Academic spin-off firms in Delft and Trondheim

How academic spin-off firms match incoming information with the resources they are lacking and how this affects their growth

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Executive summary

Academic spin-off firms tend to grow slowly which decreases the effectiveness of policies enhancing the knowledge based economy. The average growth of the 105 academic spin-off firms in this research is 1.2 fte per year, however the median is only 0.4 fte per year. In order to increase the speed at which academic spin-off firms grow, insight in what can go well and wrong needs to be obtained. This research is focussing on the match between incoming information about resources and resource deficiencies of academic spin-off firms, and the effect of this match on the firms growth. The match in this research will be defined as the response of the academic spin-off firms to resource deficiencies in terms of attracting external information about these resources. A good match would mean that the firms are acting pre-emptively, solving problems before they exist.

The main research questions which this research answers is: "***How well does the incoming information retrieved from the knowledge networks of the academic spin-off firms match with the resources they are lacking, and how does this match influence the growth***". By using common sense the following hypothesis is proposed and later tested: "***"Firms which are better at matching the incoming information from their knowledge networks with their missing resources, and thus have a higher match, grow faster"***.

This research question and hypothesis is analysed and tested by using a mixed quantitative and qualitative approach. The main part of this research is done quantitatively by using STATA®. After the quantitative results are known they are interpreted, and checked qualitatively through four in-depth interviews. These results combined generate the validated results. The dataset which is used to perform the quantitative part contains data about 105 academic spin-off firms in Delft and Trondheim. [4, p. 201].

Conclusions The trend which is found is that academic spin-off firms which are pre-emptively obtaining information about investment capital, or management skills grow faster than their counterparts which are reactive or passive. ***This conclusion also verifies the hypothesis*** and shows that firms which are better at matching the incoming information by acting pre-emptively do experience a faster growth.

Recommendations The recommendations which follow from these results are split into two categories: recommendations for the firms, and recommendations for the incubators.

The recommendations for the academic spin-off firms are as follows. ***Try to be ahead of future resource deficiencies, and solve future resource deficiencies before they emerge***. If your firm is experiencing a strong growth make sure that the management skills within the firm are developed to sustain such growth before the lack of management skills is holding the firm back.

The recommendations for the incubators are based on the recommendations to the academic spin-off firms. In order to make sure the firms act pre-emptively they need to know when to attract information. ***The incubator should therefore create an early warning system*** based upon the actual stage of development of the academic spin off firms. This stage of development should include the number of employees of the firm, the capital position of the firm, the maturity of the product the firm is selling, and the current resource deficiencies of the firm.

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1. Introduction

The introduction of this research report is structured in three parts. It will start off with the motivation and aim of the study followed by the research question. This chapter ends with an outline of the rest of this report.

1.1. Motivation and aim of this study

A lot of nowadays academic spin-off firms the Netherlands and Norway are bounded to an incubator. These incubators are funded by the government. In order to make sure this civil money is spend as effective as possible these incubators should generate a maximal return for the society. This can be done in several ways, from creating jobs, to developing new technologies to sustain and improve the way of life in the Netherlands and Norway. However there are factors that impede progress such as a low growth.

Many academic start-up firms experience resource deficiencies that slow their growth or even cause the firm to go bankrupt [1, p. 194]. This negative effect of resource deficiencies is also visible when analysing the firms in the database used in this research. While there are some fast growing firms the average growth is just above 1 fte growth per year, and the median is only 0.4 fte growth per year. This low growth is holding the firms back in achieving a maximal return to society. In order to increase the returns to society the low growth needs to be dealt with. This research does so by analysing the problem of a low growth through the use of open innovation.

There has been quite a lot of research done on open innovation in the past. However most of this research was about open innovation in settled enterprises and very little about start up companies such as the academic spin-of firms at the TU Delft. In order to fill the gap between start up and becoming a settled company this research focuses on a subgroup of the start-up firms; academic spin-off firms.
The second gap which this research tries to fill is about the type of research. Most of the re-

search done about open innovation has been done in a qualitative way while quantitative research methods haven't been applied so much. As suggested by Vrande et al this research creates a quantitative look [2, p. 436].
The third gap which this research tries to fill is to create insight into how firms match their incoming information with their resource deficiencies. Since there has been no research performed on this specific topic this research will explore a new approach to dealing with resource deficiencies.

In order to bridge these three gaps the research objective of this master thesis research is to create a quantitative insight into how well academic spin-off firms match their incoming information flows with the resources they lack, and the effect of their match on their growth. This objective is reached by conducting a quantitative comparing 105 academic spin-off firms from Delft and Trondheim. This study will use a multi factor growth model to study the influence of the match on the growth of the academic spin-off firms in terms of fte growth, and turnover. The statistical methods used for the quantitative part is OLS (ordinary least squares) regression, and generalised ordinal logistic regression [3]. More detailed information about the statistical methods can be found in chapter 3.

The match in this research is defined as the response of the academic spin-off firms to resource deficiencies in terms of attracting external information about these resources. A good match would mean that firms are solving problems before they exist, and is therefore defined as firms which are pre-emptively acquiring external information about resources. A bad match on the other hand would mean that a firm is non responsive to resource deficiencies in terms of attracting external information about this specific resource. A bad match is defined as firms which are passive to resource deficiencies in terms of acquiring external information from their knowledge networks. Firms which get the lowest matching scores possible are the firms who are experiencing severe resource deficiencies, but are neglecting them in terms of attracting external information, and are thus not having any meetings with actors in their knowledge network about

these resources.

There are four types of matches which are calculated in this research. These matches are the company wide match, and a match per resource (marketing skills, management skills, and investment capital). As a consequence of the three different knowledge domains (marketing skills, management skills, and investment capital) it is possible for a firm to get a low match for one resource and a high match for an other. The three matches per resource are independent of each other. The company wide match on the other hand is strongly correlated to each separate match. The exact formula of how the matches are calculated can be found in chapter 6.

1.2. Research question

In order to structure the research problem in a clear way the following main research question is used:

- How well does the incoming information retrieved from the knowledge networks of the academic spin-off firms match with the resources they are lacking, and how does this match influence growth?

Due to the complexity of the research problem the main research question is split up into five sub research questions. The first four sub research questions are descriptive in nature and are used to develop an understanding of the research problem. After the first four research questions have been answered the fifth will analyse the influence of the match on the growth. The five sub research questions are:

- What resources are missing, and can be seen as structurally missing?
- What content of information circulate through the knowledge networks, and are important due to the number of partners involved, and the frequency of meetings with those partners?

- To what extend does the content of incoming information match with the missing resources?
- What is the growth pattern of spin-off firms, regarding employment and turnover?
- How does the match between incoming information retrieved from the knowledge networks of the academic spin-off firms, and resource deficiencies influence the growth of the spin-off firms?

1.3. Outline

The master thesis report is divided into nine parts, starting off with the theory & concepts, and research methods. After the preliminary research has been done in the first three chapters, the fourth until the eight chapter answers the five sub research questions, followed by the verification of the results in chapter 9, and the answer to the main research question in chapter 10.

1. The first part (chapter 2), theory and concepts, explains the theories and concepts which is later on used in this research.
2. The second part (chapter 3), research methods, is about the statistical methods used, and which assumptions have to be met for the statistical tests to give valid results.
3. The third part (chapter 4), resources that are missing among the academic spin-off firms, is the descriptive analysis of which resources the academic spin-off firms lack. It also shows what resources are structurally missing, and ends with a conclusion which answers the first sub research question.
4. The fourth part (chapter 5), the contents of information that circulate through the knowledge networks of the academic spin-off firms, is the descriptive analysis of which information is externally attracted by the firms. The conclusion of this chapter consists of the answer to the second sub research question.

5. The fifth part (chapter 6), the match between the incoming information and lacking resources, is the analysis of how well firms match their incoming information with the resources they lack. The conclusion of this chapter consists of the answer to the third sub research question.

6. The sixth part (chapter 7), the growth pattern of spin-off firms, regarding employment and turnover, is the analysis of how quick the firms in the database grow. The conclusion of this chapter consists of the answer to the fourth sub research question.

7. The seventh part (chapter 8), the influence of the match on the growth of the firms, is the analysis of the the effect of the match on the growth. The analysis is performed by using a multi factor growth model. At the end of this chapter the fifth sub research question is answered.

8. The eight part (chapter 9), validation and discussion, validates the quantitative results with the qualitative results of the interviews, and discusses these results.

9. The ninth part (chapter 10), conclusion and recommendation, gives the answer to the main research question, and reflects on the research and future directions.

2. Theory and Concepts

This chapter discusses the theories and concepts on which this research is based. It starts off with the two main theories used in this research: the resource based view theory of Jay Barney [5], and the theory of dynamic capabilities of David J. Teece [6]. After these two theories have been discussed this chapter discusses the concepts which are used in this research. There are four concepts used, these four concepts are: open innovation, interorganizational learning, network externalities, and bounded rationality. After the theories and concepts have been discussed, the conceptual model and hypothesis are introduced at the end of this chapter.

2.1. Theory

Resource based view and dynamic capability The resource based view analyzes the strengths of the firms through the resources they posses [5]. These resources can be split up into three categories: physical capital resources, human capital resources, and organisational capital resources [5, p. 101]. Since this research is about how well academic spin-off firms match their incoming information with the resources they lack, this research focuses mainly on the human capital resources [7] as cited in [5, p. 101]. Becker described the human capital resource as "the training, experience, judgement, intelligence, relationships, and insight in individual managers and workers in a firm" [7] as cited in [5, p. 101]. In order to properly investigate the human capital resource through the match, the match is devised to identify the dynamic capabilities of a firm as devised by David J. Teece [6, p. 516]. Dynamic capability is the capability of a firm to spot changes in the dynamic environment in which it operates, and change accordingly [8, p. 2]. The match only looks at a specific part of the dynamic capability of the academic spin-off firms. It investigates the ability of firms to use their knowledge networks for three resources, and analyzes their timing. Due to the limitations of the database only the three most common resource deficiencies are included in this research [1, p. 195]: marketing skills, management skills, and investment capital. This research will focus on these three resources because they are common resource deficiencies of academic spin-off firms. The result of the match is an indicator of the

dynamic capability of the firms which is measured on an ordinal scale ranging from bad to good:

- Bad dynamic capability: the firm is passive and does not use its knowledge networks to solve its resource deficiency.
- Average dynamic capability: the firm is reactive and only uses its knowledge network when a resource deficiency occurs.
- Good dynamic capability: the firm is pre-emptive and uses its knowledge network before a resource deficiency occurs.

Not all academic spin-off firms posses the same human capital resources. Some founders and employees have larger networks, posses a better judgement, and or have more experience. This difference in the skills of the founders, and employees shows through the the dynamic capabilities of the academic spin-off firms. During this research the dynamic capabilities of the academic spin-off firms is approached as an indicator for the human capital resources the firms posses. Because of the differences in human capital certain firms obtain a competitive advantage or even a sustained competitive advantage [5, p. 106]. This advantage will show through their growth, which is analysed in the multi factor growth model in chapter 8.

