9.4).

3.5 Conclusion

The theoretical ideas discussed in the previous chapter (Chapter 2) are developed into a number of hypotheses in this chapter. Based on the Resource-Based View, four hypotheses were constructed. These hypotheses include the risk profile in strategy, spin-off's capability, resource deficiency and types of support. Four more hypotheses were constructed based on the Social Capital Theory. These four hypotheses include structural and relational characteristics of networks, the heterogeneity of the background of partners and spatial orientation of partners. In addition, several hypotheses concerning the moderating effect of factors, i.e. age of spin-offs, level of urbanization, level of capability and spatial orientation, were constructed. The summary of hypotheses is presented in table 3.1

Table 3.1 Summary of the hypotheses [a)]

Hypothesis Formulation		Hypothesis number	Theory
Growth of university spin-offs is positively influenced by	*Strategy, capabilities, and resources*		Resource-Based View
	Risk-avoiding in strategy	1	
	High level of spin-offs' capability	2	
	Low level of resource deficiency	3	
	High level of added value support	4	
	Social network profile		Social Capital Theory
	Tight networks	5a	
	Loose of networks	5b	
	Strong ties	6a	
	Weak ties	6b	
	Heterogeneous background of partners	7	
	Internal orientation	8a	
	External orientation	8b	
Relationship between social networks profile and growth is moderated by	Age of spin-offs	9.1	
	Level of urban system	9.2	
	Level of spin-offs' capability	9.3	
	External orientation	9.4	

[a)] a and b (hypotheses 5-6-8) express the debate that still exists in the literature, where as .1,.2, express the exploratory investigation of four interaction effects.

Chapter 4

RESEARCH DESIGN AND METHODOLOGY

4.1 Introduction

Several hypotheses on the influence of social networks and other factors in the growth of university spin-offs were formulated in the previous chapter. A two steps research design was employed to test these hypotheses. Step one was a meta-analysis study of the growth of incubators. The result of this meta-analysis was then used to develop a framework for case study selection. Step two consisted of an empirical study of the growth of university spin-offs. In this step, data was collected and various regression models were developed to confirm or reject the hypotheses formulated in chapter 3.

This chapter begins with a brief description of the research design in section 4.2. The design of the meta-analysis of the growth of incubators is presented in section 4.3 while the design of the empirical analysis of the growth of university spin-offs is presented in section 4.4. Both sections include a discussion of the sampling method, data collection, variables and techniques used in the analysis. Conclusions are presented in section 4.5.

4.2 Research design

In social science research, there are two approaches to designing research: quantitative and qualitative (McNeil, 1985). The quantitative approach is usually started by posing an established theory and then the theory is tested empirically. This approach uses procedures that are designed to ensure objectivity, generalisability and reliability. Data is mostly collected through surveys and is quantitative in nature, i.e. numeric, dichotomous, category and/or ranked. The qualitative approach is used to obtain a detailed explanation of phenomenon through direct exploration of the objects. The qualitative approach begins with observations and then new hypotheses or new theories are developed. In-depth interviews and detailed observations are usually conducted to collect narrative descriptions of the phenomenon studied and to obtain detailed information about the object of study.

The differences between the two approaches have caused a long, on going, debate among scholars concerning the value of using one particular approach over the other. In research practice, using both approaches in a single study is becoming more popular. This is because both qualitative and quantitative approaches lead to the same objective, which is to reveal the relationships among the objects that are investigated. The differences lie in the way the research strategies are used to accomplish the main objective of a piece of research (Dzurec and Abraham, 1993). Quantitative methods use statistical procedures, e.g. factor analysis, multidimensional scaling, or discriminant analysis, to generalize exploratory results, while qualitative methods use phenomenological techniques and research subjectivity, e.g.

thematic analysis and context analysis, to establish exploratory results (Onwuegbuzie, 2003). Researchers may gain the benefits of both methods by using quantitative and qualitative methods in one study (Creswell, 2003; Tashakkori and Teddlie, 2003). As quantitative and qualitative approaches can complement each other, and in the end may enrich research findings (Greene and Caracelli, 1997), both approaches were employed in this study with an emphasis on the quantitative approach. This meant that quantitative and qualitative data were collected but most of the analyses were conducted quantitatively.

The research design of this study is presented in table 4.1. In step one, a meta-analysis of factors that contribute to the growth of incubators was performed. A combination of quantitative and qualitative data was analyzed using a quantitative analysis, i.e. Rough Set Analysis, to find factors or a combination of factors that explain the differences in the growth of incubators. The outcomes were then used as a basis for the selection of two case studies of incubators. In step two, an analysis of the selected case studies was performed in terms of the growth of university spin-offs. Data was collected through face-to-face interviews with founders of university spin-offs. This analysis consisted of two parts. One, an analysis of the time pattern of obstacles faced by university spin-offs, job and network growth. Two, a descriptive analysis of the characteristics of social networks, and a statistical analysis was carried out to test the hypotheses on the influence of social networks and other factors on growth.

Table 4.1 Research design of this study

Research Step	Source of data	Type of data	Type of analysis	Result	Instrumental in research design
1. Meta-analysis study of the growth of university incubators	Papers in journals, conference proceedings, annual reports of incubators, and incubators' websites	Various type of data transformed into categorical data	Rough Set Analysis	Decision rules on factors that influence incubators' growth (chapter 5)	Two selected incubators for model development
2. Descriptive and exploratory study of the role of social networks and other factors in the growth of university spin-offs	Interviews with founder(s) of university spin-offs	Numerical, dichotomous, categorical, rank data	Statistical tests	Growth of university spin-offs: Patterns of obstacles, job and network growth (chapter 6)	Two relevant age groups for model development
			Descriptive statistics, statistical tests and linear regression models	Description of social networks variables (chapter 7)[a)] Result of hypotheses testing (chapter 7)	

[a)] The description of the other factors, namely characteristics of university spin-offs, are presented in the appendix 4.

4.3 Meta-analysis study of the growth of incubators

A meta-analysis approach was adopted in this study to determine the factors of the growth of incubators. In social science, the use of meta-analysis has grown tremendously since the early 1990s (e.g. van den Bergh et al., 1998; Cook et al., 1992; Stuhlmacher and Gillespie, 2005). Basically, the meta-analysis approach encompasses a systematic application of a range of quantitative methods to assess common characteristics and variations across a set of separate but largely similar case studies on more or less the same phenomenon. Meta-analysis allows a researcher to synthesize the results of many types of research, including opinion surveys, annual performance reports, as well as experimental and quasi-experimental studies. The result is an integrated review of findings that is more comprehensive than a single study. The procedures used to conduct the meta-analysis approach, including the sampling design, data collection, variables and measurement and method of analysis are presented below.

4.3.1 Sampling and data collection

A purposive sampling technique was used to collect data in this meta-analysis study. Purposive sampling is commonly used to allow researchers to include samples that are closely related to the subject of study. Accordingly, several predefined criteria were established. In this study, the selection of incubators serves two purposes. One, to increase the degree of communality between the incubators, in other words to decrease diversity, and two, within a more or less homogeneous group of incubators, to obtain a sufficient differentiation among the factors determining the growth of incubators. Accordingly, a number of criteria were imposed as follows:

(1) to be a technology-related incubator and university-related incubator, must support mainly technology-based start-ups and have institutional links with a university or research center and/or be located close to a university or research center.
(2) belong to a similar time frame, incubators from the 1980s cannot be compared with those in the 1990s because of the potential influence of different macro-economic factors. To reduce the influence of changes in macro-economic conditions, this study was limited to the period: 1998 – 2002.
(3) include particular characteristics in one (or more) of the theoretical factors of growth performance of incubators (as developed in chapter 5). This was intended to gain a substantial degree of variance in the scores of these factors and to avoid a particular characteristic being dominant in the sample of incubators.
(4) be located in a similar geographical area, the incubators selected for this study were located in Europe, the US, Canada and some developed countries in Asia.
(5) be supported by more than one source of data or information and presented in a way that is scientific and relatively objective. As with the meta-analysis approach in general, this study potentially suffers from the problem of data validity due to different interpretations, imprecise measurement, mismatch between the data

needed and data available and shortage of data about less successful incubators. To solve these problems and guarantee the validity of data, this selection criterion was established to ensure that every incubator had a reference for comparison to increase the validity of the data.

The data was collected from several sources such as academic journals, conference proceedings, annual reports of incubators, and websites of incubators. Electronic databases of scientific papers were used as a starting point for the data collection process. Next, a procedure similar to a snowball technique was applied. The procedure began with the identification of all published papers on incubators. A list of articles that discusses incubators and the incubation process was obtained using a search engine of electronic journal databases, e.g. Springerlink, Emerald Library, Wiley Interscience, ProQuest-ABI/Inform, Science Direct and Google Scholar. After reviewing these articles, the bibliographies of the articles were examined to identify other articles on incubators. The next step was to review those articles and if possible to find more articles dealing with the incubation process. This procedure was repeated until there was no new article found. In addition, information was gathered from the incubators' websites or other relevant websites, such as a university, a regional government, a national association of incubators, etc. Overall, 40 incubators were selected for the analysis.

4.3.2 Variables and measurement

Six exploratory variables, the model of stakeholders' involvement, level of urbanization of the city in the national urban system, uncertainty avoiding attitude, model of support provided by incubators, incubation strategy and age of incubators, were assumed to influence the growth of incubators, i.e. average annual growth. The variable growth and the exploratory variables are presented below.

Growth
The growth of incubators was measured using the average annual growth (decline) of the number of incubated firms. In this study, incubators are defined as organizations that aim to accelerate the development of university spin-offs by providing an array of resources and services. Accordingly, the process inside incubators can be conceptualized as the transformation of initial start-ups, facing high risks, into viable firms. Based on this perspective, growth of incubators was measured by the capability of the incubators to increase its number of tenants, i.e. 1: strong growth; 2: weak growth.

The model of stakeholders' involvement
There are two models of stakeholders' involvement in the organization of incubators. One, incubators are mainly organized by universities or research institutes alone. Two, different stakeholders are involved like universities, financial institutes, local government, large firms, etc, that also means potential access to a larger variety of resources and networking possibilities. In this study, the model of stakeholders' involvement was measured using a dichotomous variable to indicate the presence of multiple stakeholders, 1: single stakeholder involvement and 2: multiple stakeholder involvement.

Position in the national urban system: level of urbanization

Jacobs (1961) draws attention to the role of metropolitan cities in attracting and mobilizing talented and creative people. This has led to the understanding that metropolitan cities by providing a high diversity of amenities, entertainment and lifestyle, offer important advantages for attracting and keeping talented and creative people. Therefore, it is assumed that incubators in large metropolitan areas enjoy the benefits of attracting talented people and a large flow of new entrepreneurs. In contrast, incubators situated in non-metropolitan areas and peripheral regions are seen to be less attractive. Accordingly, a dichotomous variable was created to indicate the position of incubators in the national urban system, 1: metropolitan areas and 2: non-metropolitan areas/peripheral.

Uncertainty avoiding attitude

Hofstede (1991) describes the characteristics of national cultures using various dimensions: power distance, individualism, masculinity, long-term orientation and uncertainty avoidance. Among those dimension, van Everdingen and Waarts (2003) argue that the dimensions of uncertainty avoidance plays a role in the process of innovation. Countries with a high level of uncertainty avoidance generally show characteristics such as resistance to entering new avenues and avoidance of the risks of innovation. In this study, the uncertainty avoidance attitude was measured using a dichotomous variable, 1: low and 2: high.

Model of support provided by incubators

Conventional support is oriented towards the provision of basic/tangible assets, e.g. flexible room, laboratory facilities and financial support. Further, there has been an important evolution in the kind of support provided. Some additional values were added including connecting start-ups to various networks and the use of new methods in business mentoring, e.g. Hannon and Chaplin (2003). The model of support was measured using a dichotomous variable that classified support into merely conventional support and this support plus value added support, 1: conventional support and 2: conventional and value added support.

Incubation strategy

The selection of candidate firms is an important component of an incubation strategy. The pure incubators seek to exploit university potential by producing firms that commercialize university research results. An incubator with a profit-oriented strategy opens doors to entrepreneurs from the outside. In this study, incubation strategy was measured using a dichotomous variable, 1: research commercialization and 2: profit-focused.

Age of incubator organizations

Experience and professionalism in the selection, monitoring and coaching of start-ups seem to be critical in managing an incubator (e.g., Smilor et al., 1990). A study by the National Business Incubation Association (NBIA) in the US (Mc Kinnon and Hayhow, 1998) shows that it takes several years for incubators to become mature, in terms of gaining the capability to organize and to produce independent firms continuously. Apparently, climbing on the learning curve improves an incubator's management capability to meet objectives

effectively and efficiently, such as creating the most adequate networks and participating in them. Although learning is not a linear process, it increases with age. To explore this argument, a dichotomous variable was used to measure age of incubator, i.e 1: < 5 years old and 2: ≥ 5 years old.

4.3.3 Method of analysis

Rough Set Analysis was employed in this study to conduct the meta-analysis of factors influencing incubators' growth (Appendix 1). Rough Set Analysis is a non-parametric method that is able to handle a relatively diverse set of factors and to transform an imprecise or incomplete (fuzzy) collection of data into structured knowledge. Rough Set Analysis can also be used to classify objects into distinct classes of attributes (Pawlak, 1991). In particular, Rough Set Analysis can be used to incorporate different measurement scales and different degrees of measurement accuracy, known as granularity in classified experiments (case studies). Rough Set Analysis has become an established technique in medical and environment studies, particularly for comparative analysis of (semi) controlled case study experiments. In recent years, the use of Rough Set Analysis has become popular in the field of social studies, particularly in experimental psychology and sociology. In addition, Rough Set Analysis has been employed as decision support method in spatial and economic policy, particularly for identifying success factors or critical conditions in the performance of specific policy measures or projects, like public transport funding schemes (Ubbels and Nijkamp, 2002), urban soil rehabilitation projects and urban reconstruction projects (Nijkamp et al., 2002).

In Rough Set Analysis, information is presented in an information table (IT). The information table is a matrix in which rows are labeled by objects and columns are labeled by attributes. Objects arranged in an IT are based on their condition attributes (C) and decision attribute (D). These two attributes are analogous to the independent variables and the dependent variable found in regression analysis. The condition attributes consist of the features that describe the objects, whereas the value of the decision attribute contains the concept to be learned based on the value of the condition attributes. In this study, there were six condition attributes used in the analysis. These six condition attributes, e.g. stakeholders' involvement, position in the urban system, uncertainty avoiding attitude, model of support provided by incubators, incubation strategy and age of incubator were assumed to influence the decision attribute described as the growth of incubators.

4.4 The empirical study of the growth of university spin-offs

In step two, an empirical study with university spin-offs as the unit of analysis was conducted. The sampling and data collection, variables and measurement and method of analysis are described below.

4.4.1 Sampling and data collection

The most common sampling design that permits a reliable generalization from a sample to a larger population is random sampling design. In this it was not possible to make use of this sampling design as the total population was not known. Most universities have no inclusive database of their spin-off activities. Thus, a purposive sampling design was used. The aim of this method is to select a sample that can yield the most comprehensive understanding of the objects of study. Accordingly, a sample of candidate spin-offs, a population/database was carefully developed from several sources. An initial list of spin-offs was collected from the managers of the business incubators, officers of technology transfer offices at the universities and from professors at universities involved in the establishment of university spin-offs. Another source of information for collecting data on spin-offs is websites of organizations that hold business competition awards. In addition, a snowball technique was performed during the interview with founder(s) of university spin-offs. In this case, the respondents were asked to mention other entrepreneurs they knew to provide a further chance at gaining more data. Accordingly, the findings can still be used in the frame of generalization.

In addition, some specific criteria on the characteristics of university spin-offs were imposed. These are listed below and include the requirement:

(1) to be a technology-based firm. The products or services of spin-offs selected in this study were based on technology and innovation. This criterion excluded spin-offs engaging in business consultancy, design and architecture.
(2) to be established by students, graduates, and/or academic staff. The spin-offs selected in this study were limited only to firms established by these types of founders.
(3) to be established between 1996 to 2006. Old and mature spin-offs of e.g. fifteen years old cannot be compared with more recently established spin-offs because of the potential influence of different macro-economic factors, different resources, etc. To reduce the influence of bias, this study was limited to spin-offs that were not more than 10 years old.
(4) to have survived to 2006. In general, excluding failed spin-offs may cause a bias, but in this case the number of failed spin-offs was relatively small and there was no serious bias.
(5) to be located in a selected region. Many studies indicate the influence of different levels of urbanization, i.e. metropolitan and non-metropolitan areas on the growth of firms. Therefore, spin-offs in this study were based on two contrasting cities.

Data was collected through face-to-face interviews with the founder(s) of university spin-offs. Although interviews are costly and time consuming, this method was selected because it offers various advantages. One of the advantages is that the interviewer(s) can control the context of the interviews, and the questions can be explained meaningfully. Using this technique, a higher response rate can be obtained compared to any other survey technique

(Judd et al., 1995). An interviewer can also motivate respondents to answer fully and accurately and in the end, this increases the quality of the data (Spector, 1994).

Before conducting the interviews, considerable preparation was undertaken: the first was to develop the initial questionnaire and an interview protocol, and then several pilot studies were performed to check the applicability of the questionnaire and reliability of the answers. As a result, a semi-structured questionnaire was constructed. The questionnaire consisted of seven main parts with a focus on obstacles to growth, support, characteristics of firms and founders, and network characteristics. The questionnaire also included some open-ended questions that allowed the respondents to clarify their opinions (Appendix 2).

4.4.2 Variables and measurement

The variables used in the study will be discussed in this sub-section. There were ten explanatory variables, i.e. age, location, resource deficiency, added value support, level of capability, risk profile of strategy, tightness of networks, strength of ties, heterogeneity in the background of partner, external orientation, that were assumed to influence the growth of university spin-offs, i.e. job growth and network growth.

Growth of university spin-offs: job growth and network growth
From an economic perspective, growth can be measured using a range of different indicators, such as assets, physical output, market share, profits, sales, and employment (Weinzimmer et al., 1998; Delmar, 1997). Unfortunately, not all the indicators could be used in this study. Assets are not the best indicator for growth since assets are highly related to capital intensity in the industry. Spin-offs in ICT business can offer products or services without any large investment in assets, in contrast to spin-offs in material science that need large investment in equipment. Measuring growth in terms of physical output is also not practical since there is diversity in the business model of spin-offs. Spin-offs may sell knowledge or services instead of physical products. Regarding market share as a growth indicator, this indicator can only be used to compare within industries or a similar product range (Delmar et al., 2003). With regard to profits there is the difficulty that it has a high correlation with economic conditions and type of industry. Finally, levels of sales and employment are the most widely used indicators in empirical growth research (Delmar, 1997). Like profits, sales may not be a good indicator for high technology start-ups, such as spin-offs. As technology based firms, university spin-offs are often not able to sell products or services right after their establishment. Spin-offs may receive grants, venture capital, or work closely with existing industries, in such a way that assets and employment can grow before any sales occurs. So far it can be concluded that employment can be considered to be an adequate growth indicator. Employment is appropriate for measuring growth when a Resource-Based View is used (Penrose, 1959). If firms are viewed as bundles of resources, a growth analysis should focus on the accumulation of resources, such as employees. Furthermore, in regional economic policy practice, employment may serve as the best measurement for growth (Schreyer, 1999).

Based on the above arguments, employment was used as a growth indicator in this study. Besides measuring employment as absolute growth, growth within business networks was also used as an indicator for growth. The current trend among university spin-offs, as in small high technology firms in general, shows that growth in networks becomes increasingly common. Spin-offs may undertake product development together with other firms or they may outsource the production of specific components to different partners in their business networks. The extent of this business network was measured by asking the respondents about their opinion as to whether the spin-off had grown in networks, i.e. perceived network growth. A dichotomous variable of network growth was created, differentiating weak growth (0) from strong growth (1).

Age of spin-offs
Firms may have better opportunities to grow if they are able to learn from previous experience (Jovanovic, 1982). When firms become older, they may benefit from their previous experience. Firms improve their capability to meet objectives effectively and efficiently by learning from experience. In this study, a continuous variable of age was included as a part of the regression models and to act as a control variable.

Location of spin-offs
Jacobs (1961) draws attention to the role of metropolitan cities in attracting and mobilizing talented and creative people. In a similar vein, more recent research has focused on factors that attract talented people (Lloyd, 2002; Florida, 2002). This has led to the understanding that metropolitan cities which provide more diversity in amenities, entertainment and lifestyle, have important advantages for attracting and keeping talented and creative people. For this reasons, the location of spin-offs was included in the analysis. A dichotomous variable was constructed taking value 1 for Delft and 0 for Trondheim (The selection of Delft and Trondheim is explained in chapter 5).

Risk profile of strategy
The next variable that may influence growth is the risk profile of the strategy. This variable was measured as a dichotomous variable derived from the type of product/market, i.e. manufacturing versus services, and the level of innovativeness of spin-offs taking value 1 as a high level of risk-avoidance in strategy and 0 as otherwise.

Level of capability
Spin-offs with a high level of capability may be able to develop effective and efficient networks that support growth. This variable was measured as a dichotomous variable derived from the pre-entry business experience of the entrepreneur and capability through team starts versus single start, taking 1 to indicate a high level of capability and 0 otherwise.

Resources deficiency
Like other start-ups, spin-offs may experience obstacles to growth. There are three main obstacles for university spin-offs: lack of market-related knowledge, managerial knowledge and financial knowledge (van Geenhuizen and Soetanto, 2003). Failing to overcome these obstacles may hinder the growth of spin-offs. In this study, the variable resources deficiency

was constructed by dividing the number of missing main resources by the total of all main resources. A high value indicates a high level of resources deficiency, min: 0; max: 1.

Added value support

The nature of support may vary considerably, from conventional support which is oriented towards the provision of '*basic resources*', i.e. office, administration and financial support, to more added value support, i.e. marketing and market analysis; R&D networking; business partner networking. In this study, the variable added value support was derived by dividing the number of added value support types enjoyed by spin-offs by the total number of added value support types. A high value indicates a high level of value added support, min: 0; max: 1.

Tightness of networks

The variable, tightness of networks was measured as the quotient of the total number of ties of the network relations (*t*) and the total number of partners (*n*) per spin-off (Borgatti et al., 1998; Jensen and Greve, 2002). A high value indicates a relatively tight network, min: 0; max: 1. The formula is as follows:

$$2t/(n(n-1))$$

Example:

Spin-off A has five partners, but only two partners are connected to each other. It means that there is one tie present in the network (*t*=1), as a result, the value of tightness is:

$$(2*1)/(5*(5-1))=0.1$$

Strength of ties

According to Granovetter (1974), the strength of a tie is a linear combination of the amount of time, the emotional intensity, the intimacy, and the reciprocal service which characterizes the tie. In this study, the strength of relationship was constructed as a composite variable derived from three-rank variables: frequency of face-to-face interaction (*i*), duration of relationship (*d*), and entrepreneurs' assessment of closeness of the relationship (*c*) with partners (*n*) (Burt, 1992). A high value indicates a relatively strong relationship, min: 0; max: 1.

$$\left(\frac{\sum_{p=1}^{n} i_p + \sum_{p=1}^{n} d_p + \sum_{p=1}^{n} c_p}{3n}\right) \Big/ 3$$

Example:

Spin-off A has a very weak relationship with partner 1 and 2 (*i*, *d*, and *c* equal to 1). Spin-off A has a very strong relationship with partner 3 (*i*, *d*, and *c* equal to 3). Then the value of strength of ties is:

$$\left(\frac{(1+1+3)+(1+1+3)+(1+1+3)}{3*3}\right)\Big/3=0.55$$

Heterogeneity in the background of partners

This variable was derived from the proportion of heterogeneous partners among all partners of a spin-off (a_n) (Renzulli et al., 2000). Six social backgrounds were distinguished (big business – a_1, government – a_2, university – a_3, small business – a_4 , family and friends – a_5, others – a_6). A high value indicates a high level of heterogeneity (min: 0; max: 1). The formula is as follows:

$$1-\sum_{p=1}^{6}\left(\frac{a_p}{n}\right)^2$$

Example:

Spin-off A has five partners, three of whom are university professors, one comes from big industry and one comes from small business. Thus, the value of heterogeneity is:

$$1-\left(\left(\frac{3}{5}\right)^2+\left(\frac{1}{5}\right)^2+\left(\frac{1}{5}\right)^2\right)=0.56$$

External orientation

This variable is described as a quotient of the number of external (non-local) partners (> 30 minutes car driving) (*d*) and number of local partners (*n-d*) (shorter travel time) of a spin-off, given a maximum of five partners (Krackhardt and Stern, 1988). A high value indicates a relatively strong external orientation (more partners at a distance) (min: -1; max: 1). The formula is as follows:

$$d-(n-d)/n$$

Example:

Three of five partners of spin-off A are non-local partners. Thus, the value of external orientation is:

$$3-(5-3)/5=0.2$$

4.4.3 Methods of analysis

In this study, linear regression analysis was performed to test a model with job growth as a dependent variable. A logistic regression analysis was performed with network growth as the dependent variable, and several interaction effects of linear regression were explored with job growth as a dependent variable.

Linear regression analysis

Linear regression is a statistical technique used to analyze the relation between a single dependent variable and several independent variables. The basic assumption is that there is a linear correlation between the independent variables and the dependent variables (Aiken and West, 1991). In this study, the ordinary least square (OLS) technique was used to determine the best-fitting lines that minimized the vertical distances from all the points to the estimated line. There are four principal assumptions which justify the use of linear regression analysis, i.e. linearity of the relationship between dependent and independent variables, independence of the errors, homosecedasticity, and normality of the error

distribution. Several diagnostic tests were performed for each linear regression model to ensure that the assumptions were not violated (Appendix 5).

Logistic regression analysis

Logistic regression is a variation of ordinary regression which is used when the dependent (response) variable is a dichotomous variable, i.e. coded as 0 or 1 and the independent (input) variables are continuous, categorical, or both (Pampel, 2000). In this study, the dependent variable was a dichotomous variable for strong and weak growth. Unlike OLS regression, logistic regression does not assume that the relationship between the independent variables and the dependent variable is linear. Nor does it assume that the dependent variable or the error terms are distributed normally. As the response function is not linear, a transformation needs to be performed to make the response function linear. Logistic regression has many analogies to OLS regression. For instance, logit coefficients correspond to beta coefficients in the OLS regression equation, the standardized logit coefficients correspond to beta weights, and a pseudo R^2 statistic indicates the proportion of variability in a data set that is accounted for by the model.

Interaction effect in regression analysis

Moderated Multiple Regression or MMR involves a hierarchical regression that first tests the relationship between independent variables and dependent variable, and then tests the relationship of a term that carries information about both independent variables, the interaction term. An interaction occurs when the magnitude of the effect of one independent variable (X) on a dependent variable (Y) varies as a function of a second independent variable (Z). This is also known as a moderation effect (Aiken and West, 1991).