Open innovation This research uses the term open innovation to explain how the externally attracted information is obtained. This research uses the comparison to open innovation to explain how the academic spin-off firms obtain their externally attracted information. Chesbrough defined innovation as "invention implemented and taken to the market" [9, p. ix]. Innovation can be split into two kinds; open, and closed innovation. Closed innovation is considered the old way of innovating in a firms private R&D lab, not sharing the research with others. In our case this would mean the learn-by-doing approach of solving a lack of marketing skills, management skills, and investment capital. Open innovation on the other hand means innovating with other actors [9]. This research will focus on the latter, solving resource deficiencies with other actors.

Interorganizational learning As described in the previous paragraph this research focuses on learning process of firms which are pro-actively learning in groups or pairs by using their knowledge networks. This type of learning is called interorganizational learning [10, p. 435]. It is not necessary that two firms are looking for the same, they could be helping each other solve their individual problems. In this research the concept of interorganizational learning is used to define the learning process of academic spin-off firms through meetings with other actors of each firm individually.

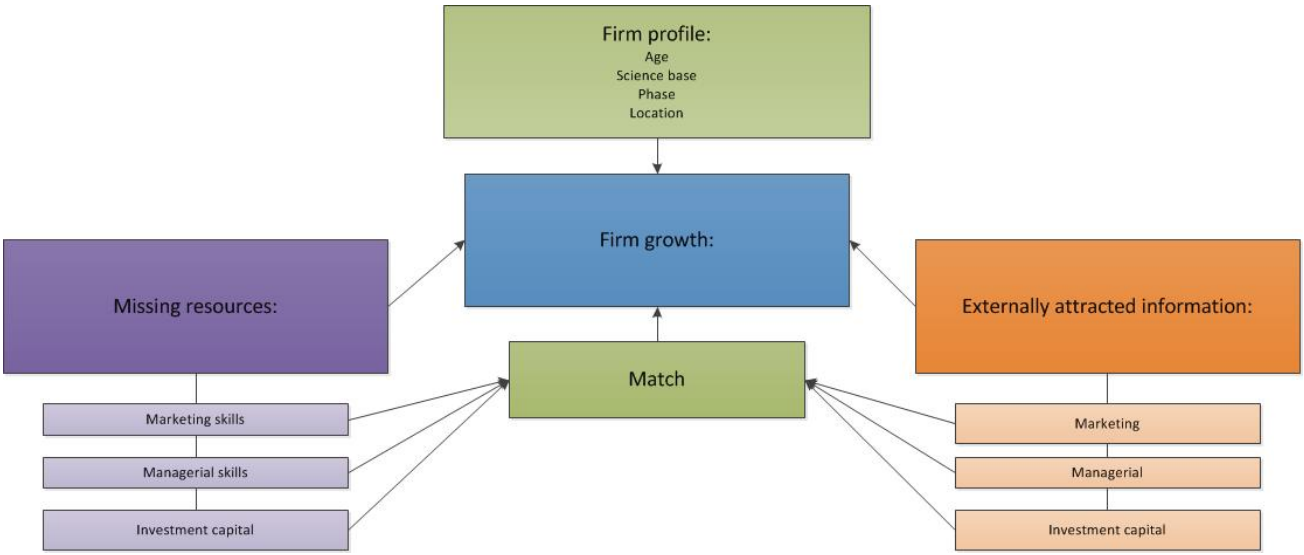
Bounded rationality This research assumes that the academic spin-off firms are making rational decisions. However due to cognitive limitations of the owners, and employees of the firm it is impossible to know every alternative and every consequence of those alternatives. It is therefore impossible to chose the best alternative possible by using a maximization strategy. The concept of bounded rationality therefore assumes that instead of exploring all alternatives, and choosing the best alternative, an alternative that fits the requirements is chosen (satisficing [11, p. 590] in stead of maximising strategy). The chosen solution is therefore not the best solution but a solution which satisfies the (minimum) requirements [11]. In this research the assumption is made that the academic spin-off firms make bounded rational decisions.

Network externalities Network externalities are effects that are not directly linked to to a product, partner, etc, but which you do indirectly experience. A good example is cell phone use, if no one uses a cell phone you can still buy one but it is not valuable since you can not use it. However if everyone uses a cell phone the cell phone becomes very useful [12]. The same happens with the academic spin-off firms in this research. A firms might be looking for one content of information but by learning about the first content they increase their network which might help solve future resource deficiencies, or even prevent them from occurring.

2.2. Conceptual model

The above theories, and the research question as stated in section 1, form the base of the conceptual model. The goal of this research is to analyse how well firms match the incoming information with the resource deficiencies they lack, and how this influences the growth. In order to do so the concept of a match as described in the introduction, and in more detail in chapter 6 is used in the conceptual model as independent variable. There are four different matches which are based on: the incoming information the firm obtains, and resources the firms lack. These four matches are focussed at determining the dynamic capabilities per resource per firm, and company wide per firm.

Figure 1: Conceptual model



Both the match between the incoming information, and missing resources, and the controlling variables are used as independent variables in the multi factor growth model in chapter 8 to show the tend between the match and the growth of the firms.

2.3. Hypothesis

When applying common-sense to the research question (How well does the incoming information retrieved from the knowledge networks of the academic spin-off firms match with the resources

they are lacking, and how does this match influence growth?) it seems logic that a firm which is putting more effort in solving resource deficiencies by using its network perform better. Therefore the following hypothesis is proposed:

- Firms which are better at matching the incoming information from their knowledge networks with their missing resources, and thus have a higher match, grow faster.

3. Research methods

This research consists of two parts, the main research which is quantitative, and the validation which is qualitative. This chapter is structured to start with the main research and its methods, followed by the validation. The first part explains the quantitative methods, their assumptions, and in some cases the consequences of failing to meet those assumptions. The second part explains how the qualitative part has been performed, it explains how the firms were selected, how the interviews were performed, and which questions were asked during these interviews.

3.1. Quantitative part

The database used for the quantitative study is obtained by D. P. Soetanto, and M. van Geenhuizen [4, p. 201] through interviews in 2006, and later on in 2011 to measure growth. All firms in the database are academic spin-off firms from either the TU Delft (Delft, the Netherlands) or the NTNU (Trondheim, Norway). The database used consist of 105 firms. All 105 academic spin-off firms were specially picked because their level of innovation, and entrepreneurship is comparable to that of other countries in Europe such as Denmark, and Scotland. Because the database consists of these carefully selected academic spin-off firms, and is sufficiently large, the results of this research are generalisable for a larger group of academic spin-off firms.

The independent matching and controlling variables, and the dependent growth variables of conceptual model as explained in chapter 2 obtained from the database. The matches are combinations of three types of resource deficiencies, and contents of information which were obtained through meetings which the academic spin-off firms had with their knowledge networks:

- Marketing match
  - Resource deficiency: Lack of marketing knowledge
  - Content of information from the meetings: Information or contact about new market/ customer

- Management match
  - Resource deficiency: Too many managerial tasks to handle
  - Content of information from the meetings: Managerial advice in managing the new firm
- Investment capital match
  - Resource deficiency: Lack of investment capital including R&D investment
  - Content of information from the meetings: Financial related information (e.g. loan, venture capital etc.)

In order to control for other influences other than the match six controlling variables are used. These controlling variables consist of the age, science base, phase, and location of the academic spin-off firm, missing resources, and externally attracted information. In this research the first four controlling variables will be referred to as the firm profile. In order to obtain the firm profile, the following questions are asked:

- What was the age of the firm in 2006?
- Was the firm a science, or non-science based firm in 2006?
- Was the firm in the exploration or exploitation phase in 2006?
- Is the firm based in Trondheim or Delft?

The number of lacking resources and number of contents of externally attracted information is determined by counting the number of resources the firm has lacked before 2006, and the number of contents of incoming information the firm has obtained before 2006. In order to ensure the generalisability of this research these values are normalised. A firm who has lacked all resources before 2006 gets a value of one for missing resources, and a firm who has obtained all contents of information before 2006 gets a value of one for externally attracted information. Vice versa if a firm has no incoming information or lacks no resources the variable incoming information,

or missing resources get the value zero.

The growth figures of the academic spin-off firms in the database are obtained by using the growth figures of the academic spin-off firms in 2010. The growth in fte is averaged from the start until 2010, and the growth in turnover is the total turnover in 2010. These two growth figures were measured on a interval, and ordinal scale respectively. Due to the different levels of measurement of these growth scales two separate statistical methods are used.

The first type of growth, the fte growth was measured on a interval scale. Because of the interval scale of the growth in fte it is possible to use a OLS regression approach for the multi factor growth model. The multi factor growth model, as explained in chapter 2 includes the matching variables, controlling variables, and the growth variable as described in figure 1 in chapter 2. The assumptions which have been checked are: linearity, independence of variables, homoscedasticity, normality of residuals, and the exogeneity assumption. The result of checking these assumptions is that the model failed the normality of residuals assumption, and the exogeneity assumption. The first failed assumption, that of normally distributed residuals will only slightly change the results because the central limit theorem can be applied, and is therefore not an issue. The central limit theorem can be applied if the size of the database is reasonably large [13], the mean of the distribution is approximately zero, and the tail of the residual distribution is limited the central limit theorem states that normality can be assumed [14, p. 184].
The second failed assumption, that of the endogenous variable incoming information, is however a problem and therefore needs to be dealt with. In order to check the influence of endogenous variable incoming information on the beta coefficients of the matches the instrumental variable method with location as instrument is used [15].

The second type of growth, the turnover growth is measured on a ordinal scale. This means that a standard OLS regression does not work. Instead the choice was made to use an ordered logistic regression approach. However ordered logistic regression assumes the coefficients between

all ordinal categories to be the same. This assumptions, which is called the parallel regression assumption assumes that the coefficient between the group of firms with no turnover versus the group with turnover should be the same as the coefficient between the group of firms with less than €100.000, and the group with more than €100.000 in turnover, etc. [16]. This assumption was not met, which made it necessary to use a different approach. Therefore instead of using the regular ordinal logistic regression approach the generalised ordered logistic regression approach is used [3]. Because of the strong correlation between the growth in fte, and the growth in turnover the results of the generalised ordinal logistic regression model are also tested for the influence of the endogenous variable incoming information. The influence of the endogeneity problem was tested by using the instrumental variable method with location as an instrument [15].

After both the OLS regression, and the generalised ordered logistic regression is performed the robustness of the models is tested by excluding outliers. The outliers which are excluded are: the firm with an average fte growth of more than 12 fte per year, the five firms which lack all three resources, the firm which is non responsive to a lack of resources.

An overview of all the assumptions which have been checked can be found below.

- assumptions to check for the OLS regression:
  - linearity: the relationship between the independent and dependent variables needs to be linear. This assumption is checked by making a scatter plot of the observed versus predicted values. In order to pass the linearity condition the values should be systematically distributed along the predicted diagonal.
  - independence of variables: the variables should not be dependent on each other. This is checked by performing a Spearman's rank test.
  - homoscedasticity: the variance of the errors should be constant. This is checked by performing a Breusch-Pagan test [17].

  - normality of residuals: the error distribution should be normally distributed. This is checked by performing the Shapiro-Wilk W test for normality [17].
  - exogeneity assumption: some variables might be suspected to be endogenous. In order to check whether this is the case a DWH (DurbinWuHausman) test is performed [18] as cited in [19].

- assumptions to check for the ordered logistic regression model:
  - parallel regression assumption or proportionality of odds assumption: the relationship between each of the outcome groups (in our case the controlling variables) needs to be the same [20]. This assumption is tested by using the "omodel logit" test of Rory Wolfe, and the "brant" test of Scott Long & Jeremy Freese in STATA [3].

3.2. Qualitative part and validation

In order to create a qualitative insight into the experience of the academic-spin-off firms to verify the quantitative results four interviews were conducted. The firms which are selected for the interviews are selected for maximal generalisability while keeping practical issues, such as travel distance in mind. In order for the travel time to be doable only academic spin-off firms which started in Delft were used for the interviews. Because the interviews also needed to pass the generalisability requirement the selected firms satisfy the following criteria:

- at least one firm with a strong growth
- at least one firm with a weak growth
- at least one old firm
- at least one young firm
- all the resource deficiencies needed to be covered
- all the different types of incoming information needed to be covered

After the firms were selected, and willing to participate, the interview consisted of 15 minutes of face-to-face time at their office. Since all the firms were Dutch speaking the interviews were held in Dutch. During the interview the firms would be asked eight questions. Because of the difference between the firms the time which each question takes differs from firm to firm. While some firms have something to say about management skills, other don't because of their firm size. To minimise the bias created by the questions which are asked the questions were asked in a general manner. For example instead of asking: "did your firm use external knowledge to improve the management skills" the firm would be asked "how did the management develop over the years, and why?".

The questions which the interview needed to answer are the following (note: while the interview was structured around these eight questions, they were merely used as a peg for the interview):

- Investment capital questions:
  - Is het netwerk van het bedrijf aangesproken voor informatie over investeringskapitaal? (waar krijg ik een lening, wie zijn investeerders etc.)
  - Hebben deze gesprekken resultaat gehad? (zijn er investeerders gevonden)
  - Heeft deze informatie tot een grotere groei geleid? (in aantal werknemers, omzet)
- Marketing questions:
  - Wanneer is het bedrijf begonnen met de marketing van producten, en/ of diensten?
  - Hoe is dit aangepakt? (was de kennis aanwezig in het bedrijf/ is er gebruik gemaakt van het netwerk van het bedrijf om kennis aan te trekken/ zijn er cursussen gebruik, of marketeers ingehuurd)
  - Na hoeveel jaar begon het gebruik van marketing technieken zijn vruchten af te werpen? (meer omzet, meer werknemers in dienst)
- Management questions:

- Kunt u omschrijven hoe het management van het bedrijf er uit zag in het verleden, en nu?
- Hoe is het management ontwikkeld? (leren door te doen/ informatie uit het netwerk van het bedrijf halen/ externe manager inhuren)

The last step of the qualitative part is to validate the quantitative results. The validation is done in a stepwise approach. The first step is to show, and interpret the statistical significant results. After the interpretations are known the assumptions on which the interpretations are based are explained. These assumptions are then checked in the last step with the qualitative part. The more assumptions can be verified the more likely the interpretation of the statistical results is. Also if one or more of the assumptions are falsified the interpretations are more likely to be false.

4. Resources that are missing among the academic spin-off firms

This chapter focuses on the first sub research question: "Which resources are missing and which can be seen as structurally missing?" In order to answer this sub research question the following three questions are analysed:

- How often are academic spin-off firms lacking a certain resource?
- How severe is the lack of resources?
- Do academic spin-off firms lack more than one resource at the same time?

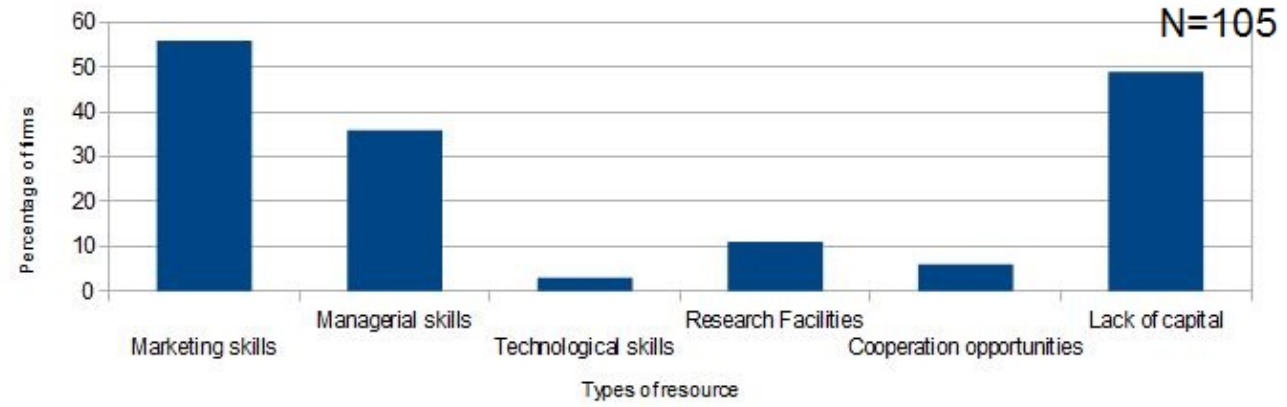
After these three questions have been analysed this section concludes with an answer on the first sub research question.

The data obtained in this section is later on used for the matching process between the incoming information, and the resources which the academic spin-off firms lack in chapter 6.

4.1. Frequency of missing resources

This subsection analyzes the initial six resources. However because three of those resources (technological skills, research facilities, cooperation opportunities) occur in only a few cases the decision is made to exclude them from the research.
The number of firms which are lacking one or more of the six initial resources (marketing skills, managerial skills, technological skills, research facilities, cooperation opportunities, and lack of capital) is analysed by asking the following dichotomous question: does the firm lack this resource? The graph below does therefore not include how severe the lacking resource is, it just shows how many firms are experiencing, or have experienced the problem before and/ or in 2006. The results are graphically depicted in figure 2. The percentages are also shown in table 1.

Figure 2: Percentage of firms missing resources



Type of resource	Percentage of firms missing the resource	N=
Marketing skills	53.3% (56 firms)	105
Managerial skills	34.3% (36 firms)	105
Technological skills	2.9% (3 firms)	105
Research facilities	10.5% (11 firms)	105
Cooperation opportunities	5.7% (6 firms)	105
Lack of Capital	46.7% (49 firms)	105

Table 1: Percentage of firms missing resources

The results clearly show that a lack of marketing, lack of managerial skills, and a lack of capital are the three resources which academic spin-off firms lack the most. This observations is also observed in the Spin-Up program [21]. The rest of this research therefore focuses on these three resources. Of the 105 academic spin-off firms 93 firms lack at least one of the three resources. The firms which are lacking more than one resource at the same time is analysed in part 4.3.

4.2. The severity of lacking resources

After knowing which resources academic spin-off firms often lack it is time to get a closer look at those resources. This subsection therefore looks at the severity of each lacking resource by examining for how many years an academic spin-off firm lacked the resource. Table 2 shows the outcomes of the severity analysis in terms of average severity, measured in the years a resource was missing, and the variance. If the resource is has a normal distribution the standard

deviation is also displayed. The details of the tests for normality can be found in appendix B. Since the average severity, and variance only include the firms which were missing the resources the number of observations per resource differ.

Type of resource	Normally distributed?	Average severity (in years missing)	Variance (standard deviation)	N=
Marketing skills	yes	3.0 years	3.1 ($\sigma = 1.8$)	56
Managerial skills	no	2.8 years	1.6	36
Lack of investment capital	no	2.1 years	1.0	49

Table 2: Severity of firms lacking resources. (NOTE: the results of the Kruskal-Wallis test show ($p < 0.01$) that the lack of marketing skills is significantly more severe than lack of investment capital, and that the lack of managerial skills is significantly more severe than lack of investment capital)

When analysing the results of table 2 lack of capital strikes out because of the low average severity. The results of the Kruskal-Wallis test show that the difference in average severity between lack of capital, and marketing is significant, and that the average severity between lack of capital, and management is significant (the detailed analysis can be found in appendix B). The lower duration of lack of investment capital can be explained in multiple ways:

- Lacking investment capital is easier to repair than a lack of marketing, or management skills.
- Lacking investment capital quickly causes bankruptcy, which causes the problem to cease existing. Also if a firm notices that it runs out of money the firm might be more eager to fix the lack of investment capital.

In order to get a better understanding of how many firms are structurally missing resources a definition of firms structurally missing resources is needed. During this research firms which are structurally missing resources are defined as firms who are lacking a resource for so long that it is unlikely to be caused by coincidence. In order to determine how many firms are experiencing resources as structurally missing this research considers resources which are lacked for longer than the average severity (as shown in table 2) to be structurally missing.

When using the above definition for structurally missing resources eighteen firms are structurally lacking marketing skills, seventeen firms are structurally lacking management skills, and thirteen firms are structurally lacking investment capital (as shown in table 3). These results are later on used to understand and interpret the results of the multi factor growth model in chapter 8.

Type of resources the firm is lacking	Number of firms lacking the resource	Number of firms structurally lacking the resource	N=
Lack of marketing skills	56	18	105
Lack of management skills	36	17	105
Lack of investment capital	49	13	105

Table 3: Number of firms structurally lacking resources, per resource

One factor which is unintentionally influencing the duration of a lacking resource is age. This is due to the simple fact that a firm can never lack a resource for a longer duration than its own age. In order to get an insight in the effect of age on lacking resources table 4 shows the frequencies of firms lacking resources sorted by the year of occurrence. Looking at table 4 it is noticeable that the amount of firms lacking resources greatly decreases when the firms grow older. This is also in line with expectations since older firms have more experience in gathering the resources. It is also imaginable that firms who lack a lot of resources have the tendency to go bankrupt, which causes a sort of natural selection procedure leaving firms who don't lack resources. A more detailed analysis of when firms lack resources can be found in appendix B.