4.5 Conclusion

This chapter contains the research design of the study, and consists of two parts, one, a meta-analysis of the growth of university incubators and two, a study of the growth of university spin-offs. The sampling design, data collection technique, variables and methods of analysis that are applied in each study are discussed. The results of the study leading to the selection of two incubators are presented in the next chapter.

Chapter 5

FRAMEWORK FOR INCUBATOR SELECTION

5.1 Introduction

A framework design for the selection of incubators in various developed countries is discussed in this chapter. The selection criteria are aimed at providing a contrast between relatively slowly and relatively quickly growing incubators. As a result, two incubators will be selected from a set of 40 incubators. This chapter starts with section 5.2 in which several expectations on factors that influence the growth of incubators are described. The procedure used in the development of the framework for the selection of incubators is described in three parts in section 5.3. Section 5.3 starts with a brief explanation of the method of analysis used. This is followed by the presentation of the results. Based on these results, a framework is developed and presented in the last part of the section. A description of the selected incubators is provided in section 5.4. The chapter ends with a conclusion on the framework development in section 5.5. This chapter is largely based on an article by Soetanto and van Geenhuizen (2007) published in the Journal of Environment and Planning B: Planning and Design.

5.2 Factors influencing the growth of incubators

The number of incubators has been growing very rapidly in the recent years (Barrow, 2001). Incubators have developed according to different business models and diverse characteristics as have the actors involved with incubators. Early incubators started as a local initiative and were established to provide simple support such as accommodation for startups. These incubators usually employ a central building that offers room for spin-offs. Alternatively, university spin-offs may be located in a faculty's building while support such as information about grants, managerial support, etc. can be accessed from different offices at the university. These early incubators often faced limited resources as they existed in association only with universities (Vedovello, 1997; Phillimore, 1999). Since then, incubators have been expanding in terms of number of actors involved and support provided. Incubators have turned into a policy tool driven by the state and/or regional/local government to encourage technology-based business in their areas and to enhance regional economic development.

While there are many ways to measure the growth of an incubator (Mian, 1997), the growth of incubators can be understood by analyzing the incubation process. There are at least three components that can be used to analyze the process. One, the main objective of every incubator is to support spin-offs and help them to survive and to become independent. Shared offices and laboratory facilities, financial support and legal advice are among the basic facilities offered by incubators to ensure the life of new spin-offs. Two, incubators have a link with universities or research institutes. These links may vary in strength and may serve

different purposes depending on the involvement of other stakeholders. Three, incubators can be seen as *organizations* performing a bridging function between promising spin-offs and the resources required by these spin-offs while protecting the spin-offs against potential failure (Hackett and Dilts, 2004). Based on the above similarities and a review of the literature, the process of incubation can be conceptualized as a transformation of initial spin-offs into viable spin-offs (Figure 5.1).

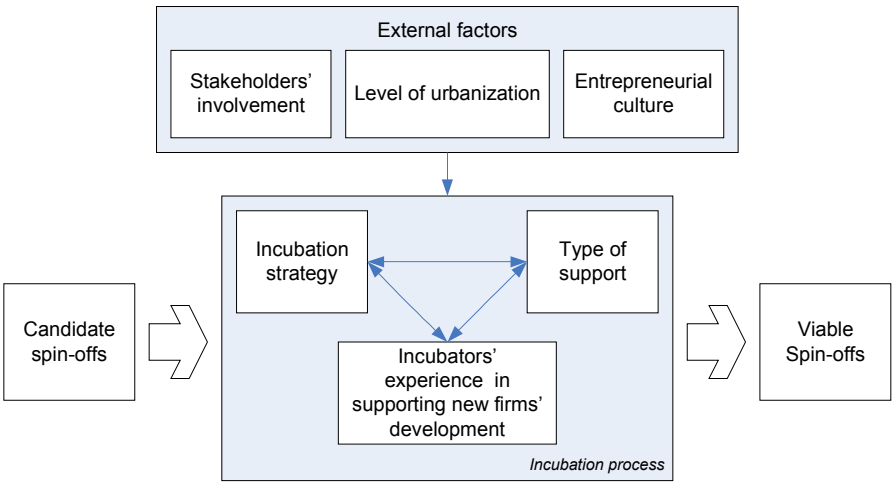

Figure 5.1 Simplified model of the incubation process

The incubation process can be seen as a function of several factors, external and internal, influencing the performance of incubators in promoting the survival of spin-offs. External factors represent major characteristics addressed in knowledge-based and institutional approaches to regional innovation, including networks of stakeholders, urban economic conditions in terms of human capital and creativity, and entrepreneurial culture. Internal factors refer to various qualities and strategies of incubator organizations in attracting and managing resources to support spin-offs, including selection procedures for candidate spin-offs, types of (tailor-made) support, capability of staff in business monitoring and coaching, and exit assessment. The expectations concerning each of these six factors are summarized in table 5.1.

Table 5.1 Expectations concerning the relationship between the characteristics of incubators and growth

Incubators' characteristics	Expectation
External factors	
Stakeholders' involvement	Involvement of different stakeholders stimulates more dynamic development of incubators compared to involvement of a single stakeholder.
Level of urbanization	Incubators in large metropolitan areas experience more dynamic development than those outside large metropolitan areas.
Entrepreneurial culture, i.e. uncertainty avoiding attitude	Incubators in countries facing lower levels of uncertainty avoidance experience more dynamic development than those in countries facing higher levels of uncertainty avoidance.
Internal factors	
Model of support provided by incubators	Incubators employing added value models of support experience more dynamic development than incubators merely offering conventional support.
Incubation strategy	Incubators employing a profit-oriented strategy experience more dynamic development than incubators focusing on research commercialization in a traditional way.
Age of the incubator organization	Older incubators face more dynamic development than younger ones

References: Etzkovitz (2002); Monck et al. (1988); Glaeser et al. (1995); Jacobs (1961); Florida (2002); Acs (2002); Armstrong and Taylor (2000); Audretsch (1998); Hofstede (1991); Van Everdingen and Waarts (2003); Hannon and Chaplin (2003); Smilor et al. (1990); McKinnon and Hayhow (1998).

5.3 Towards a framework of incubator selection

The procedure of framework development is presented in three parts in this section. In the first part, the discussion is focused on data collection and method of analysis, and then the results of the analysis, derived from Rough Set Analysis are presented. Finally, the framework is established and applied to select the case study of incubators.

5.3.1 Introduction to the analysis

The data used in the analysis on the growth of incubators was selected from an existing body of knowledge on incubators. Some specific requirements were imposed on the incubators to gain a substantial degree of variance and to avoid a particular characteristic becoming dominant in the sample of incubators (see Chapter 4). As a result of this selection process, a final sample was established which included 40 incubators. The performance of each incubator is measured as the average annual growth (decline) of the numbers of incubated firms and this varies between -3.00 and +7:00. A growth of +1.25 was taken as the borderline in the construction of the decision variable, not only because it was the median but also because the next growth class was twice as high (+ 2.50) (see Figure 5.2). Taking the average growth (+ 1.85) would have given the same borderline. Accordingly, the incubators were divided into two classes, i.e. those experiencing a relatively weak growth (- 3.00 to +1.25) and those experiencing a relatively strong growth (+ 1.25 to + 7.00). The frequency distribution of growth of incubators followed a normal distribution as evidenced by the outcomes of normality tests below (Table 5.2).

Table 5.2 Statistical result

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Average annual growth	0.13	40	0.10	0.98	40	0.54

The Kolmogorov-Smirnov test gave a value of 0.13 and p-value of 0.10, and the Shapiro-Wilk test gave a W-value of 0.98 and p-value of 0.54. Since both p-values were above 0.05, it was assumed that the distribution of average annual growth followed a normal distribution. The result showed that the selected incubators in the sample fairly represented the distribution of technology incubators in developed countries. However, the class of stationary incubators (zero-growth) is somewhat underrepresented.

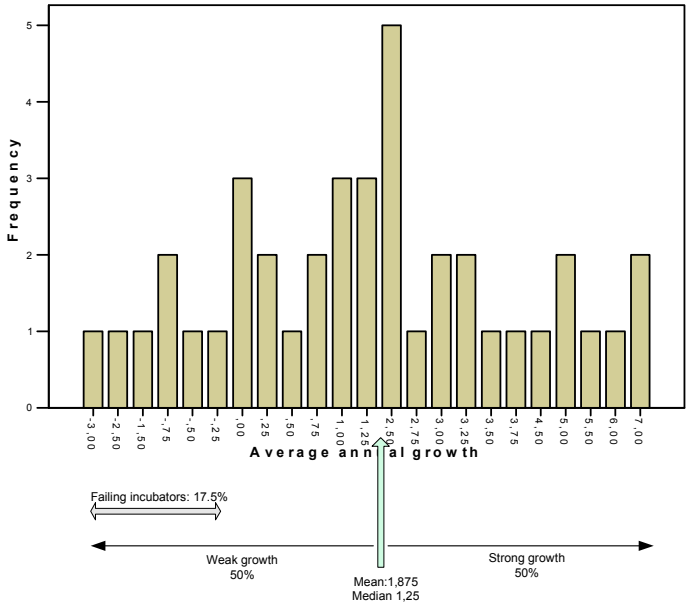

Figure 5.2 Frequency distribution of growth of incubators (average annual growth)

To perform the analysis, a relatively young technique derived from the field of artificial intelligence, namely Rough Set Analysis, was used. In Rough Set Analysis, the dependent variable is named the *decision attribute* and the independent, explanatory, variables are named *condition attributes*. Together all the attributes are placed in *an information table* (Table 5.3). The *condition attributes* represent the proposed factors determining incubators' growth, i.e. model of stakeholders' involvement, level of urbanization of the city, uncertainty avoiding attitude, model of support, incubation strategy and age of the incubator organization. Prior to the analysis, each *condition attribute* is classified into two categories. For instance, the model of support provided by incubators has two categories: conventional and added value support. Furthermore, the *decision attribute* represents the growth of incubators.

Table 5.3 Information table (selected cases for the purpose of illustration)

Object	Incubator region/city	Condition attributes						Decision attribute
		C1	C2	C3	C4	C5	C6	D
1	Cambridge, UK	1	1	1	2	1	2	2
2	Trondheim, Norway	2	2	1	1	2	1	2
3	Enschede, The Netherlands	2	2	2	1	2	2	2
4	Budapest, Hungary	1	1	2	1	1	2	1
5	Austin, Texas, US	1	1	1	2	1	2	2
6	Cleveland, Ohio, US	2	1	1	1	2	2	2
7	Styre, Austria	1	2	2	1	2	2	1
8	Shanghai, China	2	1	2	1	2	1	2
9	Växjö, Sweden	1	2	1	2	1	2	2
10	Crete, Greece	1	2	2	1	1	2	1

C1: Stakeholders' involvement, 1: single stakeholder involvement; 2: multiple stakeholder involvement.
C2: Level of urbanization, 1: metropolitan areas; 2: non-metropolitan areas/peripheral.
C3: Uncertainty avoiding attitude index, 1: low; 2: high.
C4: Model of support provided by incubators, 1: conventional; 2: value added.
C5: Incubation strategy. 1: research commercialization; 2: profit-focused.
C6: Age of the incubator organization, 1: < 5 years old; 2: ≥ 5 years old.
D: Average annual growth, 1: relatively weak (≤ 1.25); 2: relatively strong (>1.25).

5.3.2 Results of Rough Set Analysis

Rough Set Analysis produces a set of *decision rules*, presented in an '*IF condition(s) THEN decision'* format (Table 5.4).

Table 5.4 Typical output on decision rules (one sample)

Rules	Combinations of factors	Growth class	Strength / Coverage (%)
1	C4='1' and C5='1'	Weak	41.7
2	C2='1'and C6='1'	Weak	38.5
3	C1='2'and C2='2'	Strong	46.2
4	C2='2'and C3='1'	Strong	33.3
5	C5='2'and C6='2'	Strong	41.7

C1-C6: The condition attributes, i.e. model of stakeholders' involvement, level of urbanization, risk-avoiding attitude, model of support provided by incubators, incubation strategy, and age of incubator organization.

For instance, rule number 3 indicates that the combination of multiple stakeholders' involvement (C1) and a position in a non-metropolitan area (C2) leads to relatively strong growth. This rule is supported by a coverage of 46.2. Coverage indicates the strength of the rules. A coverage of 46.2% means that 53.9% of the incubators are not characterized by the rule, but they may be characterized by various other rules. Compared to other studies (e.g. Goh and Law, 2003; Sanchis et al., 2006; Warren et al., 2004), a coverage of around 45% is relatively high. The results of Rough Set Analysis applied to a range of subjects in the fields of social science and engineering fields indicate that the maximum levels seldom exceed 50%.

In this study, three types of analysis were performed with the following objectives, to find the strongest rule and the most influential factors on the growth of incubators.

(1) To identify the condition attributes that influence incubators' growth based on the frequency of the condition attributes in the decision rules.
(2) To identify the condition attributes that appears most frequently in the strongest decision rules.
(3) To identify the combination of the condition attributes that appears most frequently in the strongest decision rules.

The results of each analysis are discussed in the next section (see for more details Soetanto and van Geenhuizen, 2007).

First Analysis: identify the condition attributes that influence the growth of incubators based on the frequency of condition attributes in the decision rules

The objective of the first analysis was to confirm whether the expected condition attributes influenced the incubators' growth. As shown in table 5.5, the outcomes concerning the model of stakeholders' involvement (C1) confirmed this expectation. Incubators supported by different stakeholders tend to experience relatively strong growth; and incubators supported by a single stakeholder (university) tend to experience relatively weak growth. With regard to level of urbanization (C2), the result showed that this factor appears in the rules that reject the expectation. Non-metropolitan regions tend to produce relatively fast growing incubators whereas metropolitan regions tend to produce relatively slow growing incubators. The expectation concerning national culture and attitude towards risk (C3) is partly confirmed. Risk-avoidance seems only to promote strong growth. Incubators located in a country facing low risk-avoidance tend to perform better than those located in a country facing strong risk-avoidance. Nevertheless, low risk-avoidance also appears in the rules that explain weak growth. With regard to the next expectation, the results suggested that incubators providing added value support (C4) tend to experience relatively strong growth while the others tend to perform weakly. The models that match/tailor support with different needs of tenants, in terms of networking and business coaching, tend to lead to relatively strong growth. With regard to incubation strategy (C5), the results suggested that a profit-focused incubation strategy tends to cause stronger growth than a strategy that merely commercializes university research. Finally, the results also suggested a positive influence of age of the incubator organization (C6). Apparently, older incubators tend to benefit more from learning experience than younger incubators.

It appeared that five out of six condition attributes have a relatively high frequency rate in one particular side of the rules that explain strong or weak growth. Attributes stakeholders' involvement (C1), model of support provided by incubators (C4), incubation strategy (C5) and age of the incubator organization (C6), appear in the decision rules that explain the growth as expected and attribute level of urbanization (C2) appears in the rules that explain the growth differently compared to expectations. Only attribute uncertainty avoiding attitude (C3) appears in both sides of the rules, i.e. a strong and weak growth. In other

words, the findings showed that condition attribute uncertainty avoiding attitude (C3) had the weakest contribution in explaining the growth of incubators.

Table 5.5 Frequency of condition attributes in the decision rules

	C1 (%)	C2 (%)	C3 (%)	C4 (%)	C5 (%)	C6 (%)
Frequency rate of condition attributes that support the expectation	80.0 (16/20)	0	65.0 (13/20)	70.0 (14/20)	75.0 (15/20)	100.0 (20/20)
Frequency rate of condition attributes that contradict the expectation	0	75.0 (15/20)	25.0 (5/20)	0	0	0

C1-C6: The condition attributes, i.e. model of stakeholders' involvement, level of urbanization, risk-avoiding attitude, model of support provided by incubators, incubation strategy, and age of incubator organization.

Second Analysis: identify condition attributes that appear most frequently in the strongest decision rules

The objective of the second analysis was to identify the condition attributes that appear most frequently in the strongest decision rules. The reason for this analysis was that a high frequency of appearance of individual *condition attributes* in the strongest decision rules means that these attributes stand out in a more pronounced way than the others. Accordingly, the analysis was performed separately for the rules that explain strong growth and those that explain weak growth. The label '*strongest rule'* means that the rules were supported by the largest number of cases. In other words, the rule had the highest percentage of coverage. In the weak growth category, seven strongest rules were identified while in the strong growth category, five strongest rules were identified (Table 5.6). For each condition attribute, the frequency of appearance in one strongest rule was divided by the total number of the strongest rules in that category. For example, with regard to weak growth, model of stakeholders' involvement (C1), gives a frequency rate of 43% ((3/7)*100%).

Table 5.6 Frequency in the strongest rules (10 samples)

	C1 (%)	C2 (%)	C3 (%)	C4 (%)	C5 (%)	C6 (%)
Weak growth appearance rate (7 rules)	43.0 (3/7)	29.0 (2/7)	43.0 (3/7)	57.0 (4/7)	43.0 (3/7)	14.0 (1/7)
Strong growth appearance rate (5 rules)	60.0 (3/5)	60.0 (3/5)	20.0 (1/5)	0	40.0 (2/5)	20.0 (1/5)

C1-C6: The condition attributes (model of stakeholders' involvement, level of urbanization, risk-avoiding attitude, model of support provided by incubators, incubation strategy, and age of incubator organization).

As can be seen from table 5.6 only a few condition attributes strongly determine the growth pattern of incubators. Attribute model of conventional support (C4) tends to be important in causing relatively weak growth (57%) while strong growth is mainly caused by two attributes: multiple stakeholders' involvement (60%) and a location in non-metropolitan areas (60%). The rest of the attributes, uncertainty avoiding attitude (C3), incubation strategy (C5), and age of incubator organization (C6), have a relatively low frequency of appearance in the decision rules that explain either strong or weak growth.

Third Analysis - Identify the combination of condition attributes that appear most frequently in the strongest decision rules

As shown in table 5.7, the rules that are a combination of attribute model of stakeholders' involvement (C1) and level of urbanization (C2) appear in most of the samples, i.e. 60%. This combination appears in the three rules that explain strong growth and the three rules that explain weak growth. The rest of the combinations show a frequency of appearance of 40% or less.

Table 5.7 Frequency of the strongest rules (10 samples)

Strongest rules	Frequency rate (%)	Strong growth	Weak growth
C1 & C2	60.0 (6/10)	3	3
C4 & C5	40.0 (4/10)	2	2
C1 & C5	30.0 (3/10)	1	2
C1 & C6	20.0 (2/10)	-	2
C2 & C5	20.0 (2/10)	2	-

C1-C6: The condition attributes (model of stakeholders' involvement, level of urbanization, risk-avoiding attitude, model of support provided by incubators, incubation strategy, and age of incubator organization).

5.3.3 Framework of selection

The results of the three analyses are summarized in table 5.8 below.

Table 5.8 The summary of factors that influence the growth of incubators

	First analysis	Second analysis	Third analysis
Factors that influence the growth of incubators	**C1**	**C1**	**C1**
	C2	**C2**	**C2**
	C4	C4	
	C5		
	C6		

The table shows that attribute models of stakeholders' involvement (C1) and level of urbanization (C2) appear to be consistently important. Therefore, these two attributes were used in the framework. According to the condition attribute of model of stakeholders' involvement (C1), the selected incubators should represent the difference with regard to this model single stakeholder's involvement versus multiple stakeholders' involvement. With regard to level of urbanization (C2), the selected incubators should represent the difference in position in the urban economic condition: located in a metropolitan area versus located in a non-metropolitan area. The framework should also present a contrasting difference in the growth of incubators: strong versus weak growth. Analyzing incubators, facing contrasting characteristics was expected to provide richer information than analyzing homogeneous incubators (Yin, 2002). The framework of selection that is developed based on models of stakeholders' involvement (C1) and level of urbanization (C2) and growth is shown in figure 5.3.

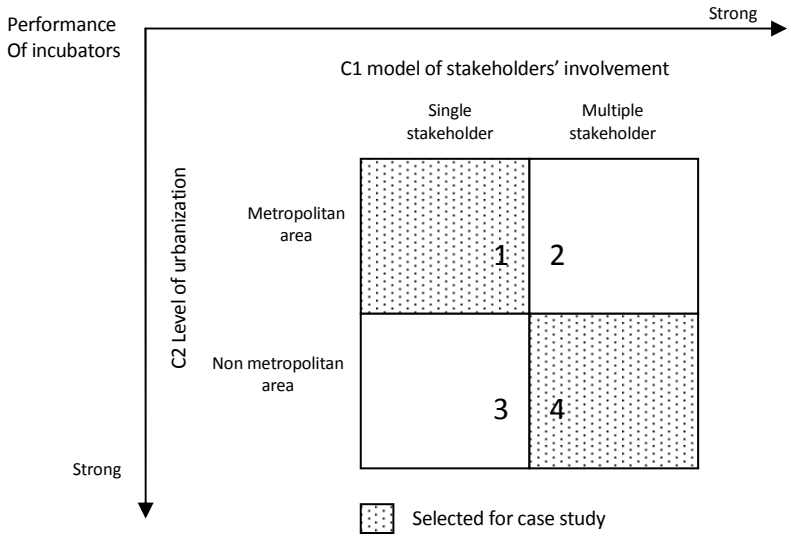

Figure 5.3 Framework of selection

As can be seen from figure 5.3 four types of incubators can be selected (1, 2, 3, and 4), however, only two types of incubators were selected to make a strong comparison for further study. The first type represents incubators with the model of single stakeholders' involvement, located in metropolitan areas and facing a relatively weak growth (type 1). In contrast to the first type, the fourth type represents a model of incubators that have multiple stakeholder involvement, are located in non-metropolitan areas and experience a relatively strong growth (type 4). This resulted in 8 candidates incubators (Table 5.9).

Table 5.9 Candidate incubators for selection

Name of incubator region (city)	C1	C2	D
Enschede, the Netherlands	2	2	2
Salzburg, Austria	2	2	2
Skone, Sweden	2	2	2
Trondheim, Norway	2	2	2
St. Petersburg, Russia	1	1	1
Atlanta, US	1	1	1
Delft, the Netherlands	1	1	1
Budapest, Hungary	1	1	1
C1: Stakeholders' involvement, 1: single stakeholder involvement; 2: multiple stakeholder involvement. C2: Level of urbanization, 1: metropolitan areas 2: non-metropolitan areas/peripheral. D: Average annual growth, 1: relatively weak (≤ 1.25); 2: relatively strong (>1.25).			

Of the above candidate incubators, two incubators were selected that are the incubator at TU Delft, in the Netherlands and the incubator at NTNU Trondheim, in Norway. The characteristics of the two selected incubators are shown in more detail in table 5.10.

Table 5.10 Characteristics of selected incubators

	Incubator at TU Delft	Incubator at NTNU Trondheim
Stakeholders' involvement	Single stakeholder involvement [a)]	Multiple stakeholder involvement
Level of urbanization	Metropolitan area	Non-metropolitan area /peripheral
Uncertainty avoiding attitude (index)	High	High
Model of support provided by incubators	Conventional [a)]	Value added
Incubation strategy	Research commercialization	Profit-focused
Age of the incubator organization	< 5 years old	≥ 5 years old
Average annual growth	Relatively weak (0.84)	Relatively strong (2.10)

[a)] Based on situation in 2004: in 2005 a major change occurred in response to the foundation of Yes!Delft.

5.4 Description of the selected incubators

The two selected incubators are described in more detail in this section, based on two contrasting characteristics, i.e. model of stakeholders' involvement and level of urbanization. The first characteristic is concerned with the type of stakeholders that are involved and their role in supporting university spin-offs, while the second characteristic is concerned with the geographical location, and scale of the city region involved. The characteristics of support provided to university spin-offs are also discussed.

Model of stakeholder's involvement – single versus multiple stakeholders
In terms of a policy to foster spin-offs, TU Delft represents a category of technical universities in Western Europe that became involved in spin-offs relatively late. The first official program, named the Techno-starter program, was introduced in 1998, but similar support was provided a few years prior to 1998. The Techno-starter program was intended to support firms founded by graduates, students, and academic staff. At the time the data was collected, the program did not provide room in a special incubator building or in a Science Park, both were under construction and finished in 2005. Rather, the spin-offs were located in faculty buildings, some old laboratories of the university (temporary) and in various business buildings in Delft. The Techno-starter program provided support in terms of initial investment, a small loan without interest, entrepreneurial courses, office space and use of equipment and laboratories at the faculties and some mentoring. This program may be qualified as 'low-selective' (Clarysse et al., 2005), meaning that the access criteria were not particularly strong in terms of level of innovativeness and start-ups' motivation (ambition). Overall, the number of stakeholders involved in supporting university spin-offs was limited since the university was the only actor in the initiative to provide support.

Recently, Delft University of Technology has boosted support for the creation and survival of university spin-offs. Through additional funding from the national government and the active participation of the municipality of Delft, a foundation was established and an incubator building, YES!Delft, was opened in 2005. The incubator building provides room (office) and additional support for university spin-offs. In 2007, the incubator building accommodated more than 20 spin-offs. Delft University of Technology also aims to improve

education and research in the field of entrepreneurship at the Delft Center for Entrepreneurship founded in 2007. This new development falls beyond the study period of investigation of this study. Moreover, promotion events have been conducted to increase the awareness of students and academic staff about the possibilities of commercializing knowledge. All these activities are orchestrated by the Valorization Center at the university, a new structure accommodating several existing organizations within Delft University of Technology that deal with knowledge commercialization and entrepreneurship. Furthermore, to strengthen the support for creation of university spin-offs at the regional level, Delft University of Technology together with Erasmus University Rotterdam and Leiden University collaborate in the Holland Program on Entrepreneurship (HOPE).

While TU Delft represents the model of single stakeholder's involvement especially before the establishment of YES Delft, for most of the study period, the policy at Trondheim represents a different model. The development of spin-offs has involved different stakeholders for a long time. Norwegian University of Science and Technology (NTNU) and SINTEF are the major stakeholders in knowledge commercialization from the university and research center. Together with Leiv Eirikson Nyfotek (LEN), a seed and venture capital company, NTNU established an incubator building at the university's premises in 2000. The incubator, called Innovasjonssenter Gloshaugen, offers office space, shared administration services, managerial support and network development support. In addition, LEN employs another incubator outside the university campus that provides a set of similar support facilities but with a focus more on IT and service industry companies as its tenants. Through these two incubators LEN has been involved in the establishment of 50 spin-offs in the period of 1995–2003. Besides the previously mentioned stakeholders, some other governmental organizations are actively involved in the development of spin-offs in Trondheim. Moreover, another organization namely the Norwegian Industrial and Regional Development Fund (SND) plays an important role in the early stages of spin-offs' establishment by providing funding. NTNU also established an Entrepreneurship Center within the Department of Industrial Economics and Technology Management, much earlier than at TU Delft. The function of the Entrepreneurship Center is to conduct research and to provide courses in the practice of entrepreneurship leading to a Master's diploma, something not available at TU Delft at the time of this study. This center is also involved in various business development projects which has led to the creation of spin-offs. In addition, NTNU established a Technology Transfer Office (TTO) in 2003. The main task of TTO is to arrange negotiations with investors, i.e. student or academic staff, concerning issues of patenting. TTO also provides a complete set of support tools for research commercialization such as consultation for developing a business plan, network building, and information about the sources of grants and venture capital. Some additional efforts have been made by TTO to attract key persons from industry to invest and to create new ventures based on research results from the university.

Level of urbanization – metropolitan versus non- metropolitan areas

Delft University of Technology (TU Delft) is based in the city of Delft, the Netherlands. Delft is a medium-sized city with 95,400 inhabitants (2007) in the province of South Holland, it forms part of the Randstad metropolitan area of the Netherlands. Unlike many other metropolitan

areas, the Randstad does not consist of one core city. Instead, Randstad is composed of several large cities that are connected to each other, i.e. it is a polycentric urban system. The Randstad area covers more than 11,350 km^2 and includes four large cities, i.e. Amsterdam, Rotterdam, The Hague, and Utrecht. Two of the cities are in the province of South Holland: The Hague, with a population of 469,000 in 2007, is the home of the national government and many international organizations while Rotterdam (596,000 inhabitants in 2007) is a center of seaport activity as a European main port, chemical industry, logistics and trading. The city of Delft enjoys the benefits of but also competes from a close distance with these large cities, approximately 10 km from The Hague and Rotterdam (Figure 5.4).

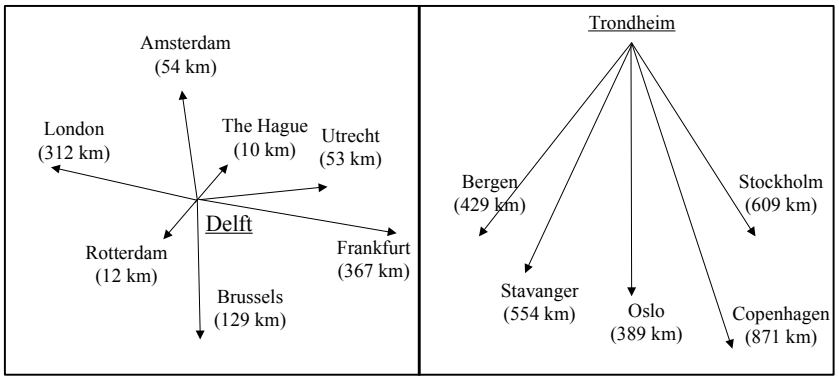

Figure 5.4 Illustration of spatial distances between Delft and Trondheim and other big cities in the Europe (source: http://www.geobytes.com/)

The incubator that provides support to spin-offs from the Norwegian University of Science and Technology (NTNU) is located in the city of Trondheim in the middle of Norway. In contrast to Delft, Trondheim is a single city at a large distance from often big cities, for example the distance from Trondheim to Oslo and Bergen is approximately 400 km and to Stockholm, Sweden is approximately 600 km. Spin-offs in Trondheim have to spend a longer travel time to get to other big cities compared to spin-offs in Delft even if air transport is used (Figure 5.3). Also, due to a smaller number of inhabitants and firms, local launching customers tend to be relatively scarce in Trondheim. Although Trondheim (unlike Delft) is located in a non-metropolitan area, it has an important function in the national city-system. Besides being the third largest city in Norway after Oslo and Bergen, Trondheim is the knowledge capital of Norway with many government research institutes. Trondheim, a city of 161,730 inhabitants in 2007, is the center of Tröndelag region, encompassing two counties, South and North Tröndelag. The Tröndelag region covers a wide area of more than 40.000 km^2 and has a population of less than 400,000 inhabitants (2007). A more detail comparison between South Holland and Tröndelag is shown in table 5.11.

Table 5.11 Comparison between South Holland and Tröndelag region

	South Holland	Tröndelag
Population (2005)	3,458.6 (in 1000)	402.6 (in 1000)
Regional gross domestic product (RGDP) (2004)	106,241.4 million Euro	12,374.7 million Euro
Regional GDP per capita (RGDPP)	30,718.0 Euro	30,737.0 Euro
Main industrial sector	Commerce and services	Mining (energy) and agriculture

Source: Eurostat, 2007

With regard to its economy, South Holland has a different structure compared to that of the Tröndelag region. The major industries in South Holland as a part of the Randstad metropolitan area, are commercial and service industries (CBS, 2007; OECD, 2007). The major industry in Tröndelag is mining and agriculture including farmed fish, processed wood and other agricultural products (Statistics Norway, 2007). The fastest growing sector in Tröndelag region is oil and gas production, which has given a major boost to regional employment and growth. With regard to the size of the economy, South Holland's economy is almost eight times bigger than that of Tröndelag (RGDP). Interestingly, the productivity per capita (RGDPP) in South Holland and Tröndelag is almost the same despite the differences in economic structure.

While the two regions show a different size and structure of their economies, the two cities share some similarities. The largest employment sector in both cities consists of the service industries, related to the fact that both Delft and Trondheim are the homes of a technical university and several research institutes. Delft University of Technology (TU Delft) was founded in 1842. Currently, TU Delft encompasses eight faculties with more than 13,000 students and almost 5,000 fte staff (Table 5.12). In addition, TNO a semi-government research institute situated close to TU Delft and throughout the Randstad provides jobs for research in the region.

The Norwegian Institute of Technology (NTH) was founded in 1910. Later, in 1950, NTH established SINTEF, Foundation for Technical and Industrial Research, aimed at commercializing the research and education at NTH. Norwegian University of Science and Technology (NTNU) was reorganized in 1996, through a merger between the NTH and the Norwegian College for Science (AVH). Today, NTNU comprises of seven faculties with 20,000 students and 3,050 employees (fte). The relatively low number of employees in NTNU can be ascribed to the fact that, in contrast to Delft, PhD students are not regarded as university employees at NTNU or within the Norwegian systems of tertiary education.

As a result of the presence of the technical university and research institutes in Delft and Trondheim, the regions have a relatively large percentage of people employed in research and development. South Holland has 1,290,600 or 3.8% of the total working population work in technology and knowledge-intensive sectors while 194,000 or 4.8% of the total working population work in these sectors in Tröndelag (Eurostat, 2005).

Table 5.12 Number of employees of university and research institutes (2005)

Delft		Trondheim	
Institution	Number of employees (fte)	Institution	Number of employees (fte)
TU Delft	4,900	NTNU	3,050
Delft Hydraulics	340	SINTEF	1,900
TNO	1,400	Marintek	950
Geodelft	470		
IHE	190		

Source: multiple sources (municipality, university and organizations' website)

5.5 Conclusion

A framework for the selection of incubators organizations is presented in this chapter. The framework required systematic insights into factors that influence the growth of incubators. To gain these insights, three analyses were performed. The first analysis suggested that fast growing incubators tend to be supported by multiple stakeholder involvement, located in non-metropolitan (peripheral/rural) areas, with a strong entrepreneurial culture, a profit-oriented strategy, to be older in age and to provide added value support. The second and third analyses found that multiple stakeholder involvement and location in non-metropolitan areas are the most important factors for explaining strong growth. Based on these findings, the framework for the selection of incubators was built. The selection was based on the contrast between multiple versus single stakeholder involvement and location in a metropolitan area versus a non-metropolitan area (periphery). As a result, two incubators were selected for further investigation from a shortlist of candidate incubators: in Delft, the Netherlands and in Trondheim, Norway. In table 5.13, a summary of the major characteristics of these incubators is given.

Table 5.13 Summary of incubators in Delft and Trondheim

	Delft	Trondheim
Model of stakeholders' involvement	University is the main stakeholder, at least until early 2005.	Collaboration between university, research institute, government and business community.
Level of urbanization	Located in the polycentric metropolitan area of the Randstad, South Holland. The service industries are the major industry in the region. Large domestic market (region). Presence of a technical university, TU Delft, and major research institute, TNO.	Located in a non-metropolitan area, Tröndelag region, Trondheim as a single city. The major industries in the region are agriculture and oil/petroleum. Small domestic market (region). Presence of a technical university, NTNU, and major research institute, SINTEF.

With regard to the models of stakeholder involvement, in Delft, the university was the main stakeholder (until 2005) while in Trondheim collaboration between several organizations has existed for a long time. This finding complies with the expectation that the involvement of many stakeholders leads to the provision of more diverse support for spin-offs. With regard

to level of urbanization, the findings showed that incubators in non-metropolitan areas experience strong growth. This finding is against the expectation that stresses the benefits of a location in a metropolitan area for innovative activities and new firms' growth (Maskell and Malmberg, 1999). The finding that relatively strong growth of incubators is found in non-metropolitan areas needs to be seen in the perspective of regional-economic policy to some extent. Spin-offs in Delft may have the advantage of a close distance to (potential) customers and suppliers while spin-offs in Trondheim may have received more attention in regional policy and network support. This may be connected with a more important role in the Norwegian national (knowledge-economy) policy for Trondheim than for Delft in the Netherlands. The fact that the incubator in Trondheim performs better than that in Delft indicates that there is 'support' that plays a decisive role in enhancing the growth of spin-offs in Trondheim. In the next chapter, an analysis will be presented of whether there is a difference in obstacles to growth and the reduction of these obstacles between the spin-offs in Delft and Trondheim in the context of a broader analysis of growth of spin-offs.

Chapter 6

GROWTH OF UNIVERSITY SPIN-OFFS: PATTERN OF OBSTACLES, JOB AND NETWORK GROWTH

6.1 Introduction

The results of the analysis of growth of university spin-offs (TU Delft and NTNU Trondheim) are presented in this chapter. A new perspective on growth is given by measuring changes in obstacles to growth. Measuring changes in obstacle is intriguing since the types of obstacles are well documented in the literature but the time-pattern of obstacles is relatively unknown. In addition, growth is measured in terms of increase in employment, i.e. job growth and expansion through business networks. The structure of this chapter consists of two parts. The focus of the first part is on obstacles overtime in the context of growth (section 6.2) and growth in terms of jobs and business networks is presented as the second part in section 6.3. This chapter ends with a summary in section 6.4.

6.2 Time-pattern of obstacles

The results of the analysis of time patterns of obstacles are presented in this section. This section begins with an explanation of the methodological issues, this is followed by a description of the type of obstacles and obstacle incidence for spin-offs of different ages. An analysis using a longitudinal perspective on obstacle incidence is presented in the last part of this section.

6.2.1 Methodological issues

Two types of analysis, cross-sectional and longitudinal, are employed in this study. Here cross-sectional analysis is used to determine obstacles at one point in time, i.e. time of the survey, for the different ages of spin-offs. Longitudinal analysis is used to determine obstacles over years in the life of spin-off firms. Longitudinal analysis offers the advantage that developments over time can be identified at the individual level of the firms. Two important methodological issues were encountered when conducting this type of analysis, i.e. questions regarding the representativeness of the sample at older ages and a potential bias due to self-evaluation data.

The representativeness of the sample in the older age category may be questioned as failed spin-offs were excluded from the sample. According to Mustar et al. (2007), despite a high number of obstacles having to be faced in the early years, the survival rate of university spin-offs is relatively high in Europe. The authors state that 75% of university spin-offs are still in business six years after establishment. In the case of spin-offs from TU Delft, it is estimated that more than 80% of the spin-offs were still operating six years after establishment (from

the expert opinion). Based on these findings, six simulation experiments were performed to check the validity of the date for the older age category. In the simulation, a new set of data for the older age spin-offs category (8-10 years) was created by adding additional spin-offs according to the above-mentioned two survival rates. A t-test is employed to test the significance of differences between the original data set and the new data set. Overall, the results show that the original set of data is representative for obstacle incidence in the age category of 8-10 years (see appendix 3 for the detailed analysis).

Moreover, using self-reporting methods for the data collection may have caused bias (Spector, 1994). As the data on obstacles incidence was collected from the personnel opinion of entrepreneurs, a potential bias could emerge because of the following conditions:

(1) differences in awareness of obstacles and different memory gaps between different (categories of) entrepreneurs. In one side, entrepreneurs of older spin-offs may no longer remember the obstacles that appeared in early years. On the other side, entrepreneurs of recently established firms may not be aware of obstacles that they need to deal with currently to continue to function well as a new firm.
(2) the need felt by some respondent to give socially desirable answers (e.g. Fowler, 2002). This may occur in different cases, such as when confirming success stories and when justifying support. Entrepreneurs may intentionally overlook the obstacles that they have faced to support their success story.
(3) differences in the personality of entrepreneurs and the ways they deal with obstacles. Entrepreneurs with an optimistic view may report a low number of obstacles, while the more pessimistic may report a high number of obstacles with a possible tendency to exaggerate.

The questionnaire design included a list of thirteen predefined types and open types of obstacles in an attempt to avoid bias from different awareness and memory gap (see Appendix 2). The two types of questions were designed to stimulate awareness of obstacles and guide all the entrepreneurs, hopefully providing the same level of comprehension, in answering the questions. The interviews used to pre-test the questionnaire gave no indication of entrepreneurs reporting mainly slight obstacles or a mix of slight and serious obstacles, but rather serious obstacles. Overall, the strategy, including pre-testing the questionnaire, using additional in-depth interviews and other data-sources, served to increase the validity of the results on obstacles (triangulation). Concerning a potential bias from socially desired answers, the answers provided no serious under/overestimation because in the communication with the respondents no attention was given to the potential consequences of the study results, and the data were processed anonymously. With regard to the differences in personality, optimistic versus pessimistic, it was expected that the influence on the validity of the answers on the aggregate level would be more or less neutral.

The following discussion is about measurement issues. Two issues emerged in this study. One, the measurement of age of spin-offs was crucial as the aim of the analysis was to clarify the age-pattern of obstacles. Age was measured on the basis of the year of establishment of

firms in the sense of registration at the Chamber of Commerce. Although this could cause entrepreneurial activities undertaken before registration to be disregarded, registration offered the advantage of a uniform start event for all the firms studied and has a formal status. The second issue was concerned with the measurement of the patterns of the obstacles. Two indicators were introduced, namely the obstacle incidence rate (OIR) and the obstacle reduction rate (ORR). The obstacle incidence rate is calculated by dividing the total number of obstacles per age-category by the number of spin-offs in that category, as follows:

$$\text{Obstacle incidence rate (OIR)} = \frac{\sum_{i=0}^{t} O_i}{\sum_{i=0}^{n} X_i}$$

Where: *O* is the number of obstacles per age (class), *X* is the number of spin-offs in the age category, *t* is the age category or year, and n is 0, 1, 2, …. Accordingly, an OIR of 1.00 for a particular age category means that one spin-off faces on average one obstacle to growth. The next indicator was developed to discover trends in solving (or preventing) obstacles, namely an 'obstacle reduction rate' or ORR. This indicator is a percentage measured by dividing the difference of OIR between two age categories with the initial OIR. As ORR measures the reduction percentage between two age categories, it allows trends in the capability of spin-offs to deal with obstacles to be indentified. The formula is as follows:

$$\text{Obstacle reduction rate (ORR)} = \left(\frac{OIR_{t+n} - OIR_t}{OIR_t} \right) * 100$$

Where: OIR_t is the obstacle incidence rate in the t age category, OIR_{t+n} is the obstacle incidence rate in the *t+n* age category, *t* is the age category or year, and *n* is 0,1, 2, ….

6.2.2 Types of obstacles and obstacles in different age categories

The nature of obstacles faced by university spin-offs is explored below. The number of obstacles experienced by spin-offs according to various categories and types is presented in table 6.1. The categories of obstacles include market-related knowledge and financial, management, physical, market and remaining obstacles. TU Delft's spin-offs experienced a slightly smaller number of obstacles compared to NTNU Trondheim's spin-offs, witness 3.4 versus 3.6 obstacles per spin-off.

In the case of spin-offs of TU Delft, a lack of marketing knowledge was the most common obstacle, 15.8%, compared to other obstacles. This was followed by a lack of sales skills, 12.8%, and difficulty in dealing with uncertainty and lack of forecasting capability about future markets, both 11.3%. Financial obstacles occurred less frequently in the case of TU Delft's spin-offs, 8.9% due to lack of investment capital and 6.4% due to lack of cash flow. In contrast, spin-offs of NTNU Trondheim experience lack of financial investment as an obstacle more often than other obstacles, 19.0%. This was followed by lack of marketing knowledge, 14.3%, and lack of cash flow, 13.6%. With regard to management-related obstacles, 12.9% of

the spin-offs of NTNU Trondheim experienced difficulty in dealing with uncertainty. Overall market-related knowledge, financial and management obstacles tended to be the most experienced obstacles faced by spin-offs of TU Delft and NTNU Trondheim, i.e. more than 75% of all obstacles. Other obstacles, like accommodation and available infrastructure, appeared to be of minor importance. Therefore, the obstacles category of market-related knowledge, financial and managerial obstacles was labeled 'main obstacles' and this set of obstacles was used in the next steps of the analysis.

Table 6.1 Current and past obstacles to growth

Categories of obstacles	Types of obstacles	TU Delft 59 spin-offs		NTNU Trondheim 41 spin-offs	
		Freq.	%[a)]	Freq.	%[a)]
Market-related knowledge	Lack of marketing knowledge	32	15.8	21	14.3
	Lack of sales skills	26	12.8	14	9.5
	Lack of forecasting capability about future markets	23	11.3	10	6.8
Financial	Lack of cash flow	13	6.4	20	13.6
	Lack of investment capital, including R&D investment	18	8.9	28	19.0
Management	Too many managerial tasks to handle	22	10.8	14	9.5
	Dealing with uncertainty	23	11.3	19	12.9
Physical	Lack of research and testing facilities	4	2.0	7	4.8
	Lack of adequate accommodation	13	6.4	1	0.7
Market	Lack of demand	18	8.9	6	4.1
Remaining	Government bureaucracy and regulation	5	2.5	5	3.4
	Lack of technological skills	1	0.5	1	0.7
	Limited access to knowledge from university/research center	5	2.5	1	0.7
Totals		203	100.0	147	100.0
Average number of obstacles per firm (n =100 spin-offs)		3.44		3.59	

[a)] Percentage of all obstacles

The main obstacles experienced by spin-offs from TU Delft and NTNU Trondheim will now be discussed. It is not surprising that lack of market-related knowledge is one of the most frequent obstacles. This obstacle was likely to happen since spin-offs evolve from an initial idea in a non-commercial environment and have to become established as competitive profit generating firms, a stage in which new and completely different resources (knowledge) and routines are required (Vohora et al., 2004). In addition, attending courses in marketing knowledge and sales skills cannot easily connect the start up entrepreneur with the highly specialized markets and different market structures. The modest number of market-related knowledge obstacles in the case of NTNU Trondheim may indicate that the Norwegian spin-offs are better prepared compared with those of TU Delft. This may happen because many spin-offs of NTNU were established by students that had followed an extensive (formal) education on entrepreneurship in the Department of Industrial Economics and Technology Management. In addition, the incubator infrastructure provided for NTNU

Trondheim's spin-offs was well established for a couple of years, this is in contrast to Delft where incubator infrastructure was set in place at the end of this research (2005) and is not included in the analyses presented in this study.

Alongside problems concerning market-related knowledge, there were financial problems, particularly a lack of investment capital. Lack of financial investment is recognized as the most common problem among young spin-offs, in stages without any profit (e.g. Roberts, 1991). While spin-offs of NTNU Trondheim experience this obstacle relatively frequent, 19.0%, spin-offs of TU Delft rarely face financial obstacles, 8.9%. This finding may be explained by the particular strategies used by TU Delft spin-offs to finance their business. First, TU Delft's spin-offs preferred to rely on own investment, i.e. personal savings or support from family and friends. The entrepreneurs felt it to be less risky than credits. The use of formal venture capital and bank loans tended not to be popular in the case of TU Delft's spin-offs (van Geenhuizen and Soetanto, 2004). Another strategy used to achieve finance is to generate turnover through providing consultancy or services. Spin-offs undertake routine work for universities or for other firms, e.g. routine analyses, sales activity, as a source of financial capital. This solution seems, however, to give rise to a new problem that of losing time for the entrepreneur to develop his/her innovation.

Concerning management skills, dealing with uncertainty is seen as an important problem. Difficulty in dealing with uncertainty has not been addressed as an obstacle in the literature. The relatively high frequency of uncertainty as an obstacle, 11-13%, indicates that entrepreneurs are not sufficiently able to deal with risks and to develop strategies accordingly. This is a situation that is likely to emerge among spin-offs from technology universities. Students and employees in technical fields are trained to avoid risks and to control variation in experiments as much as possible. Starting a business, on the contrary, means taking huge risks, e.g. in the market, financially, and in technology. Another management-related obstacle that is relatively frequently experienced by spin-offs is dealing with management overload. At the start, entrepreneurs often find themselves in a situation of shortage of human resources, because of this limitation, entrepreneurs have multi tasks, i.e. administrative tasks, product development and trying to connect with potential customers. Overall, management obstacles, unlike market-related knowledge obstacles and financial obstacles, occurred almost as frequently in Delft as in Trondheim.

The pattern of main obstacles, OIR and ORR, in three successive age categories for spin-offs of TU Delft and NTNU Trondheim separately are shown in table 6.2. Among the youngest spin-offs (1-4 years) obstacles tended to arise simultaneously. The most dominant obstacles for TU Delft's spin-offs were market-related knowledge obstacles, with an OIR of 1.2, followed by financial obstacles with an OIR of 0.9. TU Delft's spin-offs faced a relatively small number of management obstacles, with an OIR of 0.4. This situation is slightly different from NTNU Trondheim's spin-offs in which all main obstacles occur at a relatively high frequency among the youngest spin-offs. The most frequently experienced obstacles were financial obstacles with an OIR of 1.0 while the frequency of occurrence of market-related obstacles and management obstacles was also relatively high with an OIR of 0.9 and 0.8. The total OIR of the main obstacles in the first age category of TU Delft's spin-offs tended to be lower than

that of NTNU Trondheim's, witness an OIR of 2.5 and 2.7 respectively. In the age category 5-7 years, some of the main obstacles still existed with a high frequency i.e. market-related knowledge for spin-offs of TU Delft and NTNU Trondheim. Financial obstacles declined significantly. In this age category, spin-offs of TU Delft tended to experience a higher degree of obstacles compared to spin-offs of NTNU Trondheim as shown by the higher level of OIR for main obstacles, 1.1 versus 0.9. The number of obstacles decreased again for the age category of 8-10 years with spin-offs of NTNU Trondheim experiencing a slightly higher level of OIR compared to spin-offs of TU Delft, witness 0.7 versus 0.5.

The reduction rate of obstacles (ORR) will now be discussed. In the case of TU Delft's spin-offs, management obstacles showed the lowest reduction rate, witness a reduction of –33.3 from the first age category to the third age category. Financial obstacles decreased relatively strongly with an ORR of –92.3, followed by market-related knowledge with an ORR of –66.7. Compared with spin-offs from TU Delft, all obstacles decreased relatively more strongly among spin-offs of NTNU Trondheim, witness ORR between -88.2 and -94.7. The outcomes of the statistical t-tests suggest a significant decrease in obstacles between the first and the third age-category, but not between the first and second age-category. The patterns indicate a slow but increasing capability of the spin-offs to reduce obstacles including a stronger capability among spin-offs from NTNU.

Table 6.2 Current main obstacles and OIR per age category

Obstacles	TU Delft age categories			NTNU Trondheim age categories		
	1-4	5-7	8-10	1-4	5-7	8-10
Market–related knowledge	18 (1.2)	15 (0.7)	6 (0.3)	17 (0.9)	8 (0.5)	2 (0.3)
ORR 1		-16.7			-52.9	
ORR 2			-66.7			-88.2
Financial	13 (0.9)	3 (0.1)	1 (0.1)	19 (1.0)	2 (0.1)	1 (0.2)
ORR 1		-76.92			-89.5	
ORR 2			-92.3			-94.7
Management	6 (0.4)	7 (0.3)	4 (0.2)	16 (0.8)	4 (0.3)	1 (0.2)
ORR 1		16.67			-75.0	
ORR 2			-33.3			-93.8
Total spin-offs	15	23	21	19	16	6
Total main obstacles	37	25	11	52	14	4
Total OIR main obstacles	2.5	1.1	0.5	2.7	0.9	0.7
t-test 1		2.07			1.89	
t-test 2			1.82			1.64
t-test 3			3.63*			2.72*

* Significant at the 0.05 level; ** significant at the 0.01 level.
ORR 1: ORR between (1-4) and (5-7) and ORR 2: ORR between (1-4) and (8-10)
t-test 1: t-test between (1-4) and (5-7); t-test 2: t-test between (5-7) and (8-10); t-test 3: t-test between (1-4) and (8-10);

6.2.3 A longitudinal perspective on obstacle reduction

The analysis discussed in this section is focuses on the main obstacles spin-offs face during their lifetime. Table 6.3 shows that the numbers of obstacles experienced by spin-offs in Trondheim tend to be higher than those in Delft especially after year two and up to year five. In year five the number of obstacles starts to decline in both places as witnessed by ORR of -48.4 for both. In year eight, the reduction in obstacles seems to stagnate, with TU Delft's spin-offs experiencing the worst situation, an ORR of +28.2, compared with NTNU Trondheim's spin-offs, an ORR of 0.0. This is an indication that some new obstacles have appeared or existing obstacles could not be removed. Overall, spin-offs from NTNU Trondheim, although experiencing more obstacles at the beginning, tend to have a stronger capability to solve obstacles compared to spin-offs of TU Delft, this confirms the previously discussed cross-sectional pattern.

Table 6.3 Main obstacles per age (longitudinal perspective)

	TU Delft		NTNU Trondheim	
AGE	OIR	ORR	OIR	ORR
1	2.1		2.0	
2	2.2	5.0	2.2	8.9
3	2.1	-4.1	2.3	4.7
4	1.9	-11.9	2.2	-3.6
5	0.9	-48.4	1.1	-48.4
6	0.6	-39.8	0.5	-56.0
7	0.4	-35.4	0.3	-33.3
8	0.5	28.2	0.3	0.0
9	0.3	-33.7	0.2	-50.0
10	0.2	-26.9	0.0	-100.0
1-10		-88.9		0.0

Overall, the results of the longitudinal analysis indicate a positive trend of reducing of obstacles after year four. Thus year 4 was used to differentiate between development stages in the next steps of the analysis.