Age of the firm	1	2	3	4	5	6	7	8	9	10	11
Number of firms which are at least the above age	105	104	88	74	69	61	47	29	26	18	14
Number of firms lacking marketing skills at the age above	44	36	24	14	6	2	2	1	0	0	0
% of firms lacking marketing skills	42%	35%	27%	19%	9%	3%	4%	4%	0%	0%	0%
Number of firms lacking management skills at the age above	26	19	15	6	2	2	3	2	2	1	0
% of firms lacking management skills	25%	18%	17%	8%	3%	3%	6%	7%	8%	6%	0%
Number of firms lacking investment capital at the age above	32	21	14	7	1	1	1	1	1	0	0
% of firms lacking investment capital	30%	20%	16%	9%	1%	2%	2%	4%	4%	0%	0%

Table 4: Occurrence of lacking resources until 2006

Comparing the data from the firms in this database with the research of M. van Geenhuizen, and D.P. Soetanto 2012 the same decreasing trend in firms lacking resources is noticeable. However in the research of M. van Geenhuizen, and D.P. Soetanto 2012 the lack of resources in the categories marketing, and management decreased a lot slower. In their research the lack of the resource categories; marketing, management, and investment capital reduced with respectively 17%, 17%, and 77% in the first four years [1, p. 195]. When using the data from table 4 the number of firms in this dataset that experience a lack of marketing skills, management skills, or investment capital are reduced in four years with respectively 55%, 67%, and 69%. Comparing reduction in firms lacking resources in this research with the research of M. van Geenhuizen, and D.P. Soetanto 2012 it is noticeable that the lack of resources decreases faster in this research. A possible explanation for this difference could be that the database of M. van Geenhuizen, and D.P. Soetanto 2012 included older firms which weren't linked to an incubator such as Yes! Delft, while most of the firms in the database used in this research are.

4.3. Combinations of resources which are lacked

The previous parts gave insight into the lack of resources the academic spin-off firms experienced and how severe these lacking resources were. There are 93 firms who lack at least one of the three resources, but how many of these firm lack more than one resource? This part analyzes which firms lack multiple resources, and give a short analysis whether lacking one resource leads to lacking another. Table 5 shows the amount of firms lacking certain combinations of resources at the same time. There are for example thee academic spin-off firms lacking both marketing skills, managerial skills, and investment capital at the same time. The table also includes the average duration of the lack of the combination of resources and the variance of the duration. Notice that a single firm can be in more than one category, the first column just shows which resources a firm lacks, it does not show whether or not the firm lacks the other resources as well (e.g: the three firms lacking all three resources are also included in the 3 combinations of just two resources.)

Types of resources which the academic spin-off firms lack at the same time	Number of firms	Average duration	Variance	N=
Marketing skills, and investment capital	21	1.9	1.1	105
Marketing skills, and managerial skills	13	1.8	1.8	105
Management skills, and investment capital	9	1.7	1.0	105
Marketing skills, managerial skills, and investment capital	3	2	3	105

Table 5: Combinations of resources which firms lack at the same time

The number of firms lacking both marketing and investment capital at the same time in table 5 looks high, while the number of firms lacking both management, and investment capital looks quite low. In order to analyse how many firms have lacked combinations of resources (not necessarily at the same time) table 6 shows which combinations of resource deficiencies firms experienced. Table 6 also includes the expected number of firms which have lacked a combination of resources, which is calculated as if the lack of resources was independent of each other. The expected number of firms is calculated by calculating the chance of a combinations happening by using the percentages from table 1 multiplied by 105, the number of firms in the database.

Types of resources which the academic spin-off firms lack	Number of firms	Expected number of firms	N=
Marketing skills, and investment capital	26	18	105
Marketing skills, and managerial skills	16	20	105
Management skills, and investment capital	11	12	105
Marketing skills, managerial skills, and investment capital	5	6	105

Table 6: Combinations of resources which firms lack

It is noticeable that there are a lot more firms who have experienced a lack of marketing skills, and investment capital than the expected number of firms. A suggestion for further research would be to investigate whether lacking one resource leads to the other or whether there is a third variable causing both the lack of marketing skills and a lack of investment capital.

4.4. The resources which are missing, and structurally missing

The answer to the sub research question: "Which resources are missing and which can be seen as structurally missing?" consists of three parts. Firstly the marketing skills, management skills, and investment capital are, due to the amount of firms lacking the resources, selected as important resources. Secondly an analysis of the severity of the lack of resources shows that marketing, and managerial skills are lacked for a significantly longer duration than a lack of investment capital. Also respectively eighteen, seventeen, and thirteen firms are structurally lacking marketing, and managerial skills, and investment capital. Thirdly when analysing which combinations of resources firms lack it is noticeable that the combination of a lack of marketing skills, and investment capital is occurring more often then expected.

Resources which the academic spin-off firms are often missing are (as discussed in section 4.1):

- Lack of marketing skills (53.3% of the firms)
- Lack of management skills (34.3% of the firms)
- Lack of investment capital (46.7% of the firms)

The three other resources; technological skills, research facilities, and cooperation opportunities were lacked by less then 11% of the firms and are therefore not included in this research.

In order to understand the severity of a resource deficiency it is important to analyse for how long a firm is lacking a certain resource. The severity is measured in the number of years a resource is missing. This definition leads to two conclusions:

- Marketing skills, and management skills are, with an average severity of approximately three years, more severely lacked by firms than investment capital, which is lacked for approximately two years
- The number of firms lacking marketing skills, management skills, or investment capital is reduced in the first four years by respectively 55%, 67%, and 69%.

In addition to the severity of each single resource the occurrence of combinations of lacking resources has also been analysed, and compared to the expected number of firms. That is the expected number of firms calculated by using the chances of occurrence of each resource deficiency as discussed above, and in section 4.1. The results of this analysis shows that the combination of a lack of marketing skills, and investment capital is occurring 26 times. Compared to the 18 times this combination was expected it is questionable whether this combination of resource deficiencies is solely caused by chance. It would be interesting to know whether this difference is caused by chance, interdependence between lacking marketing skills, and investment capital, or whether there is a third variable influencing both. However since this analysis would be outside the scope of this research it is placed under the suggestions for further research in section 10.1.

5. The contents of information that circulate through the knowledge networks of the academic spin-off firms

This chapter focuses on the second sub research question: "Which content of information circulate through the knowledge networks, and which are important due to the number of partners involved, and the frequency of meetings with those partners?" In order to answer this sub research question the following three questions is analysed:

- How many academic spin-off firms use their knowledge networks to obtain information about their resource deficiencies?
- How important is the incoming information from the academic spin-off firms knowledge networks?
- Which combinations of incoming information flows do the academic spin-off firms have?

After these three questions have been analysed this section concludes with an answer on the second sub research question.

The data obtained in this section is later on used for the matching process between the incoming information, and the resources which the academic spin-off firms lack.

5.1. Frequency of incoming information

This subsection looks at the amount of firms using their knowledge networks to obtain information about their resource deficiencies. It does so by using the following dichotomous question: does the firm have meetings in which this resource is discussed? Table 7 below shows the results of this analysis.

Content of information	Percentage of firms obtaining information from their knowledge networks	Mean nr. of meetings if a firm has meetings	Variance (st. dev.)	N=
Information or contact about new market/ customer	86.7% (91 firms)	2.9 per month	6.6 ($\sigma = 2.6$)	105
Managerial advise in managing the new firm	73.3% (77 firms)	2.6 per month	3.4 ($\sigma = 1.8$)	105
Financial related information	52.4% (55 firms)	2.3 per month	3.4 ($\sigma = 1.9$)	105

Table 7: Percentage of firms obtaining information through their knowledge network (NOTE: the results of the ANOVA test followed by a Bonferroni test ($p < 0.01$) show that there are statistically more firms obtaining information about new market or managerial advice then there are firms obtaining information about financial related information, but that there is no statistical difference in the number of firms obtaining information about new market, and the number of firms obtaining managerial advice)

When looking at the results in table 7 it strikes out that a lot of firms are actually using their networks to acquire information about resource deficiencies. Of the three types of content both information about the new market, and information about managerial advise statistically differ from the percentage of firms using their network to acquire financial related information. A more detailed statistical analysis is performed in appendix C. For each content of information more than half of the firms are obtaining information about resources, and more than 86% is obtaining information about new markets, and customers. If we compare the results of table 7 with table 1 from section 4.1 it strikes out that there are more firms obtaining information about a certain resource then there are firms who actually lack the resource. The higher amount of meetings compared to the missing resources means that firms are pre-emptively using their networks, which is further discussed in section 6.

5.2. The importance of the incoming information

This section looks at the importance of incoming information per content of information measured in terms of number of meetings with persons of low reputation per month, and the number of meetings with persons of high reputation per month. Both indicators are considered positively related to the importance of the content of information, thus the more meetings per month the

more important a certain content is, and the higher the percentage of meetings with high reputable persons the more important certain content is. The reputation of the person with who is met is a dichotomous variable, which is either 1 if the person has a high reputation, or 0 if the person has a low reputation. Furthermore a person is considered to have a high reputation if he or she is a professor at an university, or an officer at a high level of the government, or a senior executive of a firm with a high reputation, and is considered to have a low reputation if he or she is an owner of an other small business, or is family or friend.

In order to rule out multicollinearity between the number of meetings per month and the reputation of the person with who is met a multicollinearity test is performed. The result of the multicollinearity test indicates no multicollinearity. The detailled analysis can be found in appendix C.

After testing the model for multicollinearity an analysis of the amount of meetings with persons of high, and low reputation, and per content of information is performed. The analysis focuses on the same three types of content as before:

- Information or contact about new market/ customer
- Managerial advise in managing the new firm
- Financial related information

The results of the analysis are shown in table 9. Notice that the number of observations differ per content. The reason for these difference is because the analysis only looks at the firms who are having meetings about this type of content. There are for example only 91 firms who are having meetings about "information or contact about new market/ customer". When investigating the results it is noticeable that there are slightly more meetings about information or contact about new market/ customer.

Content of information	Mean nr. of meetings	Variance (st. dev.)	N=
Information or contact about new market/ customer	2.9 per month	6.6 ($\sigma = 2.6$)	91
Managerial advise in managing the new firm	2.6 per month	3.4 ($\sigma = 1.8$)	77
Financial related information	2.3 per month	3.4 ($\sigma = 1.9$)	55

Table 8: Total importance of the incoming information from the academic spin-off firms knowledge networks

Now that the importance based upon only meetings is known the analysis is extended to also include the reputation of the person with who is met. Table 9 shows the data from table 8 split into two categories: persons with high, and low reputation.

Content of information	Persons of low reputation		Persons of high reputation		N=
	Mean nr. of meetings	Variance (st. dev.)	Mean nr. of meetings	Variance (st. dev.)	
Information or contact about new market/ customer	1.4/ month	3.4 ($\sigma = 1.8$)	1.6/ month	3.8 ($\sigma = 1.9$)	91
Managerial advise in managing the new firm	1.1/ month	2.6 ($\sigma = 1.6$)	1.5/ month	2.7 ($\sigma = 1.6$)	77
Financial related information	0.9/ month	2.2 ($\sigma = 1.5$)	1.4/ month	2.6 ($\sigma = 1.6$)	55

Table 9: Importance of the three contents of incoming information divided per category of reputation (NOTE: the results of the ANOVA test show ($p < 0.05$) that there is no significant difference between the number of meetings. The detailed analysis can be found in appendix C)

Generally speaking there are statistically more firms obtaining information about marketing skills, and managerial skills, then investment capital. This result is expected since the average severity as discussed in chapter 4 shows the same trend. However when comparing the number of firms obtaining information with the number of firms lacking a certain resource it is noticeable that this ratio is about one for investment capital, while it is about 2 for both marketing skills, and management skills.

5.3. Frequency of occurring combinations of incoming information

In the previous section an analysis of the different contents of the information flows has been mapped and tested for differences. It could however be that a firm who is using its network to

search for information about one resources also looks for information about the other resources. To give insight into which combinations of content of information the firms have looked for before 2006 this subsection compares the different combinations of content of information. The results of the analysis are shown in table 10. Notice that a firm can be in more then one category. If a firm obtains information about all three types of content then it is also obtaining information about a subset of the types of content.

Combinations of content of information which the academic obtain through their knowledge networks spin-off firms	Number of firms	Expected number of firms	N=
Information about new market/ customer, and managerial advice	68	67	105
Information about new market/ customer, financial related information	49	48	105
Information about managerial advice, and financial related information	45	40	105
Information about new market/ customer, managerial advice, and financial related information	41	35	105

Table 10: Combinations of information which firms obtain through their knowledge networks

It is noticeable that quite a lot of firms obtain incoming information about new market/ customer, and managerial advice. Comparing these numbers with the expected values (which are calculated as if the information flows of the different contents of information are independent, as shown in table 7) it is noticeable that more firms then expected are obtaining combinations of information flows. One of the reasons for this effect could be the positive network externalities which occur during meetings with persons about certain contents. Figuratively speaking meeting someone creates an opening for you to tap into his or her network. A suggestion for further research would be to investigate whether obtaining information about one resource leads to obtaining information about a second resource, or whether there is a common cause.

5.4. The circulating information, and its importance

The answer to the second sub research question: "Which contents of information circulate through the knowledge networks, and which are important?" consists of two parts. Firstly

about twice as many firms are obtaining information about marketing skills, and management skills from their knowledge networks than there are firms lacking these resources. On the other hand this does not seem to count for investment capital, where this ratio is just above one. However when comparing the number of meetings per type of content no statistical differences can be observed. Generally speaking the firms tend to put more effort into obtaining information about marketing, and management skills than investment capital. Whether this focus is wise, and improves the growth of the firms, is analysed in chapter 8.

Secondly like the tendency of resource deficiencies to attract more resource deficiencies in chapter 4 the same seems to happen with obtaining information from the knowledge networks of the firms. For example when comparing the number of firms obtaining information about all three types of content it is noticeable that the actual number of firms is higher than the expected number of firms. In order to analyse whether there is some sort of suction effect working, and why it is working extra research should be performed. However since this subject is outside the scope of this research it is placed under the suggestions for further research in section 10.1.

6. The match between the incoming information and lacking resources

This chapter is focussing on the third sub research question: "To what extend does the content of incoming information match with the missing resources?" It starts off by explaining which matches are used during this research, how they are calculated, and analyse the resulting values. After the matches are explained, and the results analysed, the third sub research question is answered.

The idea behind the match making concept is to compare the firms dynamic capabilities as devised by D.J. Teece et al. [8] by investigating how passive or pro-active they handle their resource deficiencies. In order to do so this research uses two types of match:

- Diversity match which analyzes the diversity of a firms resource deficiencies and the diversity of the incoming information on a company wide level. It does so by using Harrison's method of diversity for categories [22, p. 1210].
- Ranking match which looks at how proactive or passive the firm is per resource compared to firms of the same age. The reason for comparing the firms only with those of the same age is to remove the bias caused by age. This is needed to correct for the fact that older firms have a higher chance of having experienced resource deficiencies.

This research analyzes three types of resources; marketing skills, management skills, and investment capital. In order to get a match per resource the ranking match is divided into three sub-matches; the marketing ranking match, management ranking match, and the investment capital ranking match. The following two subsections explain the working principle, calculations, and analyse the results of the diversity match, and ranking matches.

After the matches have been fully calculated the results are used in the multi factor growth model in chapter 8.

6.1. Match 1: the diversity match

This part explains, and analyzes the diversity match. In order to get a better understanding of the diversity match, this part starts off by explaining how the diversity match works. After it is explained how the diversity match works, the second part shows how the match is calculated, followed by the analysis of the results.

The diversity match analyzes how diverse the number of incoming contents of information is, and how diverse the resources the company lacks are. The diversity indicator is build to show whether the firm is pre-emptive (the firm has no resource deficiencies, but has meetings), reactive (the firm has both resource deficiencies, and meetings), or passive (the firm has only resource deficiencies). These scores give an insight in the dynamic capabilities of the firms. Due to the lack of information about when the meetings took place it is currently impossible to determine whether a firm is pre-emptive or reactive when a firm has both a lack of resource and meetings about it. Hence a suggestion for further research would be to get information about the time of the meetings. This data could then be used to split the group of firms which has both resource deficiencies, and meetings up into a pre-emptive (the meeting start before the firm lacks the resource), and reactive group (the meetings start after the firm lacks the resource).

6.1.1. Calculation of the diversity match

The diversity match is calculated on the basis of the diversity of a firm's incoming information flows with regard to the diversity of the resources it lacks. The results of the match can range from $-\frac{3}{4}$ to $\frac{3}{4}$, where $-\frac{3}{4}$ means a firm is non responsive to resource deficiencies, and $\frac{3}{4}$ means a firm is pre-emptively using their network to counter future resource deficiencies.

The match is calculated using Harrison's method of diversity for categories [22, p. 1210] for both the diversity of incoming information, and missing resources. The equation to calculate the diversity match is shown below in equation 1.

$$\text{Diversity match} = (1 - \sum {p_{information}}^2 *) - (1 - \sum {p_{resources}}^2 **) \quad (1)$$

* $p_{information}$ is the specific weight of a certain information flow, based upon the number of meetings, compared to all analysed information flows ($p_{information}$ is calculated for marketing, management, and investment capital information flows).

** $p_{resources}$ is the weight a certain resource deficiency has, based upon the number of years the resource was lacked, compared to all analysed resource deficiencies ($p_{resources}$ is calculated for marketing, management, and investment capital deficiencies).

There are however firms which lack no resources at all, which make it impossible to calculate the p value. In order to cope with the fact that some firms do not have any information flows, or resource deficiencies a fourth category (p_{added}) is inserted into the $p_{information}$, and $p_{resources}$. By inserting the fourth category the diversity match can differentiate between firms which are lacking no resources, and firms which are lacking one resource. The fourth category gets a p value which is dependent on the number of incoming information flows, or resource deficiencies. It is calculated by dividing one by the number of resources the firm lacks plus one, or the number of different contents of incoming information flows plus one.

$$p_{added} = \frac{1}{N_{\text{information or resources}} + 1} \quad (2)$$

E.g: the value of p_{added} will be $\frac{1}{1}$ if the firm lacks no resources, or has no content flow of incoming information, $\frac{1}{2}$ if the firms lacks one resource, or has one content flow of incoming information, $\frac{1}{3}$ if the firm lacks two resources, or has two content flows of incoming information, and $\frac{1}{4}$ if the firm lacks three resources, or has three content flows of incoming information.

$p_{information}$, and $p_{resources}$ are calculated by dividing the number of meetings per month/ years a resource is lacking by the the total amount of meetings/ number of years resources were missing. This value is then multiplied by one minus the added category (which is explained above in

equation 2). An example of the calculation of the p value for marketing is given below in 3.

$$p_{marketing} = \frac{marketing_{meetings}}{total_{meetings}} * (1 - p_{added}) \tag{3}$$

E.g: if a firm has 3 meetings about marketing, 1 about management, and 0 about investment capital then $p_{information}$ will be $\frac{1}{2}$, $\frac{1}{6}$, 0, and $\frac{1}{3}$ for respectively the incoming information flows of marketing, management, investment capital, and the added fourth category (p_{added}).

6.1.2. Results of the diversity match

This part gives a general analysis of the diversity matching scores of the academic spin-off firms. It starts off with a frequency table followed by a short analysis of the academic spin-off firms. The results of the general analysis of the diversity matches of the firms is showed below in table 11. Notice that there are no firms with a match in between -0.25 and -0.5, and 0.25 and 0.5. The absence of these values is due to the limited number of three categories, and the way diversity is calculated.

							N = 105
Match value	$\geq$ -0.75 $\leq$ -0.5	$\geq$ -0.25 $<$ -0.125	$\geq$ -0.125 $<$ 0	0	$>$ 0 $\leq$ 0.125	$>$ 0.125 $\leq$ 0.25	$\geq$ 0.5 $\leq$ 0.75
Dynamic capability of the firm	non responsive	very poor	poor	average	good	very good	pre-emptive
Diversity match (nr. of firms)	1	8	12	14	23	36	11

Table 11: Frequency table of occurring diversity matches. (NOTE: since there were only three categories (marketing skills, management skills, and investment capital) the diversity of either incoming information flows or missing resources can either be 0 or range between 0.5 and 0.75. The match can therefore not get a value in-between 0.25 and 0.5, and -0.25 and -0.5

When analysing the matches of the academic spin-off firms it is noticeable that there are 12 extreme cases. There is one firm who is non responsive to a lack of resources in terms of obtaining information through meetings, and there are 11 firms who are pre-emptively using meetings to obtain information about marketing skills, management skills, and investment capital. It is also interesting to know that there are only 12 firms who did not lack any resources, and that 11 of

these firms are obtaining information about one or more of the three resources (marketing skills, management skills, and investment capital).

The other 93 firms have matching values ranging from -0.25 to 0.25. A value between -0.25, and 0.25 with the exception of zero indicates a lack of one or more resources. A value of zero means there is no difference in the diversity of incoming information, and missing resources. This can be either because the firm is not lacking any resources, and is not having any meetings (this the case with one firm), or the firm is lacking resources, but is also having an equally diverse meetings (this is the case with 13 firms). The remaining 79 firms with a non-zero matching value between -0.25, and 0.25 have dynamic capabilities ranging from very poor (-0.25) to very good (0.25).

6.2. Match 2: the ranking match

This part explains, and analyzes the ranking match. In order to get a better understanding of the ranking match, this part starts off by explaining how the ranking match works. After it is explained how the ranking match works, the second part shows how the match is calculated, followed by the analysis of the results.

The ranking match analyzes how the number of meetings about a certain resource relate to the severity of the resource deficiency. Like the diversity match the ranking match is also an indicator for a firms dynamic capabilities, split up per resource. By adding this extra layer it is possible to analyse whether firms are more focused on certain resources. Since the ranking match calculates a match per resource, three sub ranking matches are calculated (one for marketing skills, management skills, and investment capital). The rank of the firm is based upon the number of meetings, as discussed in chapter 5, and the severity of the lack of a resource, as discussed in chapter 4. Because the number of years a firm can lack a resource is dependent on the number of years a firm exists (a firm can not experience a problem for a longer duration than its own age) the match needs to account for the differences in age. Therefore the firms are

only compared to firms of the same age.