6.3 Job growth and growth in business networks

Growth was measured in two other ways connected with capacities, one, using the absolute increase in number of employees per year, i.e. job growth, and two, using a dichotomous classification for growth in business networks, i.e. network growth. Several examples presented in this study show that spin-offs have subcontracted/collaborated innovation activities with their partners. For instance, a spin-off in Trondheim that is developing a novel turbine system has subcontracted research with different faculties at the university to develop particular parts of the novel system. The descriptive statistics of job growth and business network growth for the total sample is presented in table 6.4. The average job growth was 0.86 with a standard deviation of 0.79. This high standard deviation indicates

that a wide range of job growth was experienced by the spin-offs. A relatively large share of all spin-offs (38%) grew by less than 0.5 fte per year. Overall, the majority of the spin-offs faced slow growth, 58% less than 1 fte. This picture confirms the general picture of university spin-offs in Europe (Mustar et al., 2007). Based on network growth, 57% of all the spin-offs experienced a strong growth while 43% of all the spin-offs experienced weak growth. In the growth class of 0.5-1 fte, there is a majority of spin-offs facing strong network growth. This finding confirms particularly new results in spin-off studies (e.g. Mustar et al., 2007; Davidsson et al., 2007) in which growth is seen not necessarily as increase in numbers of jobs but may take other kinds of growth.

Table 6.4 Growth of spin-offs in the total sample

	Job growth (fte/year)						Network growth	
	Mean	S.D	Frequency per growth class (%)				Weak growth	Strong growth
			0-0.5	0.5-1	1-2	>2		
Total sample (100 spin-offs)	0.86	0.79	38 (38.0)	21 (20.0)	27 (28.0)	14 (14.0)	36 (43.0)	64 (57.0)
Strong network growth			9	14	27	14		
Weak network growth			29	7	0	0		

An analysis of growth is presented in the remaining section for various categories of spin-offs. It starts with a comparison between spin-offs in Delft and Trondheim, followed by a comparison of spin-offs in different development stages, early and later development stage. On average, job growth of spin-offs in Delft was almost equal to that in Trondheim, as witnessed by 0.84 and 0.89 fte per year respectively (Table 6.5). A relatively large share of spin-offs in Trondheim, 17% tends to grow fast as indicated by job growth of more than 2 fte per year. The situation tends to be the other way around for the category 1-2 fte growth, 24.4% versus 30.5%. The result for network growth indicates that more than half of spin-offs in Delft and Trondheim experienced a strong growth in networks: 66.1% of spin-offs in Delft were categorized as strong growth while 61.0% in Trondheim fell in this category. Overall, the differences were small.

Table 6.5 Growth of spin-offs in Delft and Trondheim

	Job growth (fte/year)						Network growth	
	Mean	S.D	Frequency per growth class (%)				Weak growth	Strong growth
			0-0.5	0.5-1	1-2	>2		
Delft (59 spin-offs)	0.84	0.74	22 (37.3)	12 (20.3)	18 (30.5)	7 (11.9)	20 (33.9)	39 (66.1)
Trondheim (41 spin-offs)	0.89	0.87	16 (39.0)	8 (19.5)	10 (24.4)	7 (17.1)	16 (29.0)	25 (61.0)
Statistical test	0.29		0.98				0.28	

* $p<0.05$;** $p<0.01$: Mann-Whitney test/ t-test

The next analysis is concerning growth in different development stages. Based on the explanation in the previous section, a division into two development stages was made. Spin-offs aged less than or equal to four years are categorized as spin-offs in the early stage, while spin-offs older than four years are categorized as spin-offs in later stages. Spin-offs in the early stage experienced a small job growth, 0.60 fte per year on average (table 6.6).

Referring to the various growth classes, 53.9% of the spin-offs in the early stage experienced a growth of less than 0.5 fte per year. In contrast, spin-offs in the later stage of development showed relatively high job growth at 1.03 fte per year on average with relatively few spin-offs growing less than 0.5 fte per year, i.e. 26.7%. These differences in job growth between the two stages were confirmed by the statistical test, a significant result. In contrast, this pattern is not confirmed for network growth as 67.5% of spin-offs in the early stage had strong growth. This high percentage reveals that despite the relatively low job growth, spin-offs in the early stage active grow through networks. A rather similar pattern was found regarding spin-offs in the later stage, where 61.7% experienced strong growth.

Table 6.6 Growth of spin-offs in different development stage

	Job growth (fte/year)						Network growth	
	Mean	S.D	Frequency per growth class (%)				Weak growth	Strong growth
			0-0.5	0.5-1	1-2	>2		
Early stage (40 spin-offs)	0.60	0.82	22 (53.9)	7 (18.0)	6 (15.4)	5 (12.8)	13 (32.5)	27 (67.5)
Later stage (60 spin-offs)	1.03	0.74	16 (26.7)	14 (23.3)	21 (35.0)	9 (15.0)	23 (38.3)	37 (61.7)
Statistical test	-2.66**		-3.48**				0.36	

* $p<0.05$;** $p<0.01$: Mann-Whitney test/ t-test

6.4 Conclusion

The results the first research question, stated as follows: what is the growth of university spin-offs, in particular, how does the pattern of obstacles faced by university spin-offs change over time? were presented in this chapter. To answer these questions, an analysis was made of growth of spin-offs by identifying the time-pattern of obstacles coupled with job growth and growth within a business network.

Spin-offs in Delft and Trondheim experienced a high number of obstacles in the first years. Spin-offs in Trondheim showed stronger obstacles reduction capabilities compared to those in Delft. The differences in the capability of reducing obstacles between spin-offs in Delft and Trondheim is supported by the fact that spin-offs in Trondheim grow stronger in the high job growth category (>2fte) than those in Delft. This result shows that the differences in growth of spin-offs in both cities tend to be consistent to a modest degree with the growth of incubators examined in chapter 5. Further, in contrast to the previous findings on job growth, strong growth in business networks tended to be experienced by spin-offs in both cities and by spin-offs in the different development stages. The most important results of the chapter are presented in table 6.7.

The findings are interesting as they underpin the fact that growth can be materialized in various ways. Overall, the spin-offs tended to have relatively small job growth. In contrast, the spin-offs were able to reduce obstacles to growth over time and experienced a strong growth in their business network. On the basis of both cross-sectional and longitudinal data, the results may complement existing research on dominant problems occurring in different growth stages of new technology-based firms (Kazanjian and Drazin, 1989). In addition, the

results confirm empirically the existing concept of stage-based development among university spin-offs, by identifying the age-dimension of the early development stages (Vohora et al., 2004). For example, at the age of four, obstacles start to decline and at age eight, obstacles stagnate. The stagnation of obstacle reduction may become important in this context.

Table 6.7 Summary of findings

	Spin-offs from TU Delft	Spin-offs from NTNU Trondheim
Obstacles incidence (currently and in the past)	3.4 obstacles on average	3.6 obstacles on average
	Relatively weaker obstacle reduction.	Relatively stronger obstacle reduction.
Cross section analysis	The dominant obstacle in the first age category, 1-4 years, was market-related knowledge.	The dominant obstacle in the first age category, 1-4 years, was financial.
	Management obstacles tended to be most resistant over time while financial obstacles were the fastest declining obstacles.	There were no resistant obstacles.
Longitudinal analysis	A significant reduction of obstacles started in year four.	A significant reduction of obstacles started in year four.
Job growth	Small job growth, 0.84 fte per year, but with some variation.	Small job growth, 0.89 fte per year, with a relatively high percentage of spin-offs experiencing growth of more than 2 fte.
Growth in business network	The share of spin-offs with strong growth, 66.1%, was higher than that with weak growth.	The share of spin-offs with strong growth, 61.0%, was higher than that with weak growth.

Several results of the analysis presented in this chapter were used as a basis for the development of models in the remaining study. In the previous discussion presented in the literature review, there are many obstacles that can potentially harm the growth of spin-offs. In this chapter, it is confirmed that market knowledge, financial and management obstacles were the most experienced obstacles faced by spin-offs. In the following analysis in chapter 7, those obstacles are considered in the models and inserted as factors that may influence growth. In addition, based on the longitudinal data analysis, year four was identified as a breaking point when obstacles start to decline significantly. Hence, year four was used to break the sample into two development stages, the early and later stages for further analysis.

Chapter 7

INFLUENCE OF SOCIAL NETWORKS AND OTHER FACTORS ON THE GROWTH OF UNIVERSITY SPIN-OFFS

7.1 Introduction

The second set of research questions is answered by presenting a descriptive analysis of the social network profile and results concerning the influence of social networks on the growth of university spin-offs. This chapter starts with a section dealing with the social network profile of spin-off firms (section 7.2). The results of linear regression analysis based on the total sample with job growth as the dependent variable are examined in section 7.3. This is followed by a logistic regression analysis with growth in business networks as the dependent variable. To deepen the understanding of the influence of social networks on growth, the moderating effects and non-linear effects of network variables are analyzed in section 7.4. The influence of social networks on growth is examined under different conditions in section 7.5. To this purpose, the sample was broken down into subsamples, i.e. based on different levels of urbanization of the city location and based on different developmental stages of spin-offs. This chapter ends with a discussion and conclusion in section 7.6.

7.2 Social network profile

The profiles of social networks in terms of structural, i.e. tight and loose networks, and relational, i.e. strong and weak ties, characteristics, heterogeneity in partners' background and spatial orientation, are presented in this section.

Tightness of networks

The average tightness of networks in the total sample was 0.59 (Table 7.1). This score means that spin-offs in the sample had a relatively modest value concerning the tightness of networks. In addition, it appears that there is a statistically significant difference between spin-offs in Delft and Trondheim and in spin-offs in the early and later development stages. With an average score of 0.52, spin-offs in Delft have relatively more loose networks compared to spin-offs in Trondheim with an average score of 0.69. In other words, spin-offs in Delft employ networks of partners that are not well connected while in Trondheim spin-offs have partners, most of whom know each other. The difference between Delft and Trondheim in network development may be caused by the difference in geographical conditions between Delft and Trondheim. Being located in a metropolitan area with a large reservoir of potential partners, spin-offs in Delft are able to develop networks with partners that are not connected. Spin-offs in Trondheim employ partners that may know each other as they are connected for example, to a board of advisors.

Spin-offs in later stages employ more loose networks compared with spin-offs in the early stage, witness an average of 0.51 against 0.70. This difference in structural characteristics may be caused by the fact that spin-offs in later stages have found specialized partners from different networks that match their needs. These partners may not be connected because they are active in different spheres and specializations. In contrast, in the early stage, spin-offs are still in the process of acquiring resources to develop products or services or in the process of penetrating a market. In this stage, spin-offs may benefit from a tight network that can reduce risks and enhances opportunities to build cooperation and get access to resources from partners in the network.

Table 7.1 Tightness of networks

	Total sample	Delft	Trondheim	Early stage	Later stage
Mean (SD)	0.59 (0.3)	0.52 (0.3)	0.69 (0.3)	0.70 (0.3)	0.51 (0.3)
t-test		2.63**		3.32*	

*p<0.05;** p<0.01; min: 0 and max: 1; the higher the tighter the network.

Strength of ties

The strength of ties was measured using three variables, i.e. frequency of interaction, duration of relationship and perception of closeness. The total sample had an average score of strength of ties of 0.72 (Table 7.2). This score indicates that spin-offs in this sample have a relatively strong relationship with partners. Concerning the different categories, spin-offs in Delft and Trondheim show a significant difference, witness a score of 0.76 against 0.65. Apparently, spin-offs in Delft have a stronger relationship with partners compared to spin-offs in Trondheim. The strong relationship with partners found in Delft may be caused by the close proximity of Delft to other cities in the metropolitan area of the Randstad. This situation offers a lot of opportunities for spin-offs to maintain strong ties with their partners. Further, there is no significant difference in the strength of relationships between spin-offs in the early and later stage.

Table 7.2 Strength of ties

	Total sample	Delft	Trondheim	Early stage	Later stage
Mean (SD)	0.72 (0.1)	0.76 (0.1)	0.65 (0.1)	0.71 (0.1)	0.71 (01)
t-test		-4.84**		0.71	

* p<0.05;** p<0.01; min: 0 and max: 1; the higher the stronger the ties of the network.

Heterogeneity of partners' background

The total sample has a mean score of 0.49, there is no significant difference in heterogeneity of partners between spin-offs in Delft and Trondheim (Table 7.3). Spin-offs in later stages have significantly more heterogeneous partners than spin-offs in the early stage, witness scores of 0.52 against 0.44. In the early stage, spin-offs have just developed their networks or are still in the early phase of network development. Spin-offs in this category may still use their existing networks which often consist of people from the same environment. Spin-offs in the later stage have developed networks based on learning and experience. Spin-offs in this category may have more diverse partners from different backgrounds.

Table 7.3 Heterogeneity in partners' background

	Total sample	Delft	Trondheim	Early stage	Later stage
Mean (SD)	0.49 (0.2)	0.49 (0.2)	0.48 (0.2)	0.44 (0.2)	0.52 (0.2)
t-test		-0.39		-2.35**	

* $p<0.05$;** $p<0.01$; min: 0 and max: 1; the higher the more heterogeneous the partners.

Spatial orientation

The last characteristic of social networks discussed here is related to the spatial orientation of networks. Overall, the total sample showed a mean of -0.32 (Table 7.4). This value indicates that spin-offs have a weak external orientation moderately dominated by local partners. Spin-offs in Trondheim interact with more local partners than those in Delft, witness -0.47 and -0.21 respectively. Apparently**,** the non-metropolitan character and geographical location of Trondheim, far from other European cities, may urge spin-offs to rely on partners to be found in close proximity to their firm. In contrast, Delft is located in a metropolitan area endowed with a dense transportation network, and here spin-offs have more opportunities to develop networks with non-local partners. Further, spin-offs in the early stage have a stronger local orientation than those in later stages, -0.49 and -0.19. This finding may indicate that right after establishment, spin-offs are highly dependent on local partners. The presence of local partners such as those found at the university may be regarded as important in the early development of new products/services. As networks develop over time, partners found at great distances may be included in the network.

Table 7.4 Spatial orientation

	Total sample	Delft	Trondheim	Early stage	Later stage
Mean (SD)	-0.32 (0.5)	-0.21 (0. 6)	-0.47 (0.4)	-0.49 (0.4)	-0.19 (0.6)
t-test		-2.72**		-3.23**	

* $p<0.05$;** $p<0.01$; min: -1 and max: 1; the higher the stronger the external orientation

Overall, the above description of social network profile of spin-offs answers the second research question concerning *the characteristics of social networks of university spin-offs.* To give a clear picture about the difference in the characteristics, a summary of results is provided in table 7.5 by providing contrasting results, i.e. strong versus weak relationship, and limited to significant differences ($p<0.01$). Spin-offs in Delft have the characteristics of loose networks, strong relationships and a stronger external orientation. This network profile is different from that of spin-offs in Trondheim that have tight networks, weak relationships and a weak(er) external orientation. Spin-offs in the early stage are characterized by tight networks, partners of homogeneous background and a weak(er) external orientation. Spin-offs in later stages have loose networks, partners with a heterogeneous background and a stronger external orientation. The overall results indicate that the tightness of networks and external orientations of spin-offs develop differently in different locations and development stages. In addition, spin-offs in Delft and Trondheim show significant differences in terms of strength of ties while spin-offs in the early and later development stage show significant differences in terms of heterogeneity of their partners.

These social networks characteristics were considered together with other spin-off's characteristics in the development of the models. The description of social networks was discussed above and a detailed description of the spin-offs' characteristics is presented in appendix 4. Overall, spin-offs in Delft were older and had received less added value support compared to those in Trondheim. Further, the majority of spin-offs in the early stage employed a strategy that was less risk-avoiding while a risk-avoiding strategy was more often employed by spin-offs in later stages. The results of the analysis on the influence of social networks and other factors on growth are discussed in the following section.

Table 7.5 Summary of descriptive statistics

Characteristics of spin-offs	Spin-offs in Delft	Spin-offs in Trondheim	Spin-offs in the early stage	Spin-offs in later stage
Characteristics of spin-offs				
Age	Old	Young	Young	Old
Resource deficiency	-	-	-	-
Added value support	Less	More	-	-
Level of capability	-	-	-	-
Risk-avoiding in strategy	-	-	Less	More
Social network profile				
Tightness of networks	Loose	Tight	Tight	Loose
Strength of ties	Strong	Weak	-	-
Heterogeneity in partners' background	-	-	Homogeneous	Heterogeneous
External orientation	Strong	Weak	Weak	Strong

Note: -: the difference is not significant (p<0.01)

7.3 Growth of university spin-offs

The analysis discussed here deals with growth models based on the total sample, first with job growth as the dependent variable and secondly, with growth in business networks as the dependent variable. Job growth was selected as this indicator is arguably one of the most appropriate indicators for measuring growth of small technology-based firms (Delmar et al., 2003). For this type of firms, an increasing number of employees represent an increase in important resources in terms of human capital and knowledge owned by firms. The fact that spin-offs also have to grown in business networks through subcontracting relations (see Chapter 4) was also considered by analyzing various logistic regression models using network growth as the dependent variable.

Three models are shown in table 7.6 using a stepwise approach. The control variables together with the variables describing resources, capabilities and strategy were entered in the first model. It appears that this model is significant, F: 32.32; p<0.01, with an R^2 of 0.62 and a root MSE of 0.33. The R^2 is a statistical measure of how well the regression line approximates the real data points and the root MSE describes the average squared distance of the real data plot from the fitted line. Overall, the value of both statistical measures indicates that the model is relatively strong in representing the real data. In the second model, the control variables were entered together with the characteristics of the social network profile. The results showed that the model is significant, F: 44.82; p<0.01 and this explains about 69 percent of the variance (R^2). As the value of R^2 had increased, the value of

the root MSE decreased, i.e. to 0.29. This means that entering the social network profile causes the model to become better, indicating that the variables of the social network profile have slightly more explanatory power than the variables describing resources, capabilities and strategy. In the third model, the full model, all the variables were entered. The capability to explain the variance increases to 77 percent which is significant, F: 40.76; $p<0.01$ The root MSE has decreased from the first model and the second model to the third model, the root MSE is 0.25, indicating that entering all the variables again improves the model.

Regarding the significance of the beta-coefficients, table 7.6 shows that age and location of spin-offs did not yield a significant result in the full model. Age of spin-offs appears to be significant in the first model but loses significance in the second and third models. This suggests that the age of spin-offs tends to influence growth, but that this influence is relatively weak and diminishes due to a stronger influence of other factors, especially social network characteristics. This finding may contradict earlier arguments, e.g. by Jovanovic (1982), Almus and Nerlinger (1999), which state that the learning capability of firms increases with age. Accordingly, as firms get older they increasingly learn from previous experience and prevent mistakes in resource gathering from happening. As a result, the older the firm, the higher the chance to grow as resources can be acquired more effectively. It was not possible to confirm in this study in a direct way. The results of this study suggest that by developing an effective network of partners, spin-offs are able to compensate for their lack of experience and shorten their learning processes.

The results point out that the beta-coefficients of the remaining variables are significant except for risk-avoiding in strategy and strength of relationships. These unexpected results may be explained as follows. First, in contrast to risk-avoiding spin-offs, risk-taking spin-offs invest more strongly in and take a longer time for research and development. Although the taken risk is high, it can be partly a calculated risk, because other factors may compensate the risk. For instance, spin-offs have filled a protected niche market since their start, due to cooperating with a potential customer that substantially invests in research and development (Garnsey and Cannon-Brookes, 1993; Westhead and Storey, 1994). As a result, spin-offs with a risk-taking innovation strategy may grow. Secondly, targeted support from incubator organizations is available for spin-offs, and this may compensate for the high risk taken by spin-offs.

The beta coefficient of strength of ties was found not to be significant. Two reasons may explain this unexpected finding. One, the failure to observe any significant result on positive or negative influence of strong or weak ties may be caused by the importance of both types of ties, i.e. mixed ties, in the growth of firms (Elfring and Hulsink, 2003; Anderson, 2008). In the process of discovering opportunities, weak ties may play a dominant role and offer benefits to gather new information and find new opportunities. At the same time, strong ties have, arguably, a positive impact on the transfer of complex knowledge and provide for trust and commitment in partners. Two, the type of urban location of spin-offs may also influence the characteristics of networks. In the metropolitan area of the Randstad spin-offs in Delft can easily, more frequently, meet their partners while spin-offs in Trondheim have to

travel over long distances to the cities where their partners reside. Consequently, spin-offs in Delft have significantly stronger ties than spin-offs in Trondheim but this does not influence growth.

Table 7.6 OLS regression analysis on job growth of university spin-offs – Total sample

Variables	1	2	3
	β-coefficient (s.e.)	β-coefficient (s.e.)	β-coefficient (s.e.)
Control variables			
Age	0.28 (0.01) *	0.13 (0.01)	0.15 (0.01)
Location	0.01 (0.07)	-0.17 (0.07)*	-0.09 (0.07)
Resources/capabilities/strategy			
Risk-avoiding in strategy	-0.03 (0.07)		-0.01 (0.05)
Level of capability	0.31 (0.07)**		0.18 (0.06)**
Resource deficiency	-0.35 (0.16)**		-0.25 (0.14)**
Added value support	0.38 (0.13)**		0.13 (0.11)*
Social network profile			
Tightness of network		-0.35 (0.11)**	-0.18 (0.09)**
Strength of ties		-0.09 (0.29)	-0.10 (0.26)
Heterogeneity of partners' background		0.33 (0.21)**	0.32 (0.19)**
External orientation		0.26 (0.07)**	0.14 (0.07)*
N	100	100	100
F	32.32**	44.82**	40.76**
R^2	0.62	0.69	0.77
Root MSE	0.33	0.29	0.25

*p<0.05 ** p<0.01; s.e.: standard error

The next discussion centers on the direction (sign) of the beta-coefficients that produce significant results. The level of capability tends to enhance the growth of university spin-offs as the beta-coefficient shows a positive sign (Zaheer and Bell, 2005)**.** As far as resource deficiency is concerned, the beta-coefficient shows a negative sign. As expected, spin-offs experiencing a lack of major resources will face hampering growth. Regarding added value support, the beta-coefficient shows a positive influence on growth. Spin-offs that receive more added value support tend to grow more quickly than spin-offs receiving less added value support or receiving merely conventional support. Overall, the previous results are consistent with expectations (Chapter 3).

With regard to the social network profile, the beta-coefficient shows that tightness of networks has a negative influence on growth. This finding suggests that having partners in a tight network does not promote a spin-off's growth. Spin-offs that employ loose networks, consisting of partners that are not connected to each other, enjoy benefits from brokerage opportunities created by the lack of connections between separate clusters (Granovetter, 1995). Spin-offs, by being linked to different networks, have access to open and diverse information and knowledge transferred from partners. Further, the influence of heterogeneity of partners' backgrounds on growth is positive. This situation means that interaction with partners from different social backgrounds tends to enhance growth. Heterogeneous partners can enrich perceptions and give access to a wider range of resources for spin-offs.

Regarding an external orientation, the beta-coefficient shows a positive sign indicating a positive influence on growth. This finding is remarkable since well-known concepts such as localized learning and local knowledge spillovers suggest that close proximity between actors plays a positive role in the process of innovation and growth (Maskell and Malmberg, 1999; Bathelt and Glückler, 2003). In contrast**,** the finding of this study suggests that a focus on partners in close proximity may reduce access to new knowledge, knowledge that is better often obtained through interregional and international partners (Owen-Smith and Powell, 2003).

To summarize, it seems that most of the variables are significant, except for the control variables and the variables on strategy and strength of ties. The insignificant result of the control variables is interesting as it reveals that spin-offs' growth cannot be determined by common factors which are usually mentioned in the literature, such as age and location of spin-offs. In other words relatively young spin-offs and spin-offs located in a non-metropolitan area may experience a strong growth. Regarding the networks characteristics, it seems the growth of spin-offs is developed through diverse access of knowledge. Loose networks, heterogeneous partners' background and an external orientation positively influence growth. This finding may also indicate that these three types of networks may have a similar dimension which expresses the presence of diversity and non-redundant knowledge or information due to the position of partners in different clusters of networks. Another interesting finding to note here is the insignificance of strength of ties. Unlike many other networks studies that have emphasized the importance of strength of ties for firms' growth, in this study, the finding may indicates both types of ties, strong and weak have a positive influence on growth.

Attention will now be focused on the analyses of growth in business networks as the dependent variable. Spin-offs are considered to have strong growth if they experience growth in networks and conversely weak growth if they do not grow in networks. The control variables together with the variables describing resources, capabilities and strategy are entered in the first model. The results indicated that the model is significant, Chi^2: 37.72; p<0.00, with a pseudo R^2 of 0.29. In the second model, the control variables were entered together with the variables concerning the social network profile. It appeared that the model is significant, Chi^2: 41.28; p<0.00, and this explains 39 percent of the variance, pseudo R^2. All the variables were entered in the third model. The capability to explain the variance increases up to 44 percent, thus also appeared to be significant, Chi^2: 48.01; p<0.00. Overall, most of the findings were similar to the previous OLS outcomes except for age of spin-offs and level of capability. The significant and negative sign of the logit-coefficient of age, as opposed to no (negative) relationship in the model on job growth, suggests that older spin-offs grow less often in business networks than in employees within the firm. As spin-offs get older, business network development may become less dynamic and spin-offs may be satisfied with the networks they have in place. In addition, the influence of spin-offs' capability could not be confirmed in this model. Apparently, team founder and previous business experience have no influence on growth in business networks.

In the comparison of the result of the logistic regression and linear regression, it is quite clear that there is a different outcome regarding the variable on resource, capability and strategy. Most of them have no significant impact on the network growth as far as the logistic regression is concerned. In fact, spin-offs regardless their differences in resources, capability and strategy have grown in networks. Regarding the network characteristics, again, spin-offs with loose networks, heterogeneous partners and having an external orientation have a strong growth in networks.

Table 7.7 Logistic regression analysis on growth of university spin-offs in business networks – Total sample

Variables	1	2	3
	Logit coef. (s.e.)	Logit coef. (s.e.)	Logit coef. (s.e.)
Control variables			
Age of spin-offs	-0.17 (0.09)	-1.19 (0.11)*	-1.14 (0.12)*
Location	0.69 (0.58)	0.33 (0.76)	0.62 (0.83)
Resources/capabilities/strategy			
Risk-avoiding in strategy	-0.37 (0.54)		-0.26 (0.65)
Level of capability	1.32 (0.61)		0.61 (0.74)
Resource deficiency	-2.10 (1.49)*		-1.03 (1.01)†
Added value support	2.09 (1.18)		0.68 (1.00)
Social network profile			
Tightness of network		-1.98 (1.27)*	-1.10 (1.26)*
Strength of ties		-0.96 (0.79)	-0.97 (0.98)
Heterogeneity of partners' background		1.74 (2.92)*	1..01 (1.16)*
External orientation		2.04 (0.83)*	1.79 (1.10)*
N	100	100	100
Chi^2	37.72**	41.28**	48.01**
Pseudo R^2	0.29	0.39	0.44

†p<0.10; * p<0.05; ** p<0.01; s.e.: standard error

7.4 Moderating effects and non-linear characteristics

The results of a more detailed analysis of the influence of the social network profile on growth are presented in this section. The first analysis was focused on the presence of interaction effects and the second analysis explored the non-linear behavior of social networks in influencing growth.

In studying the interaction effects, four variables were assumed to moderate the relationship between the characteristics of networks and the growth of spin-offs. These variables were: age of spin-offs, location, level of capability and external orientation. Age of spin-offs was selected, as social networks may change over time (Hite and Hesterly, 2001; Schutjes and Stam, 2003). Based on this assumption, the importance of networks for growth may also change over time. For instance, younger spin-offs may depend on strong ties with partners while older spin-offs may depend on weak ties for growth (Elfring and Hulsink, 2003). Location was selected as the difference in level of urbanization, metropolitan versus non-metropolitan areas, may determine the characteristics of social networks. It is assumed that metropolitan areas provide more diversity and opportunities to develop networks than non-metropolitan areas. In addition, a spin-off's capability and external orientation were

included as they may determine the relationship between social networks and growth. It is assumed that spin-offs with a higher level of capability are better able to utilize their social networks to support growth. In addition, external orientation of spin-offs was selected as this orientation may directly influence the other characteristics of networks. For instance, spin-offs with an orientation at partners on a distance may develop a network consisting of open and weak relationships.

The results of the interaction between age of spin-offs and network characteristics are given in table 7.8. The interaction of age with tightness of networks and external orientation was significant, $p<0.05$, indicating that the effect of tightness and external orientation of networks on growth is dependent on the age of spin-offs. The addition of the interaction variable gives an improvement in the model, witness ΔR^2 of 0.02 and 0.03 respectively. In the next model, the interaction effect between location of spin-offs and network characteristics on growth was explored. The results showed a significant interaction effect for the strength of ties and external orientations of spin-offs. While the addition of the interaction term to the model showed the model improved, ΔR^2: 0.03 and 0.02, the coefficient of the interaction is significant, $p<0.01$ for strength of relationship, $p<0.05$ for local orientation. A similar finding was observed as far as level of capability is concerned. The interaction effect of level of capability with strength of ties and external orientation of spin-offs was significant, $p<0.05$ for strength of relationship and for external orientation. The addition of the interaction variable to the model improved the model, ΔR^2: 0.04 and 0.03. The interaction effects between external orientation and other network characteristics on growth were only significant for strength of ties ($p<0.05$) and the model improved, ΔR^2: 0.03, when the interaction term was added.

Overall, the results showed that age has a moderating influence on the tightness of networks and external orientation while location and level of capability have an influence on the strength of relationship and external orientation of spin-offs. Regarding older spin-offs, loose networks and external orientation play a dominant role in promoting growth. In terms of location, weak ties and external orientation positively influenced the growth of spin-offs in Delft. The results also showed that for spin-offs with a high level of capability, weak ties and external orientation have a positive influence on growth. Interaction effects between external orientation and social network characteristics influencing growth are absent, except for the interaction with strength of ties. Apparently, spin-offs with a strong external orientation usually experience a strong relationship between weak ties and growth.

Table 7.8 Moderating effects in the relationship between social network profile and growth

	Full model	Interaction effects β -coefficient			
Age x tightness of networks Age x strength of ties Age x heterogeneity in partners' background Age x external orientation		0.10*	-0.10	-0.03	0.24*
N	100	100	100	100	100
F	40.76**	44.85**	38.48**	40.83**	45.88**
R^2	0.77	0.79	0.79	0.78	0.80
ΔR^2		0.02*			0.03*
Root MSE	0.25	0.21	0.21	0.22	0.21
Location x tightness of networks Location x strength of ties Location x heterogeneity in partners' background Location x external orientation		-0.05	0.94**	0.06	0.17*
N	100	100	100	100	100
F	40.76**	40.22**	48.03**	42.90**	43.13**
R^2	0.77	0.77	0.80	0.77	0.79
ΔR^2			0.03*		0.02*
Root MSE	0.25	0.22	0.20	0.22	0.22
Level of capability x tightness of networks Level of capability x strength of ties Level of capability x heterogeneity in partners Level of capability x external orientation		0.02	-.19*	0.05	0.12*
N	100	100	100	100	100
F	40.76**	42.92**	45.89**	42.31**	44.54**
R^2	0.77	0.77	0.81	0.77	0.80
ΔR^2			0.04*		0.03*
Root MSE	0.25	0.22	0.20	0.22	0.21
External orientation x tightness of networks External orientation x strength of ties External orientation x heterogeneity of partners		0.16	-0.74*	-0.27	
N	100	100	100	100	
F	40.76**	42.27**	29.03**	28.07**	
R^2	0.77	0.77	0.80	0.77	
ΔR^2			0.03*		
Root MSE	0.25	0.22	0.20	0.21	

* $p<0.05$; ** $p<0.01$; only interaction terms are presented.

The non-linear relationships of the social network profile with growth are explored using the full model in the remaining section. To identify such relationships, the variables of the social network profile were transformed into quadratic terms in a non-linear regression. The results showed that strength of ties and external orientation support a curve linear relationship. For strength of ties, the *linear term* is negative but not significantly related to a spin-offs' growth, see table 7.6, whereas the *squared term* is negative and significant. The

change in R^2 between models 1 and 3 also confirms that adding the quadratic term improves the model's fit (ΔR^2= 0.02, p<0.05). Regarding external orientation, the *linear term* was significant and positively related to a spin-off's growth while the *squared term* was negative and significantly related to a spin-off's growth. The change in R^2 between models 1 and 5 also confirmed that adding the quadratic term improves the model's fit, ΔR^2= 0.02, p<0.05.

These findings make a contribution to the growing literature on the non-linear behavior of network characteristics. Regarding strength of ties, the result supports the idea that ideal entrepreneurial networks include a particular mix of strong and weak relationships (Uzzi, 1996, 1997). Strong ties are more likely to be useful to individuals in situations characterized by a high level of uncertainty and insecurity (Elfring and Hulsink, 2003). In such situations, spin-offs rely on close friends, family and colleagues for protection, uncertainty reduction and mutual learning. Strong ties also have shortcomings as there is a risk of 'overembeddedness' (Uzzi, 1996). Relying only on strong ties might prevent spin-offs from becoming aware of information that exists beyond their networks. Weak ties increase diversity and may provide access to various sources of new information and offer new opportunities. Weak ties represent connection/bridges to separate segments of social networks that might otherwise be unconnected (Granovetter, 1974, 1983; Burt, 1992). Thus, in general both strong and weak ties are useful and both contribute to the establishment and growth of firms, although they are beneficial in different ways and at different stages of a firm's development (Uzzi, 1996, 1997).

Table 7.9 Non linear (curvilinear) analysis of job growth [a)]

	1 [b)]	2	3	4	5
Quadratic terms					
Tightness of network		0.25			
Strength of ties			-0.91*		
Heterogeneity of partners' background				0.28	
External orientation					-0.15**
N	100	100	100	100	100
F	40.76**	37.55**	38.41**	34.69**	38.68**
R^2	0.77	0.78	0.80	0.78	0.79
ΔR^2			0.03*		0.02*
Root MSE	0.25	0.23	0.22	0.22	0.23

* p<0.05; ** p<0.01;
[a)] only quadratic terms are presented.
[b)] OLS, full model

Regarding external orientation, the above finding supports the concept of a favorable mix of interactions with both local and non-local partners (Bathelt et al., 2004). New and valuable knowledge will often be created somewhere outside regions, and firms that can build pipelines with non-local partners will gain competitive advantages. Information that one spin-off acquires through its pipelines may spill over to local partners. Information from outside will increase the quality, and value, of local interactions that may turn into benefits in innovation and growth.

7.5 Growth of university spin-offs in different locations and development stages

A comparison of models concerning the influence of social networks on the growth of spin-offs in different locations and development stages of the life of spin-offs is discussed in this section. In the first part, the model outcomes concerning the growth of spin-offs in Delft and Trondheim are compared. Spin-offs in Delft, part of a metropolitan area, are assumed to enjoy more benefits due to location and agglomeration advantages than spin-offs in Trondheim. In the second part of the section, the model outcomes concerning spin-offs in early and later stages of development are compared. Spin-offs in different development stages develop distinct networks that deal with a different set of needs for resources. If the obstacles faced to gain these resources are different, then the characteristics of the networks that are beneficial may also be different.

Table 7.10 OLS regression analysis on job growth of university spin-offs for different locations

	Delft	Trondheim
	β-coefficient (s.e.)	β-coefficient (s.e.)
Control variable		
Age	0.22 (0.01)	-0.09 (0.02)
Resources/capabilities/strategy		
Risk-avoiding in strategy	-0.02 (0.05)	0.08 (0.10)
Level of capability	0.08 (0.62)	0.33 (0.08)**
Resource deficiency	-0.14 (0.16)*	-0.30 (0.15)*
Added value support	0.07 (0.14)	0.14 (0.14)*
Social network profile		
Tightness of network	-0.22 (0.14)*	-0.03 (0.12)
Strength of ties	-0.34 (0.27)**	0.16 (0.06)*
Heterogeneity of partners' background	0.10 (0.21)*	0.41 (0.09)**
External orientation	0.21 (0.06)**	0.02 (0.22)
N	59	41
F	29.54**	35.13**
R^2	0.78	0.79
Root MSE	0.22	0.21

* $p<0.05$; ** $p<0.01$; s.e.: standard error

It can be seen in Table 7.10 that the full models for Delft and Trondheim are significant and they explain a relatively large share of variance, witnessing an R^2 of 78 percent and 79 percent respectively. Regarding the significance of the beta-coefficients, age of spin-offs and risk-avoiding strategy appear to have no influence on the growth of spin-offs in Trondheim and Delft. A difference is found between the two cities in which the level of capability has a positive and significant influence on the growth of Trondheim's spin-offs but not on Delft's spin-offs. This result suggests that spin-offs in Trondheim gain advantages from developing networks and utilizing them more efficiently through better capabilities. In addition, the beta-coefficient of added value support was not significant in Delft while it is positive and significant in Trondheim. The result in Delft may be explained by the fact that at the time of the data collection, incubator support mechanisms had not yet been well developed. Recently (2006), TU Delft has put more effort into supporting knowledge valorization, and it has established, in a joint effort with the municipality of Delft, an incubator building to

provide better support. Spin-offs in Trondheim have enjoyed richer support from the beginning as the university and private institutions have collaborated to support spin-offs' growth since 1998. What is supported in the analysis of both cities is that experiencing a resource deficiency influences growth negatively. Apparently, spin-offs in both cities that fail to overcome main obstacles experience weak growth.

Considering the social network profile, interactions with heterogeneous partners have a positive influence on the growth of spin-offs in both Delft and Trondheim. The largest difference between Delft and Trondheim is related with the strength of ties. This characteristic has a negative influence on growth of spin-offs in Delft. In contrast, strength of ties plays a positive and significant role in growth of spin-offs in Trondheim. This result is interesting since the descriptive statistics in the previous section show that spin-offs in Delft have stronger ties with partners than spin-offs in Trondheim. This finding may imply that strong ties, enabled by short distance and easy transportation in the metropolitan area of the Randstad, do not necessarily bring a positive influence on growth, because spin-offs may be locked into their close networks while missing opportunities of knowledge and information gathered outside their present networks. Spin-offs in Trondheim, due to the huge distances involved in networking, have developed relatively weak relationships with partners keeping their horizons open for new information. Two case studies in Delft and Trondheim are presented below to illustrate these contrasting conditions.

> *Finding a solution through weak ties.* Spin-off A was founded in Delft in 2001 and developed an innovation in the sanitary industry. At the beginning, spin-off A was highly dependent on support from closely-related people that lived or worked nearby such as professors at the university, family and friends. When it came to a problem or question, the founders often searched for a solution by visiting these partners. Despite the support from these strong ties, these initial networks could not solve the most prominent obstacles experienced by spin-off A that was difficulties with introducing the product to the market and a lack of financial investment due to a long production line. Spin-off A realized that relying only on strong ties was not enough to solve the main problems and started to search for a solution by extending its networks. After a long process of searching, spin-off A finally found a relatively weak relationship with a new partner from outside the region. Besides investing money, this partner introduced spin-off A to its first customer. From this point on, spin-off A could expand its market. Currently, its products can be found in the US and North and Western Europe.

> *Overcoming distance with strong ties.* Spin-off B was established in Trondheim in 2004 and offers solutions for the delivery and presentation of adapted multimedia for mobile terminals. Spin-off B benefited from the valuable support received from partners acting as a board of advisors. This board consisted of people from different backgrounds located in different places, e.g. Trondheim, Oslo and Bergen. At the beginning, the relationships between spin-off B and its partners were relatively weak due to the large geographic distance, however, spin-off B has managed to strengthen these relationships. As a result, there is a board meeting almost every

month in Oslo which means that all partners are connected to each other in a tight and strong network. In addition, internet technology is used to support intensive communication. With a relatively high frequency of interactions, the ties between spin-off B and its partners have become stronger through frequent travelling to attend conferences and exhibitions and to contact potential customers. Currently, spin-off B is able to sell its product to many television broadcasters in Asia and the US as well as to big companies as a promotion media.

The two case studies illustrate the differences between the characteristics of the networks of spin-offs in Delft and Trondheim. While spin-off A represents an example of how spin-offs in Delft, which are mainly dominated by strong ties, have found valuable support through weak ties, spin-off B is an example of how spin-offs in Trondheim make use of strong ties to support growth regardless of the difficulty of meeting partners due to geographic separation. This difference is interesting since it indicates the influence of geographical conditions, metropolitan versus non-metropolitan areas, in shaping social network characteristics and in ways spin-offs deal with these conditions.

Tightness of networks and external orientation tend to be different in Delft compared to Trondheim. A high level of tightness of networks gives a negative influence on the growth of spin-offs in Delft. In other words, interactions with partners from the same networks are not likely to promote the growth of spin-offs in Delft. In contrast, no influence of tightness of networks could be confirmed for spin-offs in Trondheim. As explained previously, many spin-offs in Trondheim have partners that belong to their board of directors. Although these partners may come from different cities and backgrounds, they become acquainted and develop a rather tight network. Further, the results confirmed a positive impact of external orientation on the growth of university spin-offs in Delft. The same result could not be observed for spin-offs in Trondheim, i.e. positive, but not significant. This finding may be influenced by the different geographical locations of Delft and Trondheim. Located in a metropolitan area, spin-offs in Delft can easily develop networks of partners outside the region, which turns out to be useful for growth. Spin-offs in Trondheim may have to find partners from other cities such as Oslo, Stockholm or Stavanger, all geographically separated. Comparing the variables that are significant in both models, it appears that the growth of spin-offs in Delft relies more on network characteristics which are loose, weak and have external orientation, whereas the growth of Trondheim's spin-offs relies more strongly on own resources and the capabilities of the spin-offs, added value support and strong relationships with partners.

In the remaining part of this section a comparison between spin-offs in two development stages, the early stage and later stages is presented. The first development stage is defined as spin-offs younger that five years and second, later stages, is defined as spin-offs of five years and older. Table 7.11 shows that the models are significant and have a relatively high R^2, witness 0.71 and 0.69 respectively. There is no evidence that location and risk-avoiding in the spin-off's strategy influence the growth of spin-offs in both stages. Overall, only three beta-coefficients were found to be significant in the model for spin-offs in the early stage and seven beta-coefficients were found to be significant in the model for spin-offs in later

stages. Level of capability has a positive influence, and resource deficiency has a negative influence on growth in both stages. Added value support has a positive influence only in later stages. This finding may indicate that added value support may not be directly effective in the first years of a spin-off and that its impact may take some years to be seen.

Considering the significance of the beta-coefficients of social network characteristics, only heterogeneity in partners' background appeared to influence the growth of spin-offs in the early stage. In addition, looking at the sign of the beta-coefficients reveals that growth of spin-offs in early years tended to benefit from strong ties and interaction with local partners. This situation complies with arguments in the literature (e.g. Larson and Star, 1998; Hite and Hesterly, 2001) emphasizing a prominent contribution of strong ties and local partners in the earlier stage of firms because these help firms overcome problems of resource access and of limited awareness regarding available resources and opportunities. The analysis in this study, however, found that the relationship between network characteristics and growth is not significant. In contrast, the social network profile tends to play a dominant role in the growth of spin-offs in later stages. Tightness of networks and strength of ties have a negative influence on growth whereas interactions with heterogeneous partners and external orientation have a positive influence on growth. These results can be explained as follows: as spin-offs move to later stages, tight networks, strong and local ties are less likely to provide the range of resources needed to support growth. As a result, spin-offs seek out and develop a broader and more diverse network that has the potential to provide new resources such as knowledge, information and new opportunities (Powell, 1990; Uzzi, 1996). Accordingly, loose networks, weak ties and ties with partners in other regions are more likely to provide adequate resources to spin-offs in later stages than in the early stage (Hite and Hesterly, 2001).

Table 7.11 OLS regression analysis on growth of university spin-offs in different development stages

	Early stage	Later stage
	β-coefficient (s.e.)	β-coefficient (s.e.)
Control variable		
Location	-0.20 (0.12)	0.03 (0.08)
Resources/capabilities/strategy		
Risk-avoiding in strategy	-0.04 (0.11)	-0.07 (0.06)
Level of capability	0.28 (0.29)**	0.12 (0.06) *
Resource deficiency	-0.38 (0.25)**	-0.17 (0.14)*
Added value support	0.10 (0.17)	0.14 (0.11)*
Social network profile		
Tightness of network	-0.17 (0.20)	-0.15 (0.13)*
Strength of ties	0.01 (0.42)	-0.25 (0.28)**
Heterogeneity of partners' background	0.32 (0.28)**	0.29 (0.27)**
External orientation	-0.10 (0.14)	0.28 (0.06)*
N	40	60
F	18.46**	22.15**
R^2	0.71	0.69
Root MSE	0.24	0.26

* $p<0.05$; ** $p<0.01$; s.e.: standard error

The trend that social networks play a stronger role among spin-offs in later stages than in the early stage suggests that network' benefits or drawbacks change with increasing age. Spin-offs in the early stage, usually hosted in a protected environment of an incubator, receive support that may cover their needs. Therefore, finding knowledge and other resources through social networks may not be crucial at this time. Overall, the results confirm the idea of network evolution (Elfring and Hulsink, 2003; Hite and Hesterly, 2001). Although this idea still lacks strong empirical underpinning, scholars such as Hite and Hesterly (2001) and Slotte-Kock and Coviello (2009) argue that the networks of firms evolve over time. As firms evolve through progressive stages like early growth, later growth, maturity (Kazanjian and Drazin, 1989), their need for resources also changes and each growth stage may represent a reflection of a firm' strategic issues. Consequently, networks will evolve in line with the stages of growth. The following case study provides an illustration of this development of networks.

> *From tight and strong networks to loose and weak networks.* Spin-off C was established in Delft in 1997. Initially, spin-off C offered consultation in engineering calculation. In the early years of establishment, spin-off C relied on tight and strong ties with partners. Friends from the university including former professors were among the people who supported the early establishment of spin-off C by granting projects. Although the spin-off could manage to get customers, the scale of the projects was relatively small. Moreover, spin-off C faced a difficult situation in 2002, one that set the spin-offs looking to diversify products and services and start several new activities, such as selling numerical computation software to becoming a reseller and opening a learning center. At some point in time, spin-off C arrived at the conclusion that its strong ties with partners would not help it to solve its problems. As a result, the firm started to expand its networks through active participation in conferences and exhibitions, and its new networks became more open and characterized by loose ties in which partners did not know each other. Due to the large geographical spread of these partners, spin-off C maintained relatively weak ties with them. Furthermore, through one of these new partners, spin-off C has received additional investment and has gained opportunities to access the global market. Currently, spin-off C operates a branch in Germany and is planning to open another in Belgium.

Overall, this case study illustrates that spin-offs may experience a major change in the development of their network characteristics over time. In the beginning, the partners of spin-off C consisted of friends, family and former colleagues. Overtime however, spin-off C has connected with partners from different backgrounds, location and types of business and this variety of partners has provided richer expertise and a larger richness of other resources than did the partners in the initial network.

7.6 Conclusion

The influence of social network characteristics on the growth of university spin-offs was examined in this chapter. Several models were explored using the total sample and a breakdown of this sample into categories based on different locations, i.e. level of urbanization, and on the different development stages of the spin-offs. In addition, the interaction effects and non-linear relationships of social network characteristics were explored. Overall, the following trends could be observed:

- supported by all models, heterogeneity in partners' background has a positive influence on growth. Apparently, interaction with partners from diverse backgrounds provides benefits for spin-offs such as enrichment of perceptions and access to a wider range of resources.
- supported by all models, resource deficiency and supported by all but two models tightness of networks have a negative influence on growth. Failing to acquire critical resources may hamper growth. Similarly, interacting with partners under tight networks is not likely to enhance grow. Tight network characteristics may hinder access to open and diverse information and knowledge from partners.
- loose networks and weak ties, and an external orientation have a positive influence on growth of spin-offs in Delft. In contrast, strong ties have a positive influence on spin-offs in Trondheim. These findings suggest that location may determine the characteristics of valuable networks. Different network characteristics at different locations may offer similar benefits to growth.
- loose networks, weak ties, and an external orientation have a positive influence on growth of spin-offs in later stages while only interaction with heterogeneous partners has a positive influence on growth in the early stage. This finding indicates the dynamics of networks as in the early stage, networks are not yet well established and therefore, their influence on growth is limited. Overtime, spin-offs that can utilize their networks adequately to gain resources experience strong growth.
- age of spin-offs has a moderating influence on the relationship between tightness of networks and growth and between external orientation and growth; while location and level of capability have a moderating influence on the relationship between strength of ties and growth and between external orientation and growth**.** Concerning the moderating role of network characteristics, the finding indicates that external orientation only has a moderating influence on the relationship between strength of ties and growth.
- the relationships of tightness of networks and heterogeneous partners with growth can be approximated using a linear model. In contrast, the relationships of strength of ties and external orientation with growth have some weak non-linear features. The last would mean, to a limited extent, that both strong and weak relationships may positively influence growth, and the same situation seems to be true for both local and non-local orientation.

Chapter 8

CONCLUSION AND RECOMMENDATION

8.1 Introduction

Starting a new venture based on an innovation developed at a university is full of risks. In contrast to an established firm with a product that has already been introduced to the market, university spin-offs may face a set of obstacles when developing a product for a new market. In addition to the obstacle of the liability of newness, university spin-offs often lack several resources. They mostly lack investment capital, access to a cheap accommodation, access to research facilities and the entrepreneurial knowledge required to run a new business. An examination of previous studies shows that most studies have employed Resource-Based Views to investigate how spin-offs' internal resources have impacts on growth. Until recently, scholars have acknowledged that the source of growth, especially for newly established firms, may also lie outside firms' boundaries, thus emphasizing the need to examine the process of acquiring external resources. In the case of university spin-offs, limited internal resources have forced firms to depend on support from incubator organizations and their social networks. While incubator organizations may provide funding and facilities, social networks give access to knowledge (information) about markets, product development and the management of small firms.

In the recent development of incubators, it is acknowledged by scholars that it is important to comprehend spin-offs' needs and make sure that incubators link entrepreneurs to the most appropriate networks. These networks will assist entrepreneurs to overcome obstacles they face. Without the assistance of incubator organizations, entrepreneurs might experience a hard time in locating the right individuals from the often-complex networks. Therefore, incubator organizations have an important task in assisting and supporting the creation and development of value-added network relations of their tenants. Unfortunately, little is known from previous studies about the mechanisms and structures in social networks that provide advantages (or disadvantages) to the growth of university spin-offs. Moreover, the influence of networks on the growth of spin-offs combined with other factors, such as support from incubators has been barely explored in the literature. To fill this knowledge gap, four characteristics of social networks: structural characteristics, relational characteristics, heterogeneity in partners' background and spatial orientation, and other characteristics of university spin-offs: spin-offs' strategy in taking risks, level of capabilities, resources and support received, that may contribute to growth under different conditions were examined in this study. A summary of the results and critical evaluation is presented in this chapter. It begins with a discussion of the research design in section 8.2. The findings related to the first research question are examined in section 8.3 followed by a discussion of the findings for the second research question including a summary of the hypotheses testing in section 8.4. In the last two sections (sections 8.5 and

8.6) the implications for existing research and policy addressed, limitations of this study leading to various recommendations for future research are presented.

8.2 The research design in brief

The study started with a reflection of the theory leading to the formulation of hypotheses. A two-step research design was employed in the empirical part of the study. In step one, a meta-analysis on growth of incubators was performed, followed by an empirical analysis of the growth of university spin-offs in step two. The meta-analysis of 40 incubators was used to select two case studies of incubators to be examined in the second step. For this purpose, a combination of quantitative and qualitative data from multiple sources was analyzed using Rough Set Analysis to identify factors or a combination of the factors that explain differences in the growth of incubators. The combination of level of urbanization and the model of stakeholder involvement in the incubator (single/multiple) provided the strongest explanation. As a result, two incubators: one from Delft University of Technology (TU Delft) in the city of Delft, the Netherlands and one from Norwegian University of Science and Technology (NTNU) in the city of Trondheim, Norway were selected. Following this selection, data on 100 university spin-offs was collected at both sites using face-to-face interviews. Several questions concerning spin-offs' characteristics, network profile and type of obstacles were addressed. The study of growth and networks of spin-offs started with a descriptive analysis of the characteristics of growth and variables used in the growth models. Overall, the results provided solid reasons for breaking down the sample using two dimensions, namely a different location in the urban system and development stage of spin-offs. In the main analysis, various linear regression models on growth were explored and several hypotheses were tested concerning the influence of social networks and other factors on growth.

8.3 Discussion and conclusion regarding the first set of research questions

The literature shows a substantial heterogeneity in the ways of describing the growth of firms (Delmar et al., 2003). There are plenty of indicators used to measure growth, and different indicators are used to describe different aspects of growth. While there is still a debate concerning the appropriate indicators to measure growth, many studies based on the Resource-Based View have described growth as a process of collecting resources and transferring into products (e.g. Barney and Clark, 2007). Yet, the process of university spin-offs in overcoming a lack of resources is not well understood. To respond to this matter, the first research question of this study was:

> What is the growth of university spin-offs, in particular, how does the pattern of obstacles faced by university spin-offs change overtime?