6.2.1. Calculation of the ranking match

The ranking match is calculated by taking the percentage rank of the firm compared to other firms of the same age. The reason for comparing a firm only with firms of the same age is because the severity of a lacking resource varies with age. The resource deficiency ranking score is then deducted from the incoming information ranking score (meetings rank).

$$\text{(meetings rank)} - \text{(lack of resource rank)}* \tag{4}$$

* the lack of resource rank, and meetings rank are both calculated per resource resulting in three sub matches. The rank is a percentage rank compared to the other firms of the same age, with a value of 0 (0% of the firms have less resource deficiencies or meetings) to 1 (100% of the firms have less resource deficiencies or meetings)

In other words, firms with a long lasting resource deficiency (compared to the other firms) score high, and firms with none or short resource deficiencies score low. The same counts for the incoming information, more meetings means a higher score. If a firm has the most meetings about a certain resource compared to the other firms of the same age it gets the value 1, where if a firm has the least meetings it gets the value 0 (NOTE: the values in between are calculated in the same way, if 40% of the firms have more meetings that specific firm gets a ranking score of 0.6 for the incoming information). After the ranking scores for both the incoming information, and resource deficiencies are known a match is calculated per resource, per firm. The results of the ranking match can be found below in section 6.2.2.

6.2.2. Results of the ranking match

The interpretation of the ranking matches of the academic spin-off firms is comparable to that of the interpretation of the diversity match. The only difference is that the ranking match does

not show whether a firm is pre-emptive or non responsive (a score of 1 does not necessarily mean that a firm is pre-emptive, it only tells us that the firm has the most meetings and the least years of resource deficiency for that specific resource). When analysing the ranking match values in table 12 it is noticeable that the distribution of ranking values is negatively skewed. This is due to the fact that there are more firms who are having incoming information than there are firms who are experiencing resource deficiencies (if 50% of the firms do not lack a resource they all get a value of 0 since 100% of the firms experience equal or a more intense resource deficiency).

							N = 105
Match value	$\geq$ -1 $<$ -0.7	$\geq$ -0.7 $<$ -0.4	$\geq$ -0.4 $<$ -0.1	$\geq$ -0.1 $\leq$ 0.1	$>$ 0.1 $\leq$ 0.4	$>$ 0.4 $\leq$ 0.7	$>$ 0.7 $\leq$ 1
Dynamic capability of the firm	very poor	poor	below average	average	above average	good	very good
Marketing ranking match (nr. of firms)	4	10	20	25	16	13	17
Management ranking match (nr. of firms)	8	7	8	27	21	21	13
Investment capital ranking match (nr. of firms)	7	9	12	44	11	8	14

Table 12: Frequency table of occurring ranking matches per resource

6.3. The results of the match match

The answer to the third sub research question: "To what extend does the content of incoming information match with the missing resources?" is discussed in this section

Generally speaking the firms behaviour is slightly pre-emptive. As discussed in chapter 5 there are more firms which are obtaining information about resources then there are firms which are actually lacking the resource. That being said there are a quite some firms which are lacking certain resources but are neglecting these deficiencies. This could be because the firms are trying to solve the lack of a certain resource by using internal techniques such as learning by doing. On the other hand it could also be that firms are not paying (enough) attention to these resource

deficiencies. In order to determine the effect of these matches on the growth of the firms chapter 8 analyzes the effect of the diversity match, and ranking match on the growth.

7. The growth pattern of spin-off firms, regarding employment and turnover

This chapter focuses on the fourth sub research question: "What is the growth pattern of spin-off firms, regarding employment and turnover?" The growth is measured in the average fte growth per year, and the total turnover growth. In order to ensure the compatibility with other research [1] [23] the growth in fte, and turnover is measured from the start of the firms until 2010. A more detailed description of the calculation of the growth can be found in the first part (section 7.1). After the calculation of the growth has been explained this chapter continues with the growth patterns of the firms. The results of the analysis are later on used as the growth factor in the multi factor growth model in chapter 8.

7.1. The two ways of calculating the growth

In order to ensure the validity, and comparability of this research the growth of the academic spin-off firms is analysed in two separate ways:

- the average growth of the number of full time equivalent (fte) per year from the start until 2010
- the increase in turnover until 2010 measured in five different steps (ranging from no turnover to more than €500000/ year)

The first method of calculating the growth is based upon the average annual growth of fte's. The average is calculated by dividing the total fte growth from the start of the firm until 2010 by the age of the firm in 2010. The annual growth in fte's can also be negative if the firm was shrinking in size. The average growth of fte's per year is measured on a interval scale, which makes it possible to perform a multi linear regression analysis in chapter 8.

The second method of calculating the growth is based upon the increase in turnover of the firm until 2010. The growth in turnover is measured on an ordinal scale in five categories. These

categories range from cat. 1 where a firm ends up if it has no turnover in 2010, until cat. 5 where a firm ends up if its annual turnover has surpassed the €500000 mark in 2010. Since the turnover is measured on an ordinal scale linear regression is not possible, instead generalised ordered logistics regression is used.

7.2. The fte growth of the academic spin-off firms

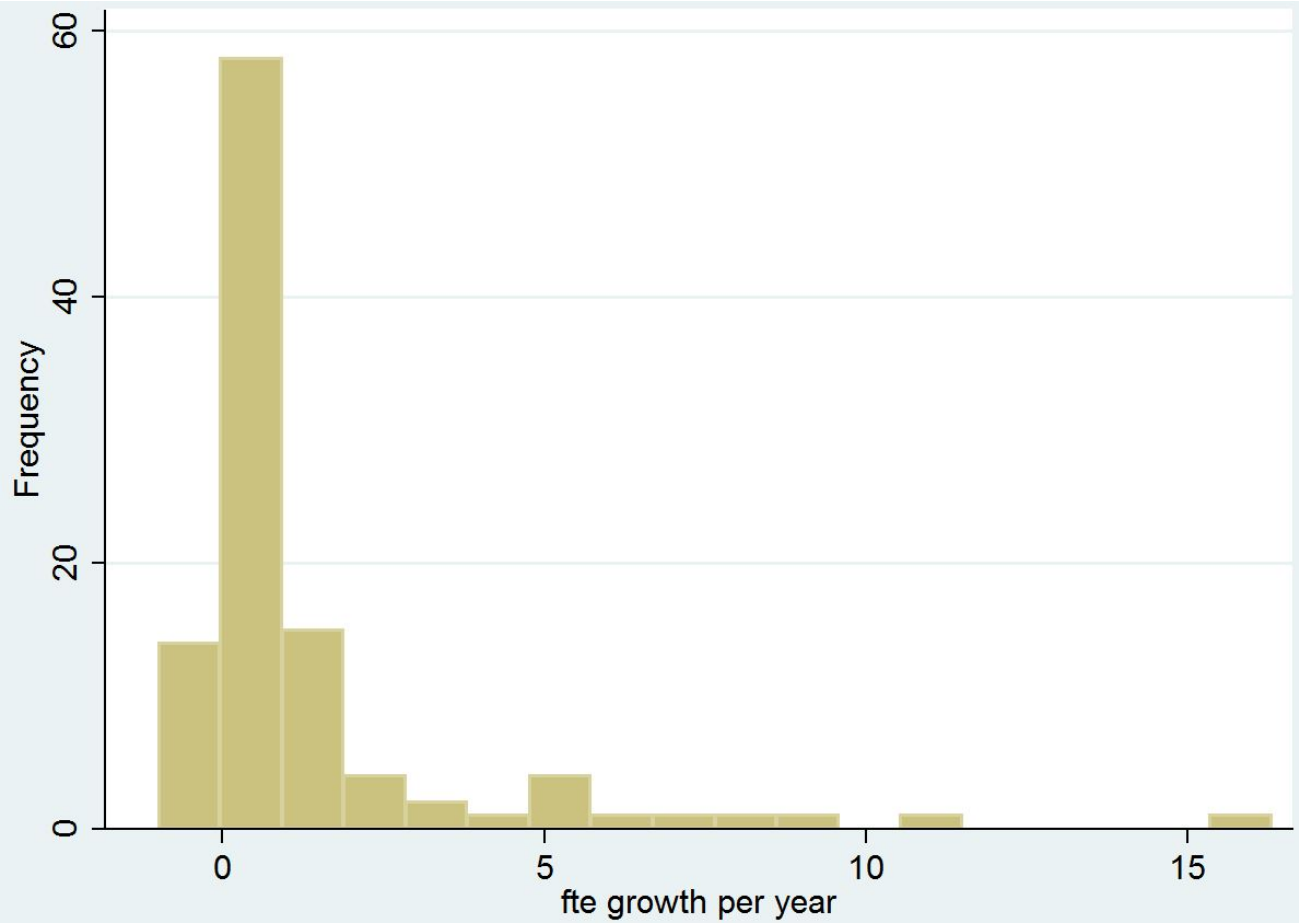
The growth figures in fte of the academic spin-off firms are shown below in table 13. In order to create insight in the growth of the firms the growth of the firms was split up into two categories; weak, and strong growth. The tipping point was chosen to be a growth of at least one fte per year because it was in between the mean growth (1.20 fte per year), and median of the growth (0.40 fte per year). At the bottom of table 13 there is also an indicator of the failing firms, and the fast growing firms. While there are a few outliers it is interesting to notice that most firms are experiencing a growth of in between 0 and 1 fte per year.

A graphical overview is also given in figure 3. The graphical overview places each firm in the closest category e.g: a firm with a growth ≥ 0, and < 1 is put in the 0.5 category. It is clear in figure 3 that the bulk of the firms grow around 0 fte growth per year. There are however nine extreme cases of firms which are growing faster than 5 fte per year, these firms are also the reason for the relatively high average of 1.20 fte growth per year.

														N = 105
Classification	Weak growth		Strong growth $\Longrightarrow$											
Annual fte growth	$\geq$ -1 $<$ 0	$\geq$ 0 $<$ 1	$\geq$ 1 $<$ 2	$\geq$ 2 $<$ 3	$\geq$ 3 $<$ 4	$\geq$ 4 $<$ 5	$\geq$ 5 $<$ 6	$\geq$ 6 $<$ 7	$\geq$ 7 $<$ 8	$\geq$ 8 $<$ 9	$\geq$ 9 $<$ 10	$\geq$ 10 $<$ 11	.	$\geq$ 16 $<$ 17
Number of firms	14	59	15	5	1	2	3	1	1	1	1	1		1
	Failing firms						Fast growing firms $\Longrightarrow$							

Table 13: Frequency table showing the annual fte growth distribution

Figure 3: Histogram showing the growth of the firms, measured in fte's



One of the disadvantages of the average fte growth per year is that a firm can (at least in theory) grow infinitely large, and thus reach an high average growth per year, while the negative growth is limited by the number of employees with which the firm starts. If a firm starts with only one person it can never get a lower average growth than -1 fte per year. This effect therefore needs to be kept in mind when the growth in fte is used in the multi factor growth model in chapter 8.