To answer this question, the growth of spin-offs was explored using three different indicators. The first indicator was the capability of spin-offs in reducing obstacles. Spin-offs need to overcome obstacles to gain competitive advantage of growth. Failing to overcome these obstacles may hinder growth. Overall, the results show that growth can be seen as a

process in which the numbers of obstacles experienced by spin-offs decline overtime. During the early years, most spin-offs experience several important obstacles, i.e. concerning market knowledge, financial and management issues. The results show that the presence of these obstacles is relatively high in the first to fourth years, but the number of obstacles declines significantly once a spin-off reaches four.

Detailed exploration of the data reveals an interesting difference between spin-offs in Delft and Trondheim. Spin-offs in Trondheim experienced a slightly higher number of obstacles in the early years compared with those in Delft, however, spin-offs in Trondheim had a relatively stronger obstacle reduction capability than those in Delft meaning that the number of obstacles had declined more significantly in Trondheim than in Delft. For example, the obstacle reduction rate of market-related knowledge is 53% for 5-7 years old spin-offs in Trondheim versus 17% in Delft. Regarding the types of obstacles experienced by spin-offs in Delft, lack of marketing knowledge occurs most often compared to other obstacles in the first age category (1-4 years). While this obstacle can be solved overtime, other obstacles such as management obstacles tend to be more resistant among spin-offs in Delft. Accordingly, the obstacle reduction rate of management obstacles was 33% compared to 92% for financial obstacles and 57% for market-related obstacles. Spin-offs in Trondheim experienced a lack of financial investment more often than other obstacles. Interestingly, the spin-offs experienced almost no resistant obstacles, witness a reduction rate of approximately 90% for Trondheim. The strong capability of spin-offs in Trondheim to reduce obstacles indicates the prominent role of support provided by the incubator organizations to university spin-offs. At the time of the survey, spin-offs in Trondheim had received better, more advanced, support than those in Delft. The incubators in Trondheim were founded with strong involvement from industry causing more resources and networks to external resources to be accessible to the spin-offs. Apparently, the quality of support is able to compensate for the disadvantage of being located in a non-metropolitan area. In contrast, spin-offs in Delft have received less added value support from the incubator organization. Apparently, spin-offs in Delft have solved obstacles by utilizing networks which are relatively easy to develop in a metropolitan area.

The second growth indicator was job growth. The findings show that spin-offs tend to experience relatively slow growth. On average, spin-offs experience job growth of 0.86 fte per year (1995-2005) with more than 50% of spin-offs facing less than 1 fte per year. Spin-offs in Trondheim have a slightly higher share of spin-offs with strong growth, more than 2 fte per year, than Delft. The finding of weak growth for university spin-offs contradicts many previous arguments and studies regarding the magnitude of the job creating power of small technology based firms (e.g. Broersma and Gautier, 1997; Picot and Dupuy; 1998). In this study it was found that university spin-offs may survive for a long period, although they tend to remain relatively small with most spin-offs not larger than 10 employees after six years of existence. This finding supports the study by Mustar et al. (2007) indicating relative modest growth and high survival rate of university spin-offs in the European Union.

The last growth indicator was growth in business networks. Spin-offs may extend their networking activities by subcontracting agreements and outsourcing. A dichotomous

variable was created to differentiate between weak growth and strong growth. The result showed that almost 60% of the spin-offs in the sample experienced strong growth. In contrast with the above findings on job growth, spin-offs in this study tended to experience relatively strong growth in business networks. Apparently, they lacked resources and to grow, they sub-contracted research and development or production processes to other firms and research institutes. This finding reveals evidence for a new trend in growth that is currently employed by university spin-offs.

Using these three indicators, a general description of the growth of university spin-offs can be obtained. In general, spin-offs grow relatively modestly in terms of job growth. Some interviews with founders' of spin-offs revealed their worry about future uncertainties that prevented them from hiring a new employee. However, many of them admitted that the decision to hire the first employee is one of the biggest decisions toward growth. In contrast, this finding appears to be different in terms of growth in business networks. Most of the spin-offs agreed that network is one of the important components that support growth. In the exploration of the pattern of obstacles, it was found that spin-offs in Delft and Trondheim experienced relatively different types of obstacles. The pattern of obstacles of spin-offs in those two cities was also different. The finding may indicate that several condition factors, namely location of spin-offs or types of support, have an influence on the capability of spin-offs in reducing obstacles to growth.

8.4 Discussion and conclusion regarding the second set of research questions

The second set of questions was concerned with spin-offs access to external resources related to the profile of social networks through which knowledge and information flow. The second research question was:

> What are the characteristics of social networks of university spin-offs, to what extent and under what conditions are characteristics of social networks beneficial for growth?

To answer the first part of the question, it was found that overall the social networks of university spin-offs are characterized by relatively modest tight networks and heterogeneity of the partners' background. University spin-offs in this study experienced strong ties with partners and a strong internal orientation for their networks. To commercialize knowledge and innovation from university, university spin-offs as new firms apparently tend to rely strongly on the relationships with close and local partners that provide trust and support. As spin-offs try to enter a new market, strong ties with partners may give protection and comfort in the face of uncertainty. Although spin-offs can have a global market and may collaborate with global partners, they do not have a strong external orientation. Instead, spin-offs tend to experience a strong internal orientation in their networks, most probably related to the presence of local partners and knowledge spillovers in their location.

Looking in more detail at the characteristics of social networks of different categories of spin-offs, some interesting contrasts are revealed. The profile of spin-offs in Delft is dominated by loose networks, strong ties and a strong external orientation while the profile

in Trondheim is largely dominated by tight networks, weak ties and a weak external orientation. These contrasting characteristics may be due to the different levels of urbanization between Delft and Trondheim.

Further, the social networks of spin-offs in the early stage are characterized by tight networks, homogeneous partners' background and weak external orientation while those in the later stage are characterized by loose network, heterogeneous partners' background and a strong external orientation. These differences indicate that spin-offs in different development stages face divergent capabilities and needs when building networks.

To answer the second part of the question regarding to what extent and under what conditions are characteristics of social networks beneficial for growth, nine hypotheses were developed and tested using six regression models. The first two models were built using the total sample and a different dependent variable, namely job growth for model one and business network growth for model two. In the rest of the models job growth was used as a dependent variable and the sample was broken down into four categories. The third and fourth models were based on the locations of spin-offs in Delft and Trondheim while the fifth and sixth model were based on the development stages of spin-offs divided into early and later stages, i.e. 1-4 years and 5 to 10 years. A summary of the outcomes of the hypotheses testing is presented in table 8.1.

Table 8.1 Summary of the hypotheses

No	Hypotheses	Total sample	Total sample	Location		Development stages		Summary
		1 Job growth	2 Network growth	3 Delft	4 Trondheim	5 Early	6 Later	
	Growth of university spin-offs is positively influenced by							
1	Risk-avoiding in strategy	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected	All rejected
2	High level of spin-offs' capability	Supported	Rejected	Rejected	Supported	Supported	Supported	4x supported
3	Low level of resource deficiency	Supported	Supported	Supported	Supported	Supported	Supported	All supported
4	High level of added value support	Supported	Supported	Rejected	Supported	Rejected	Supported	4x supported
5a	Tight networks	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected	All rejected
5b	Loose networks	Supported	Supported	Supported	Rejected	Rejected	Supported	4x supported
6a	Strong ties	Rejected	Rejected	Rejected	Supported	Rejected	Rejected	5x rejected
6b	Weak ties	Rejected	Rejected	Supported	Rejected	Rejected	Supported	4x rejected
7	Heterogeneous background of partners	Supported	Supported	Supported	Supported	Supported	Supported	All supported
8a	Internal orientation	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected	All rejected
8b	External orientation	Supported	Supported	Supported	Rejected	Rejected	Supported	4x supported
	The relationship between the profile of social networks and the growth of university spin-offs is moderated by							
9.1	Age of spin-offs	Supported only for tightness of network and spatial orientation						
9.2	Level of urbanization	Supported only for strength of relationship and spatial orientation						
9.3	Level of spin-offs' capability	Supported only for strength of relationship and spatial orientation						
9.4	Spatial orientation	Supported only for strength of relationship						

Hypotheses regarding strategy, capabilities and resources

The first hypothesis dealt with a spin-off's strategy in dealing with risks. It is assumed that there are two types of strategy. One, spin-offs avoid taking risks by making only a small investment in research and operating in a service industry. Two spin-offs take risks committing to high trends of investment in research and operating in a manufacturing industry. Since taking more risks means that spin-offs need to collect more resources, which they can also easily loose, it is assumed that spin-offs with a risk-avoiding strategy in their early years have a chance for stronger growth compared with those with a risk-taking strategy. The results of the hypothesis testing show that this was rejected for all the models. Thus, it cannot be concluded that spin-offs with a risk-avoiding strategy grow stronger than spin-offs with a risk-taking strategy. The lack of support for this hypothesis may be caused by the fact that the developed variable could not appropriately measure the risk faced by spin-offs. In particular, it appeared that spin-offs with a risk-taking strategy will have received a grant(s) from a government or support from potential buyers to reduce risk.

The next hypothesis dealt with the level of capability (hypothesis 2). Spin-offs with a high level of capability through previous experience or a team start have developed networks as an effective way to find resources. Overall, this result confirms previous studies that postulate a positive impact of prior business experience and team start on growth (Kor, 2003; Chandler and Jansen, 1992). The hypothesis is supported by model 1 job growth; 4 Trondheim; 5 early stage and 6 later stage but is rejected by model 2 network growth and 3 Delft. The failure to find a significant influence of capability on growth in Delft may be caused by the fact that most spin-offs were established by founders lacking prior business experience. In contrast, various spin-offs in Trondheim were established as a joint effort between students/graduates and serial entrepreneurs or senior academic staff. This combination turns out to influence positively the growth of university spin-offs in Trondheim.

The next hypothesis dealt with a spin-off's ability to overcome or prevent obstacles as indicated by resource deficiency (hypothesis 3). Overall, the result showed that all the models support the hypothesis. This finding means that a high level of resource deficiency has a strong and consistent negative influence on growth. Spin-offs that are not able to overcome resource related obstacles tend to be hindered from growing.

The last hypothesis in this category dealt with the influence of added value support on growth. Support provided by incubator organizations may vary in amount of added value support. Added value support means more than just basic support such as accommodation and financial support. Added value support is aimed at improving the chance spin-offs growth by providing e.g. market analysis, personal training and networking support. It is assumed that a large amount of added value support received by spin-offs has a positive influence on growth (hypothesis 4). The result shows that models 1, job growth; 2, network growth; 4, Trondheim and 6, later stage, support the hypothesis. Apparently, added value support has no significant impact on growth of university spin-offs in Delft and in the early stage of a spin-off (1-4 years). The result for Delft can be understood by the fact that the

incubator organization at the time of the survey was not well developed. It was mainly conventional support that was provided, such as financial support and accommodation. Moreover, the influence of added value support on growth of spin-offs in the early stage could not be confirmed. It may be that the impact of the quality of support on growth manifests itself after spin-offs move to later stages, e.g. when the quality of networking becomes critical for gaining a position in the market.

Hypotheses regarding social network characteristics

Four characteristics of social networks were distinguished in this study that may influence the growth of university spin-offs. These include: structural characteristics, tight and loose networks, and relational characteristics, strong and weak ties, heterogeneity in partners' backgrounds, and the spatial orientation of a spin-offs network.

Regarding the structural characteristics, the literature shows two different arguments, namely the closure and the structural hole argument. The closure argument stresses that a tight network of partners can easily transfer tacit knowledge, reputational effects and provides continuous access to resources. The structural hole argument claims that a loose network provides access to a wider circle of information about resources and opportunities, and referrals on a wider potential of partners. Given the ambiguity in the literature, the impact of these characteristics of networks was tested using hypotheses 5a and 5b. Hypothesis 5a refers to a tight network with a high level of connection among all partners. The results from the hypothesis testing showed that all the models reject this hypothesis. Thus, closure (tightness) does not show a significant impact on growth. Hypothesis 5b states that a low level of connection among partners has a positive influence on growth. The result shows that models 1, job growth; 2, network growth; 3, Delft and 6, later stage confirm this hypothesis.

Overall, the finding that the closure argument could not be confirmed supports previous discussions on the negative effect of tight networks. For instance, Portes and Sensenbrenner (1993) observe that although entrepreneurs benefit from the support and resources provided by tight networks, the difficulties met when trying to fill the demands posed by the networks may curtail a spin-off's ability to pursue new opportunities. Moreover, engaging in a tight network may filter out vital information, and generate a cognitive lock-in effect that isolates entrepreneurs from the outer world (Grabher, 1993; Uzzi, 1997).

The alternative hypothesis concerning loose networks which emphasized the structural holes argument is supported except for the model of Trondheim and the early stages of spin-offs development (1-4 years). Overall, this finding is consistent with previous studies (e.g. Burt, 2000, 2004; Zaheer and Bell, 2005; Scholten, 2006) that put an emphasis on the important role of structural holes. The lack of influence of loose networks on the growth of spin-offs in Trondheim may be caused by the fact that spin-offs in Trondheim employ a different network structure to those in Delft. To be established as a new firm, spin-offs in Trondheim need to compose a board of advisors who are not part of the firm but are committed to the growth of the firm. Commonly, the partners do not know each other

before but they become familiar as they join in the board of advisors. In contrast, this kind of organization structure is not required for spin-offs in Delft. Networks of spin-offs in Delft are relatively open compared to close networks of spin-offs in Trondheim. In addition, the importance of loose networks is rejected by the model of spin-offs in the early stage (1-4 years). Apparently in this stage, dense networks relying on safe and familiar relations are more important.

The next hypotheses dealt with the relational characteristic of strength of ties. In the literature, the role of strength of ties in growth is still under debate. Several studies stress that strong ties are more beneficial while others argue the importance of weak ties (Gulati, 1995; Larson 1992). Strong ties may contribute to the transfer of complex knowledge whereas weak ties may benefit from the introduction of novel information (Hansen 1999; Elfring and Hulsink, 2003) and the facilitation of explorative activities (Rowley et al., 2000). In this study, these arguments were tested using hypotheses 6a and 6b. The result showed that most of the models reject both hypotheses. Only model 4 Trondheim supports the hypothesis on strong ties while models 3 Delft and 6 later stages support the hypothesis on weak ties. It is interesting that spin-offs in Trondheim, located on a large distance from metropolitan cities such as Oslo or Stockholm, tend to experience a positive influence of strong ties on growth. Presumably, these spin-offs compensate the lack of knowledge spillovers at their location by strengthening their social relationships. In contrast, spin-offs in Delft, facing a large opportunity to develop networks due to their favorable location in a metropolitan area, experience a positive impact on growth from weak ties. The same situation happens to spin-offs in later development stages. Weak ties show a positive influence on growth in later stages. On the whole, the failure to confirm the hypotheses on strength of ties may support what has been indicated in several studies as the benefit to be gained from various, simultaneously occurring, combinations of strong and weak ties (Elfring and Hulsink, 2003; Burt, 2000; Jack, 2005).

The next hypothesis dealt with the social background of partners. Spin-offs that employ a heterogeneous network of partners originating from different backgrounds are believed to be rich in information and knowledge (Marsden, 1987). The findings showed that all the models consistently supported the hypothesis about the importance of heterogeneity in partners' background. Apparently, the growth of university spin-offs benefits from engagement with a diverse range of partners. Informal communication between spin-offs and partners from different social circles increases the chance of an unforeseen novel combination of knowledge that can lead to growth and innovation (Pittaway et al., 2004). The result confirmed the argument in the literature on importance of diversity of relationships in networks and its positive impact on innovation (e.g. Kaufmann and Tödtling, 2001; Perez and Sanchez, 2002; Romijn and Albu, 2002).

The last hypotheses dealt with the spatial orientation of spin-offs. Two types of orientation, mainly internal and mainly external orientation were distinguished. Spin-offs with mainly an internal orientation employ partners in close proximity. Some studies find that, in terms of knowledge utilization, partners in close proximity bring positive benefits for growth, while other studies find that an external orientation stimulates growth by introducing more novel

information and knowledge (Bathelt et al., 2004). These two arguments are covered in hypotheses 8a and 8b. The result of the hypotheses testing showed that the hypothesis on the influence of internal orientation, hypothesis 8a, was rejected in all the models while the hypothesis on the influence of external orientation, hypothesis 8b, was accepted in models 1 job growth; 2 network growth; 3 Delft and 6 later stages. Apparently, an internal orientation is not likely to promote growth while an external orientation, to some extent, causes a positive influence on growth for spin-offs. Spin-offs in Trondheim and spin-offs in the early stage do not support the last hypothesis. This may be understood as follows, the geographical location of Trondheim tends to limit the composition of partners to a larger share of local partners, while spin-offs in the early stage may depend on local partners, known from the past for information on product development, potential markets, etc., due to a still weak organizational capability.

Overall, the results of the hypotheses testing revealed an interesting understanding of the influence of network characteristics. While tight networks, heterogeneity in the background of partners and internal orientation are consistent for rejection or acceptance of the hypotheses, strength of relationship produced mixed results. Apparently, strong ties and weak ties have a positive influence under different conditions (Jack et al., 2004). To identify such a relationship, the variables of the social networks were transformed into quadratic terms. The result showed that strength of ties and external orientation has a non-linear relationship with growth. Although the models are significant, the level of improvement is relatively low (2-3%). This result indicates a modest trend implying that having too many strong ties and external orientation may negatively influence growth.

Hypotheses regarding moderation effects

In addition to the hypotheses on the influence of resource/capability related and network characteristics on growth, various hypotheses were formulated based on the expectation that several variables play a role in moderating the relationship between network characteristics and growth. The first factor was age of spin-offs. It has often been argued, but with limited empirical evidence, that older spin-offs have different network characteristics compared with younger ones. It is assumed in this study that the older the spin-offs are the stronger the relationship between network characteristics and growth is. The results, however, only confirmed the influence of age of spin-offs on moderating the relationship between tightness of network and spatial orientation on growth (hypothesis 9.1). The results suggested that strong growth among older spin-offs tends to be derived from more loose networks and an external orientation than among younger spin-offs.

The next factor tested was location of spin-offs. Based on the presumed advantages of a location in metropolitan areas (Cooke, 2007), it was assumed that the relationship between networks and growth would be stronger for spin-offs in Delft than for those in Trondheim. The results showed that this hypothesis is partially supported (hypothesis 9.2), level of urbanization moderates the relationship of strength of ties and spatial orientation with growth. Strong growth of spin-offs in Delft tends to be derived from weak ties and external orientation while strongly growing spin-offs in Trondheim tend to have strong ties and an

internal orientation. This finding is similar to the one for capability level. Spin-offs with a high level of capability more often have weak ties and external orientation than spin-offs with a relatively low level of capability (hypotheses 9.3).

The last exploration of factors that moderate the relationship between network characteristics and growth was a spatial orientation of spin-offs. It was assumed that spin-offs with mainly an external orientation have different network characteristics compared to spin-offs with a mainly internal orientation (hypotheses 9.4). The results showed that spatial orientation moderates the relationship between strength of ties and growth. Apparently, spin-offs mainly employing an external orientation have weaker ties compared with spin-offs that mainly employ an internal orientation

8.5 Implications

In this section, the implications of the study to knowledge in the field and policy practice are discussed in a broader empirical context. The discussion includes a threefold contribution to the field, i.e. the understanding of social networks, benefit of metropolitan and non-metropolitan area, and of obstacles overtime.

Characteristics of social networks tend to have different impacts under different conditions

Until recently, the literature on social networks has focused on the influence of particular characteristics of networks under one set of conditions. Yet the results of this study demonstrate that certain network characteristics play a different role under different conditions. The impact of the strength of ties and of the spatial orientation of spin-offs varies with the various conditions under which the spin-offs operate. For instance, weak ties have a positive influence in Delft while strong ties have a positive influence in Trondheim. In a more detailed analysis, more factors, such level of capability also influence the relationship between strength of ties and growth. The findings on moderation effects show that compared with other network characteristics, strength of ties is the one that is most influenced by other factors. In addition, the result of analysis on the influence of social networks on the growth of spin-offs in different growth stage showed that there is a trend that social networks play a stronger role among spin-offs in later stages than in the early stage. Loose network, weak ties and ties with partners in other regions are more likely to support growth of spin-offs in later stages.

Regarding the practical implications, it is important for entrepreneurs and incubator managers to increase the awareness of the importance of network characteristics. Entrepreneurs preferably should develop new social ties on a regular basis by participating in exhibitions, seminars and other networking events. As a result, entrepreneurs may connect with partners from new network clusters, locations and social backgrounds as a bridge to new network relation. In addition, interacting with partners from a heterogeneous background plays an important role in supporting growth, as extending networks facilitates an increase in the number of structural holes. When maintaining networks, entrepreneurs need to be aware of the importance of the dynamics of their

preferred network(s), i.e. the changing relevance of strong and weak ties according to developmental stage of the spin-offs.

Accordingly, for incubator managers, besides providing critical resources, universities and incubation organizations can adopt the role of an intermediary to connect spin-offs with the right mix of networks of partners (McAdam et al., 2006; McAdam and Marlow, 2008). Incubators may provide training and coaching to increase the networking capability of spin-offs, particularly the capacity of spin-offs to evaluate their networks critically**.** Incubator managers can help ensure that spin-offs remain active in a heterogeneous network, that connects different spheres of social and economic life, and avoid tight networks. Incubation programs should preferably enhance the rise of loose networks to ensure open circulation of knowledge. At the same time, it seems necessary to provide co-ordination of interactions and network training as early as possible after a spin-offs is established, such that spin-offs can create value from their networks soon after start up and not just after a couple of years.

Metropolitan and non-metropolitan areas

The next contribution of this study concerns with how spin-offs may overcome the disadvantages of being located in non-metropolitan areas. In spatial innovation and incubation theory, it is assumed that the location where spin-offs start their new business influences their growth. Firms in metropolitan areas may enjoy more benefits in terms of economic externalities compared with spin-offs in non-metropolitan areas. In metropolitan areas, firms may enjoy stronger knowledge spillovers, a larger labor supply and ease of relations with suppliers and customers. Spin-offs in non- metropolitan areas need more effort to find information on resources and to connect with a (launching) market. In contrast to these views, in this study it was found that spin-offs in non-metropolitan areas, in this case, Trondheim, show broadly the same growth performance as spin-offs in metropolitan areas. Thus, despite smaller agglomeration advantages in Trondheim, as the theory suggests, the growth patterns of spin-offs in Trondheim turn out to be similar to those of spin-offs in Delft (Soetanto and van Geenhuizen, 2008). The social networks, however, are different, i.e. relatively open, strong and located more often outside Delft, as opposed to relatively closed, weak and local-oriented in Trondheim. One characteristic is similar, that is the heterogeneity in social background of partners. Of all four network characteristics studied, it is precisely this factor that tends to influence growth in the same (positive) direction in both cities. An important difference is the strength of relationships: stronger relationships tend to hamper growth in Delft but tend to stimulate growth in Trondheim. As far as the role of proximity in social networks is concerned, the results gave two important insights. One, employing networks over larger areas tends to enhance growth in Delft, but not in Trondheim; two, strong interaction effects between external orientation and social network characteristics in influencing growth are absent, except for the interaction with strength of relationships. The latter result would suggest that relations beyond the local are only favourable if these are weak, and accordingly yield a better quality of knowledge compared to strong relations. Apparently, spin-offs in Trondheim have adapted themselves to obtain a quicker growth from locally available knowledge by efficiently using network capabilities and support, and by stronger relations

with local partners compared to the Delft's spin-offs. Overall, the results reveal more differences than similarities between the two cities in the social network profile and in its influence on growth, and in this sense contrasting urban environment matters.

Obstacles overtime

Another contribution of this study is the insight gained into the obstacles to growth faced by spin-offs during their first ten years. The results of an exploration of trends in obstacles to growth clarified particular problematic situations of spin-offs at various ages. This was done using both cross-sectional and longitudinal data. Overall, market-related problems tend to be most resistant over time. Remarkably, financial problems tend to be solved more quickly, a situation typical for service firms and for firms preferring self-financing, but this holds more in Delft than in Trondheim. The results of the study also add to the theory of stage-based development of academic spin-offs: a preliminary identification was made of the way the age-dimension of a spin-offs affects the credibility threshold (Vohora et al., 2004). For spin-offs in Delft and Trondheim, the age at which the credibility threshold of the spin-off's development is seriously manifest tends to be between years two and four. The number of obstacles to growth increase in year two and decline to a small extent in years three and four. This is followed by relatively strong levels of obstacle reduction. In addition, the results have increased the knowledge that can be used in practice for fostering university spin-offs. A major result is the need to adopt a differentiated approach when designing support programs for academic spin-offs, given the diversity in age and location of the spin-offs. The rise of credibility problems between ages of two to four years for spin-offs suggests that support should not be stopped in these years but continued, and that is should be focused on particular needs to prevent/solve credibility problems. For example, through early personal training of entrepreneurs to develop skills in connecting (negotiating) with potential market partners and in building a good mix of such partners. The last recommendation complies with the previously mentioned idea that networking, as the main ingredient to enhance performance, should be based on the right strategy, i.e. one of including sufficient openness and variation in partners (Walter et al., 2006; Hughes et al., 2007). Early support and training in profitable networking may prevent a situation in which large numbers of spin-offs of an older ages are found to be without stable customer relations and as a result, without the power to grow.

8.6 Recommendation for further study

Two technical universities in Europe, i.e. Delft (the Netherlands) and Trondheim (Norway) and their spin-offs were investigated for this study. Those two universities were selected using a rigorous process of a meta-analysis study. It is believed that the results from both universities are representative for a broader group of technical universities, namely those located in countries with a rather risk-avoiding culture in entrepreneurship (GEM, 2008) and with strong business links to energy (including off-shore), ship-building and information and communication technology. Despite the interesting results achieved of this study, it is acknowledged that there are some limitations in the study that point to important avenues for future research.

The first limitation is the issue of measurement. Measuring a component of risk in strategy as done in this study may not be able to catch the real risks faced by university spin-offs as the hypothesis concerning growth was constantly rejected. The measurement of strength of ties also faces a limitation. As suggested by Granovetter (1983), strength of ties can be measured as an aggregation of three different indicators. This measurement may just roughly describe the characteristics of ties. In business network, firms might meet each other quite often but the level of emotion between entrepreneurs and their partners are still low as their discussion is restricted to business matters only. A better indicator for presenting those measurements needs to be identified for future researches.

The second limitation is related to the relatively small number of observations made in the case studies. For this reason only four important features of social networks were included in the growth model, thereby excluding others. One of these was the content of the knowledge involved in spin-offs development which seems to change with the development stages of the networks of spin-offs (Hoang and Antoncic, 2003; Larson and Starr, 1993; Soda et al., 2004). In addition, there is limitation related to not paying attention to the different strategies of spin-offs for developing and managing their networks. As Stuart and Sorensen (2008) argue differences between entrepreneurs in terms of their strategic preferences for certain network characteristics, and their ability to acquire and benefit from the networks may confound individual-level effects with network-level effects. Although some spin-offs' characteristics, e.g. level of capability, are considered in this study, the personal preferences of entrepreneur may also influence the social network characteristics of university spin-offs. In future research, in which more data should be collected, there are two things that could be done, one test the current results presented here more rigorously and two, extent the model.