7.3. The turnover growth of the academic spin-off firms

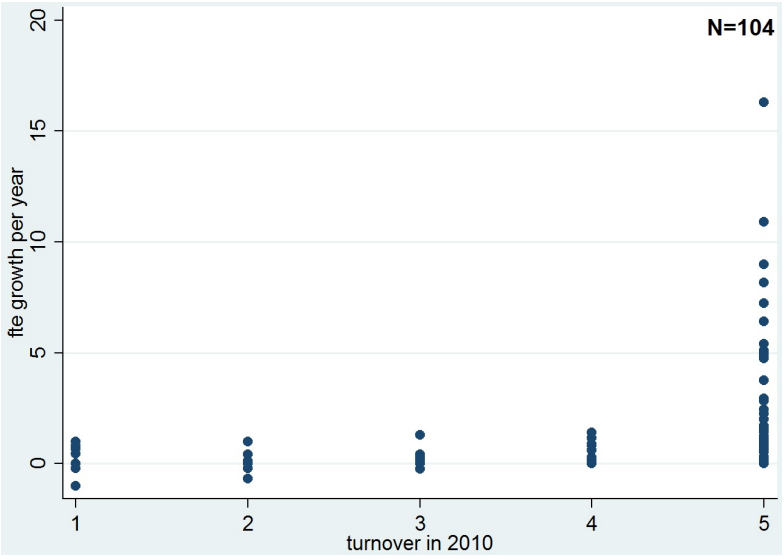
The turnover growth of the academic spin-off firms is measured on an ordinal scale with five categories. An overview of these categories and growth figures in 2010 can be found in table 14.

					N = 104
Category	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
Turnover	no turnover	$<$ €100000	$\geq$ €100000 $<$ €300000	$\geq$ €300000 $<$ €500000	$\geq$ €500000
Number of firms	16 firms	14 firms	14 firms	12 firms	48 firms

Table 14: Frequency table showing the turnover growth per category (NOTE: there was no information about turnover available for one of the original 105 firms, which is therefore not in any of the categories)

Due to the the absence of information about the turnover of one of the firms the turnover the data-sample contains 104 firms. It is interesting to see that 48 of the 104 firms are in the highest category of more than €500000 turnover per year. Because of this large amount of firms in the last category it is impossible to differentiate between them. This effect is also depicted in figure 4, where the growth in turnover is set against the growth in fte. When comparing the two growth indicators it is noticeable that firms in the last turnover category grow a lot faster than the firms in the other categories. The non-linear behaviour of the growth in turnover (shown in figure 4) might become an issue when the matches are regressed against the growth in turnover using the ordered logistic regression in chapter 8.

Figure 4: Diagram showing the growth in turnover versus the growth in fte



7.4. The growth pattern in terms of employment and turnover

The answer to the fourth sub research question: "What is the growth pattern of spin-off firms, regarding employment and turnover?" is discussed in this section

The growth pattern of the academic spin-off firms is generally showing slow growth. 59 firms experience a fte growth of in-between zero, and one fte per year, and 56 firms had a turnover of below €500.000 in 2010. Having said that the good news is that there is also a small set of fast growing firms. Nine firms are hiring people at rapid pace of above five fte's per year. Generally speaking about 70% of the firms are having trouble growing, shown by a growth of less then one fte per year. In order to analyse this problem from a match perspective chapter 8 analyzes the influence of the match on the growth.

8. The influence of the match on the growth of the firms

After chapter 6 analysed how well academic spin-off firms match their incoming information with the resources they lack, and chapter 7 analysed the growth of the firms this chapter focuses on the fifth sub research question: "How does the match between incoming information retrieved from the knowledge networks of the academic spin-off firms, and resource deficiencies influence the growth of the spin-off firms?" This chapter starts with the Spearman's rank correlation between every combination of variables to check for possible multicollinearity issues.
The second part explains the logic behind the approach of the stepwise regression. It also explains which variables are, and are not used in the final model, and why.
The third and last part analyzes the results of the final regression analysis. In this part the statistical results are presented and interpreted.
At the end of this chapter the fifth sub research question is answered. The results from this chapter are discussed in chapter 9, and are the basis for the conclusion in chapter 10.1.

8.1. Spearman's rank correlation between the variables

This subsection shows, and discusses the results of the Spearman's rank correlation. It starts off by explaining why the matches are replaced by semipartial matches [24], followed by the simplified Spearman's rank correlation matrix, and the conclusions which can be drawn from it.

When looking at the correlations in table 15 it is noticeable that the correlations of the matches is replaced by the correlation of the semipartial matches. The reason for taking the semipartial part of the matches is to avoid multicollinearity issues. As discussed in chapter 6 the match consists of mainly the lack of resources, and number of contents of externally attracted information. Due to the origin of the matches all matches were strongly correlated with both a lack of resources, and the number of contents of externally attracted information. In order to avoid measuring the effect of the lack of resources, and number of contents of externally attracted information through the matches the semipartial correlation coefficient of the matches has been

taken.

The semipartial match has been calculated by taking the residuals of the OLS regression with the match as dependent variable, and the lack of resources, and the number of contents of externally attracted information both as independent variables. This process has been performed for each match.

	Log of growth in fte	Growth in turnover	Age	Science base	Location	Lack of resources	Semipartial mar. ranking match	Semipartial man. ranking match
Growth in turnover	0.72							
Age	0.21	0.34						
Science base	0.03	-0.05	-0.27					
Location	0.26		0.28					
Phase		-0.24	**-0.60**	0.22	-0.23			
Lack of resources	-0.22							
Externally attracted information	**-0.20**	**-0.21**			-0.21			
Semipartial diversity match						0.26		
Semipartial man. ranking match							-0.39	
Semipartial inv. cap. ranking match								-0.28

Table 15: All significant Spearman's rank correlation coefficients between all variables (NOTE: while the Spearman's rank correlation of a variable with itself is 1 this is not shown in this table)

The Spearman's rank correlations which are significant on a 5% level are shown in table 15. Most of the correlations are as expected, the growth in turnover is correlated with the growth in fte, and most firm profile variables are correlated with the growth of these firms. There are however some results which are either unexpected, and\ or possibly problematic. These results are:

1. the correlation between externally attracted information and the growth in either fte or turnover is negative

2. age, and phase are strongly correlated

The first result, the negative correlation between the externally attracted information and the growth in either fte or turnover, is unexpected but can be explained in two ways.
The first explanation is that the negative correlation is due to an information overflow caused by the incoming information. In this case more information causes a bigger overflow, and thus a lower growth figure.
The second explanation is reverse causality. While we assumed the number of contents of externally attracted information to influence the growth through the possibility to solve the lack of resources it might actually be steered by the growth. When a firm is experiencing low growth (and is thus still a small firm) it might be motivated to search for ways to solve its low growth outside the academic spin-off firm. However when the academic spin-off firms start to grow its number of employees increases. This in turn creates the possibility for the firm to solve its resources deficiencies in other ways such as by learn-by-doing. The substitution effect, as described above could cause firms with a low growth figure to attract more external information, which explains the negative correlation coefficient.

The second result about the strong correlation of age, with phase is inconvenient, and might cause a multicollinearity problem when running the final model. In order to ensure the validity of the model the effect of including or excluding either of them is tested in appendix E. The results of these tests indicate that phase has almost no influence on the coefficient of determination, and is therefore left out of the model.

8.2. Approach and logic behind the multi factor growth model

This subsection explains the approach and logic behind the multi factor growth model. It starts off by explaining why, and how the growth in fte is transformed, followed by explaining why the

bidirectional elimination approach is chosen, and which logic is applied.

8.2.1. Transforming the growth

The original growth in fte was measured as an average growth from the start of the academic spin-off firm until 2010. However the limited possibility to get a negative growth figure, and the unlimited possibility to get a positive growth figure (as explained in chapter 7) creates a bias. In order to overcome this bias the difference between the lowest growth figure (-1 fte per year), and the highest growth figure (16.3 fte per year) needed to be dealt with. In other words the skewness of the distribution needed to be fixed.
A second problem with the growth figure in fte is the fact that more than half of the firms have a fte growth in-between zero, and one. This huge clump of academic spin-off firms causes the the growth in fte distribution to be leptokurtic.

In order to minimise the problems with both the skewness and kurtosis, the growth in fte was transformed by using a natural logarithmic transformation. The choice for the log base e instead of the suggested log base 10 was used to further decrease the kurtosis of the distribution [25], and [26] cited in [27]. The value of C as described by Howell [25] cited in [27], and Fidell [26] cited in [27] is determined by trial and error, and was found to reduce the skewness and kurtosis the furthest if a C-value of 1.32 was used. The final transformation used in the multi factor growth model is thus: "transformed growth" $= log($"growth in fte" $+ 1.32)$.

8.2.2. Bidirectional elimination approach

The conceptual model consists of 12 variables of which two dependent growth variables, and ten independent variables of which six are controlling variables of which four are firm profile variables. In order to determine the added value of each group of variables, and each individual variable a bidirectional elimination approach is used. The selection procedure has three phases, each starting with forward selection, followed by backward elimination.

The first phase starts by including the firm profile variables in the model (age, science base, phase, and location). Since there is a known multicollinearity problem between age, and phase both variables are separately removed to measure their individual influence on the coefficient of determination of the model. By eliminating both variables separately it became clear that the influence of the phase on the growth is almost non-existent. The choice was therefore made to exclude phase from the model.

The second phase starts by taking the three variables which are still in the model (age, science base, and location) and add the lack of resources, and number of contents of externally attracted information. First the two variables are added separate to check their individual influence on the model. After their separate influences are known both variables are added tot the model together. By adding the two variables separate it is possible to check their individual influence on the model, followed by their collective influence on the model. The results of the bidirectional approach in the second phase show that both variables improve the model, and that the low correlation between the number of contents of externally attracted information and location does not create multicollinearity issue. However when checking the number of contents of externally attracted information for endogeneity^{end} it is found to be endogenous confirming the expectations in subsection 8.1. More detailed information about the endogeneity test can be found in tables 37, 38, 39, and 40 in appendix E.

^{end} The number of contents of externally attracted information has been checked by using a DWH test, and using the location as an instrumental variable. The test was found significant on a 95% confidence interval.

After all controlling variables have been added in the first two phases the third phase consists of adding the matching variables to the model. Due to the design of the matches (which is to measure the level of dynamic capability of the academic spin-off firms in four ways: on a company level, and per type of resource) each semipartial matching variable is added separately

to the model. After the results of the regression are known a second run with only the significant control variables, and the match is performed. The detailed results of adding the matches to the model can be found in appendix E. The conclusions which can be drawn from these results are discussed below in subsection 8.3.

8.3. The results of the multi factor growth model

This subsection analyzes the results of the OLS regression, and the generalised ordered logistic regression on the multi factor growth models. This subsection starts off with the results of the OLS regression, followed by the results of the generalised ordered logistic regression. In order to focus on the important findings only the results which were significant on at least a 10% level are shown. The rest of the results can be found in appendix E, and E.

8.3.1. Results of the OLS regression

The first three OLS regressions in which the semipartial diversity, marketing, and management match were included showed no significant matching results. The last OLS regression in which the semipartial investment capital ranking match was analysed did show a significant result. This section analyzes the results of the influence of the semipartial investment capital ranking match on the growth in fte. The results of the significant OLS regression can be found below in tale 16. The non-significant OLS regressions can be found in appendix E.