Another limitation is the lack of attention paid to capturing the dynamic relationship between social networks and growth (Slotte-Kock and Coviello, 2009). In this study the assumption is made that social networks influence the growth of university spin-offs, but causality may also run into the opposite direction. Quickly growing spin-offs may be perceived as an attractive partner, and therefore their network characteristics may be different compared to slow growing spin-offs. In future, a longitudinal perspective should be adopted that can be used to track the interaction between network and performance over time. As in this study the influence of social networks is dealt with a mainly linear way, this may have obscured information about the optimum levels of these networks. In future research, the various optimal levels of social networks should be identified, to account for different contexts such as those that appeared to be relevant in this study, i.e. spin-offs' location: metropolitan versus non-metropolitan, and the development stage of the spin-offs.

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Appendix 1 Rough Set Analysis

The meta-analysis of incubator performance deals with qualitative and quantitative information and is based on a relatively small sample. Therefore, this study employed Rough Set Analysis to identify and disentangle causal relations (Pawlak, 1991). This approach enables the transformation of an imprecise or incomplete (fuzzy) collection of data into structured information. Unlike conventional methods based on statistical assumptions (like regression models) this analysis makes only one assumption in that the value of the determining factors can be categorized. In particular, Rough Set Analysis enables to incorporate different measurement scales and different degrees of measurement accuracy (Soetanto and van Geenhuizen, 2007).

In Rough Set Analysis, objects described by the same properly selected information are indiscernible (similar) in view of available information and form blocks, which can be understood as elementary granules of knowledge. These granules are called elementary sets or concepts, and can be considered as elementary building blocks of knowledge about the reality. In Rough Set Analysis, information is presented in an information table (IT) that is a matrix in which rows are labeled by objects and columns are labeled by attributes. Objects arranged in an IT are based on their condition attributes (C) and decision attribute (D). The condition attributes consist of the features that describe the object, whereas the value of the decision attribute contains the concepts to be learned based on the value of the condition attributes. Objects in elementary sets are those that can be clearly distinguished on the basis of condition attributes and can be defined as belonging to a concept. In addition, some subsets of objects cannot be distinguished on the basis of the available attributes, they can only be roughly defined. The Rough Set is defined as a pair of crisp sets corresponding to approximations, i.e. the lower and the upper approximation of set X. The lower approximation of set X, denoted by AX, is the set of all elementary sets; objects in this lower approximation can unambiguously be classified as belonging to set X. By contrast, the upper approximation of X, denoted as ĀX, is a group of elementary sets which possibly belong to X (Figure 1). The sets are mathematically represented as follows:

$$\bar{A}X = \left\{x \in u : [x]_A \cap X \neq 0\right\}$$

Where:
AX is the lower approximation of set X and $\bar{A}X$ is the upper approximation of set X;
A is the given set of condition attributes;
$x_1, x_2, x_3, \ldots x_n$ is a finite set of objects;
U is the given universe.

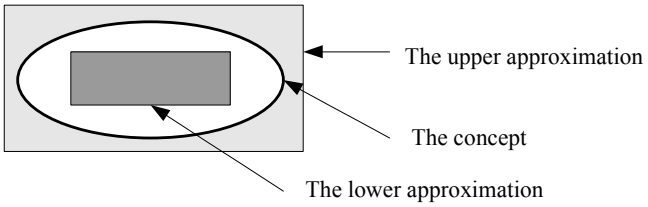

Figure 1. Illustration of the upper and lower approximation of concept X

The basic procedure in Rough Set Analysis works through the reduction of attributes, i.e. finding a smaller set of attributes with the same or close classificatory power as the original set of attributes. Reduct and core are basic concepts in this context. A reduct is the essential part of an information table (subset of attributes) that can discern all objects that can be discerned by the original information table. A core is a common part of all reducts. On the basis of a reduced information table, *decision rules* are composed by determining the decision attributes based on condition attributes. In other words, the procedure aims to identify under which conditions certain attributes are necessary to "explain" the existence of a feature of the decision attribute. A rule is presented in a ''IF condition(s) THEN decision'' format. Condition attributes that are in the core have the strongest explanatory power; these are indispensable in explaining the variation in the decision attribute. All other condition attributes appear at a lower frequency in the rules. In general, a high frequency rate in the decision rules means that the attributes stand out in a more pronounced way than others. A final concept of Rough Set Analysis to be discussed here is *coverage* (or strength) of the rules. This value indicates the rate in which objects in a subset with the same decision attribute support the decision rule. It needs to be mentioned that a related technique for a comparative project analysis is fuzzy set analysis; this technique matches better with very small samples (e.g. 4/5 case studies) and produces more refined decision rules.

Stepwise approach

Despite its various strong points, Rough Set Analysis has also potential weaknesses. As Rough Set Analysis is a tool based on deterministic calculation, it is always capable of producing a result even with a fuzzy input, although it usually does not provide a reliable indication of the quality of the result. Addressing this problem, a step-wise procedure was developed, including the performance of several tests to ensure the quality of the result. In order to make the results more solid this study inserted two new elements in the procedure. First, instead of one sample, the stepwise approach used trends found in 10 random samples drawn from the base population of selected objects; this is to prevent any sensitivity of the results from the structure of the sample. In this study, a sample size based upon a common statistical procedure, viz. 25 (Cochran, 1977) was measured. Secondly, this study is intended to know the accuracy with which the decision rules could predict the outcomes (decision variable) applied to a set of *new* samples. For each sample, Rough Set estimation was conducted in a basic way using ROSE2 software, that is a modular system implementing the basic elements of Rough Set theory and the decision rules. To summarize, the steps were as follows (Figure 2):

Step 1) Collect initial data and create the information table including 40 selected incubators (base-population). The table contains condition attributes (C) and decision attributes (D). The condition attributes are the determinant factors of growth of incubators, whereas the decision attribute is the growth of incubators.

Step 2) By using a random selection, construct 10 data sets for further analysis. Each sample consists of 25 incubators.

Step 3) Apply Rough Set Analysis using these samples. Through this process, redundant attributes are removed. The results are *reduct*, *core*, and *decision rules*. After the

attribute reduction process, the procedure generates the decision rules.

Step 4) Measure the accuracy of the decision rules in two ways. First, use the value of the core attributes and all attributes' accuracy in predicting growth following the routine in ROSE2. Secondly, draw 10 *new* samples and test the accuracy with which the decision rules can predict growth.

Step 5) Draw conclusions about the condition attributes, in terms of supporting or contradicting the hypotheses. In the final examination of the data, the combination of condition attributes in the *strongest rules* is measured as a percentage of all strongest rules, and the frequency of the strongest rules in the samples is measured as a percentage of all samples.

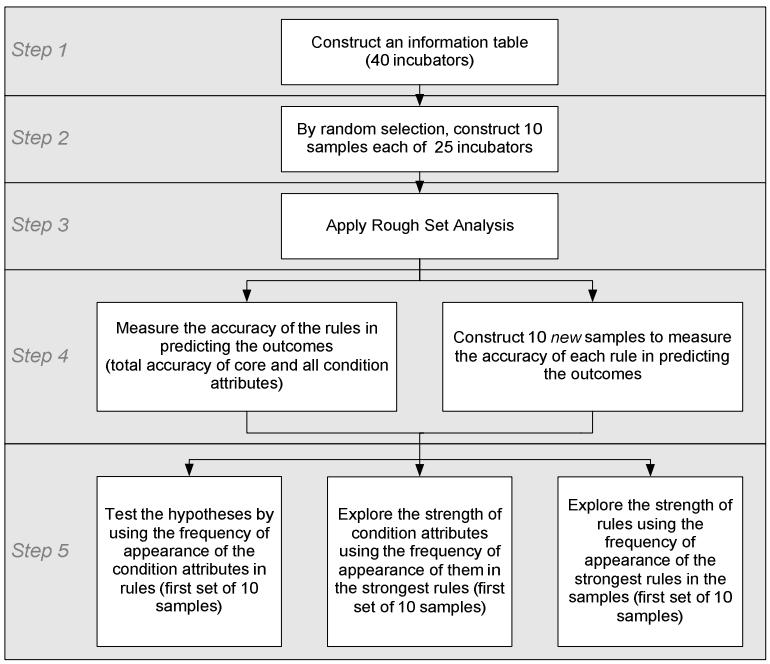

Figure 2. Step-wise procedure

In this study, the analysis is conducted by means of ROSE 2 software (http://idss.cs.put.poznan.pl/site/rose.html). ROSE2 (Rough Sets Data Explorer) is a software implementing basic elements of the Rough Set theory and rule discovery techniques. The system contains several tools for Rough Set based knowledge discovery, e.g.:

- data preprocessing, including discretization of numerical attributes,
- performing a standard and an extended Rough Set based analysis of data,
- search of a core and reducts of attributes permitting data reduction,
- inducing sets of decision rules from rough approximations of decision classes,
- evaluating sets of rules in classification experiments,
- using sets of decision rules as classifiers.

Appendix 2 Questionnaire

1. Firm profile

Year and city/municipality where the firm started *(Registered at the Chamber of Commerce)*		..... year ..... city
	At the time of the start	Current (2006)
Number of employees including founder(s)	..... (fte)	..... (fte)
Number of R&D employees including the founder(s)	..... (fte)	..... (fte)
Annual turnover in the last year (Euro) [b]	☐ < 100.000 ☐ >300.000	☐ 100.000-300.000 ☐ No turnover
Source of turnover : [a] (please give the indication of their percentage from total turnover)	☐ Selling products - ..... % ☐ Consultation - ..... % ☐ Development and design - ..... % ☐ Others : ..... - ..... %	
Have you experienced growth in (current situation) [a]	☐ Turnover ☐ Network ☐ market position ☐ Others :	
Do you have own R&D		(Yes/No) [c]
Average annual spending on R&D over the last three years (percentage from turnover) :		..... %
If turnover *is not the only* source of capital used to finance your R&D activities, please mention the other sources : [a]		☐ Subsidies/grant ☐ Own money ☐ Others .....
If you have *no* turnover yet, please mention the source of capital used to finance your R&D activities: [a]		☐ Subsidies/grant ☐ Own money ☐ Others .....
Please describe the main product/service of your company (e.g. software, instruments, coatings, etc)		

a) *Multiple answers are possible*
b) *Please tick the correct class*
c) Circle the right answer

2. Entrepreneurs' profile

		1st Founder	2nd Founder	3rd Founder	4th Founder	5th Founder
Educational background	Degree (e.g. BSc, MSc, PhD)					
	Discipline (e.g. electronics, business, etc)					
Age when starting up firm (year)						

Have the founders experience in starting a new firm? If Yes, when? (years)	(Yes/No) [c)]	(Yes/No) [c)]	(Yes/No) [c)]	(Yes/No) [c)]	(Yes/No) [c)] .....
Have the founders got working experience before starting a new company? If Yes, what experience : [a)] 1. Research experience 2. Managerial experience 3. Other ..... If Yes, how long? (years) If Yes, is the previous job or started firm in the same sector as the current firm?	(Yes/No) [c)] ☐ ☐ .... (Yes/No) [c)]	(Yes/No) [c)] ☐ ☐ .... (Yes/No) [c)]	(Yes/No) [c)] ☐ ☐ .... (Yes/No) [c)]	(Yes/No) [c)] ☐ ☐ .... (Yes/No) [c)]	(Yes/No) [c)] ☐ ☐ .... (Yes/No) [c)]

3. Each newly established firm faces different needs over time. Please tick the problematic needs faced by your firm and give the years. You can have more than one answer.

Needs related with :	Tick if true	From (year)	Until (year)
Lack of marketing knowledge	☐		
Lack of sales skills	☐		
Lack of technological skills	☐		
Limited access to knowledge from university or research center	☐		
Lack of opportunities for cooperation with other firms	☐		
Lack of forecasting capability about future market	☐		
Lack of market demand	☐		
Lack of cash flow	☐		
Lack of investment capital, including R&D investment	☐		
Lack of research and testing facilities (laboratory, equipment)	☐		
Lack of adequate accommodation (office, manufacturing facilities)	☐		
Too many managerial tasks to handle	☐		
Dealing with uncertainty	☐		
Government bureaucracy and regulation	☐		
Other (please explain)	☐		

Explain the problem solving undertaken by you in overcoming the obstacles related with the above needs:

.....

4. Most people discuss from time to time about important issues with others, for example with family, friends, colleagues, etc. Please indicate up to five (5) important partners (not employed by your firm) from whom you are able to receive information and knowledge. (For instance: advice on managing business, finding investment, competition, new ideas on product development, open new market opportunities, connect to new customers or suppliers, etc)

Person	1	2	3	4	5
Initial					
How long have you known in person? (years)					
How well do you know the person? 1. Very well 2. Somehow 3. Very little	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐	☐ ☐ ☐
How did you get into contact with the person? 1. Own contact 2. Referred by other person in personal network 3. Referred by other person in university network 4. Referred by other person in business network 5. Other : ……	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐
How many times in a month (on average) do you have a conversation *face to face* with this 'person' about your business?					
How long does it take to reach this 'person' by car? (Travel time)					
City (of partner)					
Is he/she [a)] 1. A senior executive of firm with a high reputation 2. An officer at a high level of the government 3. A professor at a university 4. Owner of other small business 5. Family or friend Other :	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐

5. Think about the relationship between the five people you named above. For each pair, indicate the relationship between these 2 people as far as you know.

	Stranger	Somewhat acquainted	Well acquainted (know each other very well)	Not Sure
Persons (1) and (2)	☐	☐	☐	☐
Persons (1) and (3)	☐	☐	☐	☐
Persons (1) and (4)	☐	☐	☐	☐
Persons (1) and (5)	☐	☐	☐	☐
Persons (2) and (3)	☐	☐	☐	☐
Persons (2) and (4)	☐	☐	☐	☐
Persons (2) and (5)	☐	☐	☐	☐
Persons (3) and (4)	☐	☐	☐	☐
Persons (3) and (5)	☐	☐	☐	☐
Persons (4) and (5)	☐	☐	☐	☐

6. Did you receive support from the incubator organization in developing your business? (Yes / No)[a)]
If Yes, in what form? Please tick the correct answer(s) and based on your experience, give also your opinion about the value added of each type of support.

Types of support provided by incubator:	Support received from incubator organizations (inc. university)	Support received from others but through incubator organizations (inc. university)	Value added to your firm				
			Strongly Unimportant	Unimportant	Moderate	Important	Strongly Important
			1	2	3	4	5
Marketing assistance and market analysis	☐	☐	☐	☐	☐	☐	☐
Accounting	☐	☐	☐	☐	☐	☐	☐
Law and intellectual property right consulting	☐	☐	☐	☐	☐	☐	☐
General consulting or business mentoring	☐	☐	☐	☐	☐	☐	☐
Office and facilities	☐	☐	☐	☐	☐	☐	☐
Access to grants, seed and venture capital funding	☐	☐	☐	☐	☐	☐	☐
Search for R&D partners	☐	☐	☐	☐	☐	☐	☐
Search for business partners (firms outside the incubator)	☐	☐	☐	☐	☐	☐	☐
Business connections between tenants of incubator	☐	☐	☐	☐	☐	☐	☐
Training/seminar to develop business skills	☐	☐	☐	☐	☐	☐	☐
Loan from venture capitalists	☐	☐	☐	☐	☐	☐	☐
Loan or grant from government	☐	☐	☐	☐	☐	☐	☐
Technological consulting	☐	☐	☐	☐	☐	☐	☐
Access to research results from university or research center	☐	☐	☐	☐	☐	☐	☐
Access to research facilities	☐	☐	☐	☐	☐	☐	☐
Other (please explain) ……	☐	☐	☐	☐	☐	☐	☐

Appendix 3 Simulation on the validity of the age category 8-10 years

One of the analyses in this study focused on the obstacles experienced by university spin-offs in different age category. While there were many firms presented in the first and two age category, the third age category consisted of a low number of spin-offs. It was predicted that the low number of spin-offs might be caused by the fact that many spin-offs had failed before they reached this age category. A contrasting argument poised by Mustar et al. (2007) that spin-offs in Europe have a relatively slow growth but still exist until a relatively old age. This argument was also supported by an interview with some experts. Based on this argument, a simulation was performed to defend the validity of the third group category. The simulation consisted of six steps as follows:

1. Identify the number of spin-offs in the third age category.
2. Measure the number of additional spin-offs based on two arguments, i.e. Mustar et al. (2007) and the experts' opinion. According to Mustar et al. (2007), 75% of spin-offs are still in business six years after set up. In other words, the failure rate of spin-offs is 25%. Thus, it means that the number of spin-offs in the third age category should be added by the number of failing spin-offs. Moreover, the experts from TU Delft had described that from 64 spin-offs in 2005, only 5 spin-offs failed in 2005 (failure rate of 7.81%, however, for a practical reason, it was round up to 10%). Table 1 shows the calculation.
3. Add imaginary obstacles for each additional spin-offs
4. Perform a statistical test on the differences between initial and new age category.
5. Perform a statistical test on the differences between a new age category with the first age category (1-4, 5-7)

Table 1. Number of spin-offs for simulation

	Failure rate	Spin-offs in the third age category will be added with
Total sample	25%x27= 6.75 10%x27=2.7	2,3, 6,7.
Delft	25%x21=5.25 10%x21=2.1	2, 3, 5, 6.
Trondheim	25%x6=1.5 10%x6=0.6	1, 2.

The table below shows the result of the simulation. Overall, the statistical test failed to find any significant differences between the initial third age category and the new age category. Moreover, the statistical test shows a significant result on the differences between the third age category and the first age category. Overall, the results of the simulation proved that the initial third age category was valid for the analysis of this study.

Table 2 Summary of the simulation result

Simulation	Add one financial obstacles			Add one financial obstacles and one market related obstacles		
	OIR	t-test a	t-test b	OIR	t-test a	t-test b
Total sample						
2 spin-offs	1.5	0.3	2.5*	1.7	0.5	2.1^{+}
3 spin-offs	1.4	0.4	2.4*	1.7	0.6	2.0^{+}
6 spin-offs	1.5	0.2	2.6*	1.7	0.3	2.4*
7 spin-offs	1.7	0.2	2.8*	1.8	0.2	2.1*
Delft						
2 spin-offs	1.6	0.3	2.2*	1.7	0.2	2.2^{+}
3 spin-offs	1.4	0.5	2.3*	1.8	0.3	2.2^{+}
5 spin-offs	1.6	0.5	2.5*	1.8	0.5	2.5*
6 spin-offs	1.9	0.3	2.2*	1.8	0.4	2.2*
Trondheim						
1 spin	1.8	0.6	2.4*	1.8	0.4	2.5*
2 spin	1.8	0.6	2.3*	1.8	0.4	2.2*
Add						

* significant at the 0.05 level

$^{+}$ significant at the 0.10 level

t-test a: Comparing old and new age category 3 (spin-off with $\geq$ 6 years old)

t-test b: comparing new age category with first age category (spin-off with $<$ 3 years old)

Note: The significant results clarified that there was no difference between the two age categories. On the other hand, the insignificant results of the t-test clarify that there was no difference between the two age categories

Appendix 4 Characteristics of University Spin-Offs: Resources/capabilities/strategy

A core idea in the Resource-Based View is that firms need to acquire resources in order to grow. A firm's resources consist of all assets tangible and intangible that are possessed or controlled by the firm. This study considers several factors, namely age, spin-offs' strategy, level of capability, resource deficiency, and added value support, which are all related with to the resource acquisition process. These factors are elucidated in the remaining appendix.

Age of spin-offs

In the total sample, the average age of spin-offs is 5.1 years (Table 1). Spin-offs in Delft are significantly older than spin-offs in Trondheim, witnessing an average age of 5.8 years and 4.2 years respectively. This difference may be caused by the location strategy of spin-offs in both cities. As Delft is situated in a large metropolitan area, spin-offs in Delft feel no pressure of moving to other areas to get closer to their market (customer) or production plants. Most partners can be reached by means of easy transportation. In contrast, spin-offs in Trondheim might decide to move to big cities after the first years. Cities such as Oslo or Bergen in Norway and Stockholm in Sweden are becoming a favorite destination as the market for their products may reside. In most cases, their partners are also located in other cities. In addition, table 1 shows the average age of spin-offs in the two stages. In the early stage category, the average age of spin-offs is 2.0 while in later stage is 7.2.

Table 1. Age of spin-offs

	Total sample	Delft	Trondheim	Early stage	Later stage
Mean (SD)	5.1 (3.0)	5.8 (3.0)	4.2 (2.9)	2.0 (1.1)	7.2 (1.9)
Min	1	1	1	1	5
Max	10	10	10	4	10
t-test		-2.65**		-17.13**	

*p<0.05;** p<0.01

Resource deficiency

According to RBV, the availability of critical resources is a key condition for growth whereas failing to acquire those resources may hinder growth. This study uses the number of main obstacles faced by spin-offs as an indicator for resource deficiency. Based on the previous analysis, three types of obstacles are experienced by most spin-offs. These main obstacles refer to market knowledge, managerial-related problems and financial obstacles. Table 2 shows a mean score of 0.41 in the years covered by the survey. This score means that spin-offs in the sample experience a relatively moderate number of main obstacles. Spin-offs in Delft experience fewer main obstacles compared with those in Trondheim, witnessing a score of 0.39 compared to 0.45 respectively. This finding seems not consistent with the fact that the incubator organization in Trondheim has started earlier and is better organized than that in Delft in the years covered by the survey. However, spin-offs in Trondheim may experience a high number of obstacles by nature (such as limited number of launching customers) which is almost impossible for incubators to deal with. On the other hand, the low level of obstacles incidence experienced by the spin-offs in Delft may due to a relatively large capability in solving obstacles by finding critical resources outside the incubator. Their location in metropolitan areas may increase their chance to meet different potential

resources. Further, spin-offs in the early stage experience 0.45 obstacles on average, while spin-offs in later stages experience 0.39 obstacles on average. The difference between these two stages is significant and may imply that most obstacles tend to occur in the early stage.

Table 2. Resource deficiency

	Total sample	Delft	Trondheim	Early stage	Later stage
Mean (SD)	0.41 (0.3)	0.39 (0.2)	0.45 (0.2)	0.45 (0.2)	0.39 (0.2)
t-test		1.40		1.02	

*p<0.05; **p<0.01; max: 1 and min: 0; the higher the more resource deficiency experienced by spin-offs.

Added value support

In order to grow, spin-offs often need to acquire resources. One of the sources of external resources that can be useful for spin-offs is the university incubator (incubation program). Incubators often provide accommodation as well as financial and managerial support to new ventures. Moreover, the provision of added value support (e.g. marketing and market analysis; R&D networking; business partner networking) is believed to be effective in promoting growth. The total sample shows on average a score of spin-offs of 0.24 meaning that most of them receive a relatively low level of added value support (Table 3). However, a significant difference is found concerning added value support received by spin-offs in Delft in comparison with spin-offs in Trondheim. Spin-offs in Trondheim receive added value support twice as much as those in Delft that is 0.37 versus 0.14. This finding implies that the incubators in Trondheim at the moment of survey were able to provide a relatively large variety of added value support to their spin-offs compared with the incubator in Delft. However, no significant difference is found for spin-offs in the different development stages.

Table 3. Added value support

	Total sample	Delft	Trondheim	Early stage	Later stage
Mean (SD)	0.24 (0.3)	0.14 (0.2)	0.37 (0.4)	0.22 (0.3)	0.24 (0.3)
t-test		T-test: 3.74**		T-test: -0.31	

* p<0.05; ** p<0.01; max: 1 and min: 0; the higher the more added value support received.

Level of capability

Entrepreneurship research has shown that spin-offs' capability contributes significantly to the exchange of information that may lead to new opportunities exploitation (e.g., Eisenhardt and Schoonhoven, 1996). Apparently, firms with strong capabilities have more chances to survive and grow. In this study, spin-offs' capability is measured based on two factors, i.e. single team start and previous experience of founders. It can be seen in Table 4 that the majority of the spin-offs face a low level of capability, which seems to be a common phenomenon among university spin-offs. The founders they have recently graduated from university and have had no previous experience, university spin-offs lack capabilities. In the total sample, 65% of the spin-offs have a low capability, a similar pattern is found for the four sub categories of spin-offs. The general pattern that spin-offs have a low level capability may be caused by the fact that most of spin-offs come directly from university and lack business experience.

Table 4. Level of capability

Freq (%)	Total sample	Delft	Trondheim	First stage	Second stage
Low level of capability	65 (65.0)	38 (64.4)	27 (65.9)	28 (70.0)	37 (61.7)
High level of capability	35 (35.0)	21 (35.6)	21 (35.6)	12 (30.0)	23 (38.3)
Mann-Whitney test		-0.15		-0.85	

* $p<0.05$;** $p<0.01$

Risk profile of strategy

In business, innovation is seen as a source of competitive advantage. Some spin-offs take a higher risk as they expect to become the first player in the market. These spin-offs allocate a high investment in research and development. In contrast, others prefer to adopt a risk-avoiding strategy by investing fewer resources. In this study, the risk component in strategy adopted by spin-offs is measured using two characteristics, i.e. percentage of R&D investment and type of industry. Table 5 shows that spin-offs employing a risk-taking strategy represent the largest share (61%) of spin-offs. This pattern is found to be almost similar for Delft and Trondheim. With regard to the development stages, the early stage is dominated by spin-offs with a risk-taking strategy (80%) whereas in later stages, the risk-taking strategy occurs almost as often as the risk-avoiding strategy. The high share of spin-offs with a risk-taking strategy in the early stage may be caused by the endorsement of the current policy to support the creation of more innovative spin-offs in Delft and Trondheim. In addition, the incubator organizations have become strict in defining selection criteria and targeting only innovative spin-offs. Moreover, a relatively low share of spin-offs employing a risk-taking strategy in later stages indicates that spin-offs may have changed their initial strategy and shifted to a less risky business models after some years due to difficulty in acquiring resources to grow or difficulty in accessing a market.

Table 5. Spin-offs' strategy

Frequency (%)	Total sample	Delft	Trondheim	Early stage	Later stage
Risk taking in strategy	61 (61.0)	35 (59.3)	26 (63.4)	32 (80.0)	29 (48.3)
Risk avoiding in strategy	39 (39.0)	24 (40.7)	15 (36.6)	8 (20.0)	31 (51.7)
Mann-Whitney test		-0.41		-3.17**	

*$p<0.05$;**$p<0.01$

Appendix 5 Linear Regression diagnostic

Table 1. Summary of linear regression diagnostic

Type of diagnostic	Description	Total sample Job growth	Delft	Trondheim	Early stage	Later stage
Detecting unusual and influential data	There are two types of methods for assessing outliers, i.e. statistics such as residuals, leverage, Cook's D and statistics such as DFBETA.	After checking some statistical analysis and looking on the graphical analysis, two outlier data has been removed from the sample.				
Test for normality of residuals	To check the normality, inter-quartile range (Iqr) test and Shapiro-Wilk test for normality are performed. If Iqr test shows a presence of any severe outliers, then it is suffice to reject the normality at a significance level of 5%. Mild outliers are common in samples of any size. For Shapiro-Wilk, the p-value is based on the assumption that the distribution is normal. If the p-value is large, then it cannot be rejected that r is normally distributed.	Iqr test: 4 mild outliers Shapiro-Wilk test: Z:-0.023 p-value: 0.51	Iqr test: 2 mild outliers Shapiro-Wilk test: Z:-0.043 p-value: 0.76	Iqr test: 3 mild outliers Shapiro-Wilk test: Z:-0.069 p-value: 0.64	Iqr test: 5 mild outliers Shapiro-Wilk test: Z:-0.042 p-value: 0.66	Iqr test: 3 mild outliers Shapiro-Wilk test: Z:-0.034 p-value: 0.75
Test for heteroscedasticity of residual	There are two tests for heteroscedasticity, white's test (1) and Breusch-Pagan test (2). Both test the null hypothesis that the variance of the residuals is homogenous. Therefore, if the p-value is very small, the hypothesis has to be rejected while the alternative hypothesis that the variance is not homogenous is accepted.	(1) Chi^2: 17.29 p-value: 0.03 (2) Chi^2: 09.56 p-value: 0.01	(1) Chi^2: 16.44 p-value: 0.07 (2) Chi^2: 10.01 p-value: 0.08	(1) Chi^2: 19.97 p-value: 0.02 (2) Chi^2: 11.32 p-value: 0.09	(1) Chi^2: 15.90 p-value: 0.04 (2) Chi^2: 08.36 p-value: 0.03	(1) Chi^2: 18.78 p-value: 0.04 (2) Chi^2: 07.09 p-value: 0.03
Test for multicolinearity	To check the presence of two variables that are highly correlated, this study computes the variance inflation factor (VIF). As the rule of	Mean VIF: 1.8	Mean VIF: 2.2	Mean VIF: 2.6	Mean VIF: 2.5	Mean VIF: 2.1

	thumb, a variable whose VIF values are greater than 10 may need to be excluded or need a further investigation					
Test for non-linearity	To test the presence of non-linear relationships, scatter plot between the dependent variable and the independent variables are performed.	The overall scatter plots show a relatively linear relationship between the dependent and the independent variables. However, some variables (strength of ties and spatial orientation) show a very small indication about the possibility of having a non-linear relationship.				
Test for model specification error	To test the model specification error, a regression specification error test is performed (linktest and ovtest). The test is based on the idea that if a regression is properly specified, one should not be able to find any additional independent variables that are significant except by chance. The result shows that there no significant a specification error.	F: 23.13 p-value: 0.69	F: 23.03 p-value: 0.66	F: 23.13 p-value: 0.45	F: 19.02 p-value: 0.64	F: 25.63 p-value: 0.55

Summary in English

How do social networks influence the growth of university spin-offs? To address this question, various characteristics of social networks were identified and investigated in this study. In particular, the influence of these characteristics was examined under different conditions, namely location, i.e. level of urbanization and the development stage of the spin-offs. This is because it is assumed that the diverse conditions under which spin-offs operate may cause different influences of social network profiles on growth.

The emergence of the economic crises in 2008 has prompted questions on how the economy can be stimulated. In this context, attention for the quality of social networks and beneficial (or hampering) impacts on these networks is needed in the face of a shortage of financial investment capital. In times in which financial capital is more difficult to obtain, attention paid to the benefits to be gained from social networks can be easily increased in an attempt to promote innovation and sustained growth.

Driven by the challenge to understand the influence of the above, four network characteristics on growth of university spin-offs, the following two research questions: (1) What is the growth of university spin-offs, in particular, how does the pattern of obstacles faced by university spin-offs change overtime? (2) What are the characteristics of social networks of university spin-offs, to what extent and under what conditions are characteristics of social networks beneficial for growth? are addressed in this dissertation.

Chapter 2 starts with a conceptualization of university spin-offs. There are various concepts of university spin-offs to be found in the literature. In this study, university spin-offs are conceptualized as independent technology-based firms founded by academic entrepreneurs with the objective to commercialize knowledge from a university or research center. In addition, university spin-offs are established by academic staff members, students, and graduates or by a team of academic founders. The remaining part of chapter 2 consists of an explanation of the two theoretical foundations of the study, Resource-Based View (RBV) and Social Network Theory (SNT).

According to Resource-Based Views, firms are conceptualized as a collection of productive resources, tangible and intangible, tied to the firm's management. The theory provides an understanding of how resources are connected with competitive advantages. Firms acquire or search for resources as inputs and convert these into products or services for which revenue can be obtained (Barney and Clark, 2007). Four RBV factors influencing the growth of university spin-offs are addressed in this study. These factors are the risk profile of spin-offs' strategies, level of spin-offs' capabilities, resource deficiencies experienced by spin-offs and the added value support received by spin-offs from incubator organizations.

Social Network Theory offers a way to understand how university spin-offs acquire external resources through networks. In particular, a source of advantages of firms over competitors arises from superior capability in receiving, creating and enriching knowledge in these networks. Accordingly, learning through good quality networks allows firms to gain and

accumulate the knowledge needed to thrive, and to turn it into practice. Despite a broad consensus on the importance of social networks, there is a debate concerning the quality characteristics and the mechanism through which social networks impact on growth (Moran, 2005). To clarify the importance of the profile of social networks for growth, four characteristics of social networks, namely structural and relational characteristics, heterogeneity of partners' social background and spatial orientation in the networks were dealt with in this study. Based on the Resource-Based View and Social Network Theory, several hypotheses were constructed and are presented in Chapter 3. In total nine hypotheses were formulated, some of which were developed to confirm clear and straightforward assumptions, while others, in the frame of contradictory views concerning the impact on growth of different network characteristics, were developed to reconcile or at least clarify opposing views.

The next chapters, 4 and 5, provide various preparatory steps for the analysis of social networks of university spin-offs. Chapter 4 contains the research design and methodology, including the step of selection of incubators of spin-off firms and of the study of influence of social networks on growth of spin-off firms. Chapter 5 is concerned with the procedures used for the selection of incubators from which the spin-off firms were drawn. A framework for the selection of incubators is also presented in chapter 5. To understand the factors that contribute to the growth of incubators, the incubation process is seen in this study as a function of several factors, external and internal. The external factors include major characteristics addressed in knowledge-based and institutional approaches to regional innovation, including models of stakeholders' involvement, level of urbanization of the cities involved, and uncertainty avoiding attitude among incubator managers and firms. The internal factors consist of the various qualities and strategies of incubator organizations in attracting and managing resources to support spin-offs, including the model of support provided by incubators, e.g. amount of value added support, and incubation strategies in terms of profit-making and hosting other firms that strictly spin-off firms, and age of incubators.

A combination of quantitative and qualitative data was investigated using Rough Set Analysis in the selection procedure to find factors, or a combination of factors, that can be used to clarify the differences in growth of incubators. A purposive sampling technique was used to collect data on 40 incubators. Rough Set Analysis is a non-parametric method that is able to handle a relatively diverse set of factors and to transform an imprecise or incomplete (fuzzy) collection of data into structured knowledge. Overall, the results of the Rough Set Analysis showed that the models of stakeholders' involvement and level of urbanization of the city concerned were consistently important. Therefore, these two attributes were used in the selection framework. As a result, the incubator at TU Delft, the Netherlands and the incubator at NTNU Trondheim, Norway were selected. Spin-off firms were drawn from these incubators to serve as data provides for an analysis of growth and network influence on such firms. The sample of candidate spin-off firms was carefully developed drawing on several sources, including using a snowball technique during a face to face interview with founder(s) of university spin-offs. This led to a sample of 100 university spin-off firms.

The empirical findings concerning the growth of university spin-off firms are presented in chapter 6. A new perspective on growth was found by measuring changes in obstacles to growth. In addition, growth was measured in terms of increase in employment, i.e. job growth, and expansion through business networks. In the case of spin-offs of TU Delft, a lack of marketing knowledge was most often found as an obstacle to growth, 15.8 percent of all obstacles. This was followed by lack of sales skills, 12.8 percent, and difficulty in dealing with uncertainty and lack of forecasting capability for future markets, both 11.3 percent. Financial obstacles occur less frequently in the case of TU Delft's spin-offs, i.e. 8.9 percent for lack of investment capital and 6.4 percent for lack of cash flow. In contrast, spin-offs of NTNU Trondheim experienced a lack of financial investment more often than other obstacles, 19.0 percent. Overall market-related knowledge, financial and management obstacles tend to be the most experienced obstacles among spin-offs of TU Delft and NTNU Trondheim, i.e. more than 75 percent of all obstacles.

Two analyses, cross-section and longitudinal analysis, and two indicators, namely the obstacle incidence rate (OIR) and the obstacle reduction rate (ORR) are introduced to measure changes in obstacles. The most dominant obstacles for TU Delft's spin-offs are market-related knowledge obstacles, with an OIR of 1.20, followed by financial obstacles, with an OIR of 0.87, and management obstacles, with an OIR of 0.40. This situation is slightly different with NTNU Trondheim's spin-offs in which all the main obstacles occur at a relatively high frequency among the youngest spin-offs. The most frequently experienced obstacles were financial obstacles, with an OIR of 1.00, followed by market-related obstacles, with an OIR of 0.89, and management obstacles, with an OIR of 0.84.

In the case of TU Delft's spin-offs, management obstacles face the lowest reduction rate (ORR) as they got older, whereas financial obstacles decrease relatively strongly, followed by market-related knowledge. In contrast, all obstacles decrease relatively strongly among spin-offs of NTNU Trondheim. The longitudinal analysis shows that the numbers of obstacles experienced by spin-offs in Trondheim tends to be higher than those in Delft in the first years. In year five the number of obstacles starts to decline in both places. Overall, spin-offs of NTNU Trondheim although experiencing more obstacles in the beginning tend to have a stronger capability to solve obstacles compared with spin-offs of TU Delft. This difference is supported by the fact that spin-offs in Trondheim grow more strongly in the high job growth category (>2fte) than those in Delft. In general spin-offs in Delft and Trondheim have relatively moderate job growth, with an average annual job growth of 0.86 fte. In contrast, strong growth in business networks tends to be experienced by spin-offs in both cities. The analysis provided ground to break down the sample into two meaningful groups for further analysis, that is spin-offs younger than five years and spin-offs of five years and older, i.e. early and later development stage.

A descriptive analysis of social network profiles in the two selected cities and in the two development stages of spin-offs is presented first in chapter 7. Then, an explanatory analysis of the influence of social network characteristics on growth of university spin-offs is presented. Spin-offs in Delft typically face loose networks, strong relationships, and a relatively strong external orientation, i.e. beyond the region. In contrast, spin-offs in

Trondheim typically face tight networks, weak relationships and a weaker external orientation. Spin-offs in the early stage are characterized by tight networks, partners with a homogeneous background and weak(er) external orientations. Spin-offs in later stages have loose networks, partners with a heterogeneous background and strong(er) external orientations.

Furthermore, various regression models on growth were investigated using OLS and Logistic Regression Analysis including a stepwise approach. The focus of analysis was on the total sample and a breakdown of this sample into categories based on different location, i.e. level of urbanization, and on the different development stages of spin-offs. In addition, the interaction effects and curvilinear relationships of social network characteristics were explored. Overall, the following trends were observed:

- supported by all models, heterogeneity in partners' background has a positive influence on growth. Apparently, interaction with partners from diverse backgrounds provides benefits for spin-offs such as enrichment of perceptions and access to a wider range of resources.
- supported by all models, resource deficiency and tightness of networks have a negative influence on growth. Failing to acquire critical resources may hamper growth. Similarly, interacting with partners in tight networks is not likely to enhance grow.
- loose networks and weak ties, and an external orientation have a positive influence on growth of spin-offs in Delft. In contrast, strong ties have a positive influence on spin-offs in Trondheim. These findings suggest that location may determine the characteristics of valuable networks.
- loose networks, weak ties, and an external orientation have a positive influence on growth of spin-offs in later stages while only interaction with heterogeneous partners has a positive influence on growth in the early stage. This finding indicates the dynamics of networks in the early stage, networks are not well established and therefore, their influence on growth is limited.
- age of spin-offs has a moderating influence on the relationship between tightness of networks and growth and between external orientation and growth, while location and level of capability have a moderating influence on the relationship between strength of ties and growth and between external orientation and growth.
- the relationships of tightness of networks and heterogeneous partners with growth can be approximated with a linear model. The relationships of strength of ties and external orientation with growth have some weak non-linear features. The last would mean to a limited extent that both strong and weak relationships may positively influence growth, and the same situation seems true for both local and non-local orientation.

The key findings of hypothesis testing are summarized in chapter 8. Overall, this study makes various contributions to the existing body of knowledge and to policy practice, for example, concerning obstacles to growth and concerning the characteristics of social networks and their influence on growth. With regard to the obstacles to growth faced by spin-off firms, the

results suggest that when spin-offs enter year five obstacles preventing growth start to decrease substantially and thresholds of entrepreneurial commitment and credibility may be passed. With regard to the characteristics of social networks, the results of his study demonstrate that social networks may vary in profile according to different conditions, in this case, location in different cities and different development stages of spin-offs. In addition, the influence of social networks on growth also varies with these conditions. The contribution of this research to policy practice resides in the 'proof of importance' of *quality* aspects of social networks and in calling for attention to be paid to aspects both among entrepreneurs and among managers of incubators. Despite the interesting results achieved in this study, it is acknowledged that there are some limitations that point to important avenues for future research. These limitations center on measurement issues, particularly measurement of the risk profile of spin-offs' strategy; the small number of observations made prevented the use of extensive regression models thereby forcing the exclusion of variables like the content of knowledge and entrepreneurial network strategy of spin-offs leading to a lack of attention being paid to capturing the dynamic relationships between social networks and growth.

Summary in Dutch / Samenvatting in het Nederlands

Sinds enkele jaren staat kennisvalorisatie hoog in het vaandel bij universiteiten in Europa; dit mede in het kader van beleid gebaseerd op de Lissabon-doelstelling. Kennisvalorisatie is letterlijk het toevoegen van waarde aan nieuwe kennis door het omzetten van deze kennis in een nieuw product, proces of methode geschikt voor de markt of voor maatschappelijke toepassing. Er zijn vele vormen van kennisvalorisatie vanuit de universiteit, zoals contractonderzoek door de universiteit in opdracht van bedrijven, het in licentie uitgeven van beschermde kennis aan bedrijven, het publiceren van praktische onderzoeksresultaten in een commercieel boek, het doorontwikkelen van nieuwe kennis door universitaire spin-off bedrijven, etc. Deze studie betreft de laatste vorm van kennisvalorisatie.

Jonge hightech bedrijven hebben vaak een tekort aan resources. Dit geldt in het bijzonder voor universitaire spin-off bedrijven. In dit verband worden netwerkcontacten vaak gezien als een bron van resources en hierdoor van concurrentievoordeel. In de eerste jaren van spin-off bedrijven gaat het dan veelal om sociale netwerken, dus netwerken die voortborduren op het recente verleden zoals collega-studenten, familie en vrienden maar ook zakelijke netwerken die een belangrijke sociale component hebben. Over de voordelen van sociale netwerken, bijvoorbeeld in kennisuitwisseling, is veel theorie te vinden, maar deze is soms tegenstrijdig over de richting van de invloed van bepaalde netwerkkenmerken. Voor- en nadelen van bepaalde netwerkkenmerken zijn echter nauwelijks empirisch aangetoond.

“Op welke wijze beïnvloeden sociale netwerken de groei van universitaire spin-off bedrijven?”. Om deze vraag te kunnen beantwoorden, zijn verschillende kwaliteitskenmerken van sociale netwerken opgespoord en onderzocht in deze studie. Hiernaast is de invloed van sociale netwerken op de groei nagegaan onder diverse omstandigheden, namelijk een verschillende stedelijke ligging van de spin-off bedrijven (mate van verstedelijking) en een verschillende ontwikkelingsfase van de bedrijven zelf.

Het uitbreken van de economische crisis in 2008 heeft hiernaast de vraag urgent gemaakt op welke wijze de economie gestimuleerd kan worden. Aandacht voor sociale netwerken en het sociale kapitaal dat hiermee verbonden is, is belangrijk in een situatie waarin beschikbaarheid van privaat financieel kapitaal tekortschiet. Bij stimulering van de juiste netwerken kunnen startende hightech bedrijven gemakkelijker toegang verkrijgen tot ontbrekende resources zodat minder financieel investeringskapitaal nodig is. Hiernaast is veel economisch beleid op lokaal niveau gericht op stimulering van netwerkvorming door nabijheid, zoals in incubatoren en science parks.

Hoofdstuk 2 begint met conceptualisering van spin-off bedrijven. In deze studie worden zij gezien als zelfstandige, technologie gebaseerde bedrijven opgericht door universitaire ondernemers met het doel om kennis van universiteit (of andere kennisinstelling) te commercialiseren. Het gaat hierbij om studenten, afgestudeerden en stafleden van de universiteit. In hoofdstuk 2 wordt ook geruime aandacht besteed aan de twee theoretische perspectieven die aan de basis van de studie liggen, namelijk de ‘resource-based view’ en

'social network theory'. Aan het eerste perspectief worden in deze studie vier factoren ontleend die naast netwerken de groei van spin-off bedrijven kunnen beïnvloeden: risicoprofiel van de strategie, niveau van interne capaciteiten, gebrek aan resources en aard van ontvangen incubatiesteun (aandeel toegevoegde waarde steun gericht op capaciteiten van de ondernemers). Aan het tweede perspectief zijn vier netwerkkenmerken ontleend: open/dichte netwerken, sterke/zwakke relaties met partners, heterogeniteit in de sociale achtergrond van partners en ruimtelijke (interne/externe) oriëntatie. Netwerken worden opgevat en gemeten als egonetwerken. In Hoofdstuk 3 worden negen hypothesen op dit vlak geformuleerd.

Hoofdstuk 4 en Hoofdstuk 5 betreffen voorbereidend werk voor de eigenlijke analyse van groei van spin-off bedrijven. In Hoofdstuk 4 wordt de onderzoeksopzet en methodologie van de studie besproken, terwijl in Hoofdstuk 5 de selectieprocedure uit de doeken wordt gedaan van een tweetal incubatieorganisaties uit een pool van 40. De basis van de selectie is een schatting van factoren die een voorname invloed hebben op de groei van incubatoren. Hiertoe is 'rough set analysis', een soort kwalitatieve correlatie analyse, gebruikt en dit mondt uit in twee keuzedimensies: (1) de mate van betrokkenheid van diverse stakeholders in management van de incubator, en (2) de urbanisatiegraad van de vestigingsplaats. Op basis van relatief groot contrast op deze dimensies zijn de incubatie organisaties van TU Delft (Nederland) en NTNU Trondheim (Noorwegen) gekozen. Te samen zijn vervolgens een honderdtal spin-offs ondervraagd in een face-to-face interview.

In hoofdstuk 6 worden empirische gegevens over groei van de universitaire spin-offs besproken. Hierbij is groei ruimer opgevat dan groei in aantal arbeidplaatsen alleen. Er is tevens naar obstakels in groei gekeken en naar groei in zakelijke netwerken bijvoorbeeld door uitbesteding. Gemiddeld genomen groeien de spin-off bedrijven wat aantal banen betreft langzaam en hierbij lopen Delft en Trondheim niet ver uiteen, met een gemiddeld jaarlijkse groei van net iets minder dan 1 fte. In Trondheim zijn er echter wel wat meer snelle groeiers dan in Delft. Ook loopt het aantal obstakels dat de spin-offs in hun groei ervaren in Trondheim sneller terug dan in Delft. Het aandeel spin-offs dat een beduidende groei in zakelijke netwerken doormaakt is daarentegen weer gelijk in Delft en Trondheim.

Hoofdstuk 7 is gewijd aan een beschrijvende analyse van de sociale netwerken in de twee steden en voor twee categorieën spin-offs: die in de eerste fase en die in latere fasen. In dit opzicht kunnen vele significante verschillen worden waargenomen. Spin-offs van TU Delft hanteren open netwerken, sterke relaties en zijn sterk extern gericht (bovenregionaal). Spin-offs van NTNU Trondheim hanteren daarentegen dichte netwerken, zwakke relaties en een beperkte externe oriëntatie. Spin-offs in de eerste fase hanteren dichte netwerken, partners met een gelijksoortige sociale achtergrond en zijn meer intern georiënteerd. Spin-offs in latere fasen hanteren open netwerken, partners met een heterogene achtergrond en zijn sterke extern gerichtheid.

Verschil in netwerk profiel gaat ook gepaard met een verschil in invloed op groei. Dit is bepaald op basis van het schatten van diverse regressiemodellen. De volgende trends zijn hieruit naar voren gekomen:

- Alle modellen ondersteunen dat heterogene netwerken een positieve invloed op de groei hebben en dat dichte netwerken een negatieve invloed op de groei hebben.
- Open netwerken, zwakke relaties en een meer externe oriëntatie werken positief op groei in Delft, terwijl juist sterke relaties positief werken op groei in Trondheim. Wat dit laatste betreft zouden bepaalde tekorten in de vestigingsplaats kunnen worden gecompenseerd door specifiek netwerk gebruik.
- Open netwerken, zwakke relaties en een meer externe oriëntatie werken ook positief in latere fasen van spin-off ontwikkeling, terwijl in de eerste fase alleen heterogene netwerken positieve invloed hebben op de groei. In de eerste fase lijken de netwerken nog niet vastomlijnd te zijn want deze hebben over het geheel weinig invloed op groei.
- Interactie-effecten van bepaalde kenmerken op de invloed van netwerken op groei zijn geconstateerd voor: leeftijd, interne capaciteiten en vestigingsplaats (Delft of Trondheim).
- De relatie van de vier netwerkkenmerken met groei kan goed worden benaderd met een lineair model; hiernaast zijn zwakke aanwijzingen gevonden voor niet-lineaire eigenschappen voor sterkte van de relaties en voor externe oriëntatie.

In hoofdstuk 8 worden de resultaten besproken van de toetsing van de hypothesen. De conclusie is dat alleen bepaalde netwerkkenmerken een positief effect hebben op de groei van spin-off bedrijven en dat dit in zekere mate varieert naargelang de aard van de vestigingsplaats en fase in ontwikkeling van de spin-offs. In dit opzicht heeft de studie belangrijke nuances kunnen aanbrengen en kunnen wijzen op het belang van de kwaliteit van netwerken. Een tweede bijdrage van de studie is dat de resultaten over groei (obstakels) de tijdsdimensies in groeimodellen concreter heeft gemaakt. Met ingang van de leeftijd van vijf loopt het aantal obstakels in de groei sterk terug, hetgeen kan wijzen op het passeren van twee belangrijke drempels, namelijk die van ‘entrepreneurial committment’ en van ‘credibility’. (Vohora et al., 2004).

Wat betreft concrete aanwijzingen voor beleid en management kan het volgende worden gesteld. Op de eerste plaats zal het bewustzijn moeten toenemen over het belang van de kwaliteit van netwerken, zowel bij het management van incubatie organisaties als bij de spin-offs zelf. Wat Delft betreft, is het nastrevenswaardig om dichte netwerken, sterke relaties en een zwakke externe oriëntatie te vermijden. Hiernaast is het van belang te benadrukken dat positieve (en negatieve) effecten ook kunnen veranderen met de tijd. Een bewust netwerk management lijkt hiervoor dan ook de oplossing te zijn. Dit zou dan bij voorkeur direct vanaf de start moeten worden geïntroduceerd zodat spin-offs ook in de eerste jaren na de start van een goede samenstelling van hun netwerken kunnen profiteren. Aan dit aspect zou meer aandacht kunnen worden besteed in trainingen en in directe begeleiding van spin-offs.

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I started my PhD study with a huge ambition and great excitement, but I had no ideas about how strenuous the process would be. I experienced ups and downs. Sometimes I thought I was at the top of mountain, while at other times I found myself in the deepest valley. Many times I felt that this was too much to take and I could not go on anymore. There were also times when I questioned how other people seemed to have no problem with their study and life while I had to work hard and it was still not good enough. However, as I look back at the process, I realize that this study has become a rite of passage for me. It has changed, shaped and developed me into a different person in a positive meaning. For that, I am forever grateful, not only because I finally succeeded in completing this study but most of all for whom I have become at the end of the process. Therefore, I want to take this opportunity to thank some people who have directly and indirectly contributed to my development as a person and to the writing of this dissertation. Without their encouragement, support, and criticism, this dissertation would not be possible.

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He has made everything beautiful in its time
Ecclesiastes 3:11

About the author

Danny Prabowo Soetanto (1971) was born in Surabaya, Indonesia. After graduating from Petra 2 high school in 1987, he studied Electrical Engineering at Petra Christian University, Surabaya, Indonesia. He completed his undergraduate study in 1995 and began his career as an entrepreneur. At the same time, he worked as a teaching assistant at Petra Christian University. In 1997, he decided to commit himself to academic work by becoming lecturer at the Department of Industrial Engineering, Petra Christian University. At that time, he taught different courses such as numerical methods, computer programming and system information system. He organized an event called 'industrial engineering bazaar', one-week-event where students can learn how to become a real entrepreneur. Living in the academic environment, he became passionate of many different fields. He began to explore other areas of study, from entrepreneurship to strategic management while keeping his interest in computer programming and electrical engineering. In 1999, he got a MBA (Double degree) in International Management from University of Ista Esanta Upadhita, Surabaya, Indonesia and International Management Institute, Antwerp, Belgium. In 2000, he went to Germany with an intention to pursue a master's degree in industrial engineering. However, in the same year, he was awarded a STUNED Scholarship and chose the Netherlands as a place to pursue his further study. After obtaining his master degree in System Engineering and Policy Analysis from Delft University of Technology, the Netherlands, he decided to go back to Indonesia in 2002 and continued his teaching career. One year later, in 2003, he started to work on a PhD thesis at the Faculty of Technology, Policy and Management, Delft University of Technology. During his time at TU Delft, he also gave assistance in teaching some courses in the areas of policy analysis and regional economics. His research interest covers issues dealing with entrepreneurship, knowledge commercialization, incubator and incubation process, and social networks. He has published his researches in several conference proceedings, book chapters and journals. In his spare time, he enjoys a 'freestyle' writing and dreams of publishing his novel someday in the future.

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Honors and awards

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