	Model 1	Model 2	Model 3
	β (s.e.)	β (s.e.)	β (s.e.)
Control Variables			
Age	0.048 (0.025)*	0.046 (0.025)*	0.050 (0.025)**
Science base 0 = non science based 1 = science based firm	0.169 (0.173)	-	-
Location 0 = Trondheim 1 = Delft	0.267 (0.152)*	0.287 (0.150)*	used as an instrument[iv]
Lacking resources	-0.375 (0.289)	-	-
Ext. att. information	-0.538 (0.257)**	-0.537 (0.257)**	-3.054 (1.350)**
Matching variable			
Semipartial investment capital ranking match[spc]	0.272 (0.177)	0.304 (0.175)*	0.306 (0.179)*
N	105	105	105
F	3.76***	4.96***	4.99***
R^2	0.187	0.166	0.129
Adjusted R^2	0.138	0.132	0.113
Root MSE	0.716	0.718	0.730
NOTE	Ext. att. inf. is endogenous[end]	non nor. resid.[clt] Ext. att. inf. is endogenous[end]	non nor. resid.[clt]

Table 16: Results of the stepwise regression analysis between the semipartial investment capital ranking match (without the indirect effect of the lacking resources, and externally attracted information), and the transformed growth of the firms in fte (the growth of the firms was transformed by "transformed growth" $= log($"growth in fte" $+ 1.32)$)

* p<0.1; ** p<0.05; *** p<0.01

[spc] without the indirect effect of the lacking resources, and externally attracted information

[clt] The results of the normality tests indicate non-normal residuals. However since the sample size is reasonably large [13], the mean of the distribution is approximately zero, and the tail of the residual distribution is limited the central limit theorem states that normality can be assumed [14, p. 184].

[end] Externally attracted information has been checked by using a DWH test, and using the location as an instrumental variable. The test was found significant on a 95% confidence interval [18] as cited in [19].

[iv] Used as location as instrument on the instrumented endogenous variable incoming information

to perform the method of instrumental variable [15].

The following assumptions have been checked: linearity, collinearity, homoscadasticity, normality of residuals, and endogeneity.

Assumptions When analysing the results of the OLS regression with the transformed growth in fte as dependent variable, and controlling variables, and the semipartial investment capital ranking match as independent variables (table 16) it is noticeable that the match becomes significant after taking the science base and lack of resources out of the model. The reason for this is probably the correlation between the two variables (as shown in table 15). In order to make sure the results are valid the OLS models (1,2, and 3 in table 16) are tested for linearity, collinearity, homoscadasticity, normality of residuals, and endogeneity. These tests resulted in two failed assumptions. Firstly the Shapiro-Francia normality test [28] showed that the residuals of models 2, and 3 are not normally distributed. However since the sample size is reasonably large [13], the mean of the distribution is approximately zero, and the tail of the residual distribution is limited the central limit theorem states that normality can be assumed [14, p. 184]. The second violated assumption is that of exogeneity. Due to the results from the Spearman's rank test in table 15, and the negative beta coefficient of incoming information in table 16 the incoming information was suspected to be negatively correlated to the growth of the academic spin-off firms. In order to check whether this is the case a DWH test (Durbin-Wu-Hausman test) [18] as cited in [19], with location as instrument was performed on incoming information. The DWH test confirmed the suspicion that incoming information was indeed endogenous to the growth in fte. In order to check how this affects the results the method of instrumental variable is used to perform a 2 SLS (two stage-least-squares) [15, p. 37] in model 3. The results of the 2 SLS method are roughly the same of that of model 2, with the exception of incoming information. The small difference between the results of the beta coefficient of the semipartial capital ranking match in model 2, and model 3 in table 16 indicate that the endogeneity problem does not affect the results of the semipartial investment capital ranking match. Thus the results of the stepwise regression analysis are valid.

	Model 3.1	Model 3.2	Model 3.3
	β (s.e.)	β (s.e.)	β (s.e.)
Type of outlier	Extreme growth (fte per year > 12)	Extreme resource deficiency (lacking all resources)	Non responsive diversity match ≤ -0.5
Control Variables			
Age	0.050 (0.024)*	0.050 (0.026)*	0.052 (0.025)**
Location 0 = Trondheim 1 = Delft	used as an instrument	used as an instrument	used as an instrument
Ext. att. information	-2.813 (1.312)**	-3.148 (1.417)**	-2.851 (1.431)**
Matching variable			
Semipartial investment capital ranking match	0.242 (0.174)	0.303 (0.185)	0.261 (0.178)
N	104	100	104
F	4.36***	4.63***	4.61***
R^2	0.116	0.127	0.122
Adjusted R^2	0.089	0.010	0.095
Root MSE	0.730	0.747	0.722

Table 17: Results of the robustness check for IV 2 SLS regression between the semipartial investment capital ranking match, and the transformed growth in fte

* p<0.1; ** p<0.05; *** p<0.01

Robustness The robustness of model 3 in table 16 is being checked by analysing the influence of outliers on the results. There are three types of outliers which are excluded from the model, the firm with an enormous growth of more than 12 fte per year on average, the firms who lack all resources at the same time, and the non responsive firm from table 11 in chapter 6. The results of the robustness test of model 3 are shown above in table 17. These results indicates that the model is strongly dependent on the fast growing firms, and the non responsive firm. However since the firm who appears non responsive also has a huge fte growth of more than 7 fte per year it seems like the model is mostly sensitive to the elimination of fast growing firms. Eliminating just one firm with a large grow decreases the beta coefficient of the semipartial investment capital ranking match with around 15-20%. On the other hand eliminating firms who lack all three resources has almost no influence.

Results The significant positive beta coefficient of the semipartial investment capital ranking match suggest that being pre-emptive in stead of passive in matching incoming information with a lack of resources positively influences the growth. This trend was expected in the hypothesis in chapter 2.3. In order to validate these quantitative findings they are compared to qualitative data in chapter 9.

8.3.2. Results of the generalised ordered logistic regression

Of the four generalised ordered logistic regressions only two regressions showed significant results. These regressions are the ones in which the semipartial marketing ranking match, and the semipartial management ranking match are compared to the growth of the academic spin-off firms in turnover. This section therefore only analyzes the results of the semipartial marketing ranking match, and the semipartial management ranking match. The results of the other two matches can be found in appendix E.

	Model 1	Model 2	Model 3
	β (s.e.)	β (s.e.)	β (s.e.)
Control Variables			
Age	0.195 (0.074)***	0.195 (0.067)***	0.198 (0.068)***
Science base 0 = non science based 1 = science based	-0.155 (0.483)	-	-
Location 0 = Trondheim 1 = Delft	β^1 = 0.430 (0.680) β^2 = 0.953 (0.553)* β^3 = 0.804 (0.515) β^4 = -0.833 (0.528)	-	used as an instrument^{iv}
lacking resources	β^1 = 1.130 (1.480) β^2 = 0.232 (1.038) β^3 = 1.195 (1.060) β^4 = -2.245 (1.086)**	-0.834 (0.759)	-0.722 (0.754)
Ext. att. information	β^1 = -3.079 (1.412)** β^2 = -2.595 (1.012)** β^3 = -2.855 (0.951)*** β^4 = 0.640 (0.950)	-1.13 (0.698)	-2.42 (3.844)
Matching variable			
Semipartial marketing ranking match^{spc}	β^1 = -2.036 (0.944)** β^2 = -1.204 (0.684)* β^3 = -1.482 (0.678)** β^4 = 1.765 (0.673)***	β^1 = -1.525 (0.753)** β^2 = -0.859 (0.579) β^3 = -0.797 (0.563) β^1 = 0.876 (0.554)	-2.226 (3.530)
N	104	104	104
LR Chi2	55.33***	28.59***	26.28***
Pseudo R^2	0.186	0.096	0.088
NOTE	failed to satisfy the parallel regression assumption^{par} Ext. att. inf. is endogenous^{end}	failed to satisfy the parallel regression assumption^{par} Ext. att. inf. is endogenous^{end}	failed to satisfy the parallel regression assumption^{par}

Table 18: Results of the stepwise ordered logistic regression analysis of the semipartial marketing ranking match versus the growth of the firms in turnover (NOTE: due to the small size of only 14 firms in turnover category 1 & 2 the first two β coefficients are unreliable)

	Model 4	Model 5	Model 6
	β (s.e.)	β (s.e.)	β (s.e.)
Control Variables			
Age	0.188 (0.073)**	0.201 (0.071)***	β^1 = 0.201 (0.071)***
Science base 0 = non science based 1 = science based	-0.067 (0.461)	-	-
Location 0 = Trondheim 1 = Delft	β^1 = 1.131 (0.696) β^2 = 0.974 (0.502)* β^3 = 1.050 (0.509)** β^4 = -0.568 (0.510)	β^1 = 1.328 (0.687)* β^2 = 1.094 (0.494)** β^3 = 1.146 (0.502)** β^4 = -0.432 (0.497)	used as an instrument^{iv}
lacking resources	-0.839 (0.795)	-	-
Ext. att. information	-1.098 (0.727)	-	β^1 = -11.911 (6.157)* β^2 = -9.811 (4.426)** β^3 = -10.273 (4.506)** β^4 = 3.875 (3.246)
Matching variable			
Semipartial management ranking match^{spc}	β^1 = -0.019 (0.767) β^2 = 0.989 (0.719) β^3 = 2.250 (0.946)** β^4 = -2.769 (0.809)***	β^1 = 0.084 (0.771) β^2 = 1.129 (0.725) β^3 = 2.262 (0.929)** β^4 = -2.667 (0.775)***	β^1 = 0.084 (0.771) β^2 = 1.129 (0.725) β^3 = 2.262 (0.929)** β^4 = -2.667 (0.775)***
N	104	104	104
LR Chi2	59.11***	55.70***	55.70***
Pseudo R^2	0.198	0.187	0.187
NOTE	failed to satisfy the parallel regression assumption^{par} Ext. att. inf. is endogenous^{end}	failed to satisfy the parallel regression assumption^{par} Ext. att. inf. is endogenous^{end}	failed to satisfy the parallel regression assumption^{par}

Table 19: Results of the stepwise ordered logistic regression analysis of the semipartial management ranking match versus the growth of the firms in turnover. (NOTE: due to the small size of only 14 firms in turnover category 1 & 2 the first two β coefficients are unreliable)

* p<0.1; ** p<0.05; *** p<0.01

^{spc} without the indirect effect of the lacking resources, and externally attracted information

^{par} Due to failing to satisfy the parallel regression assumption a generalized ordered logistics regression has been used [3]

^{end} Externally attracted information has been checked by using a DWH test, and using the location as an instrumental variable. The test was found significant on a 95% confidence interval [19]. ^{iv} Used as an instrument on the instrumented endogenous variable incoming information to perform the method of instrumental variable [15].

The empty cell issue has been checked by using cross tabulation, and the parallel regression assumption has been checked by using the "omodel logit" test of Rory Wolfe [3], and the "brant" test of Scott Long & Jeremy Freese [3].

Assumptions During the ordinal logistic regression the significant matching variables did not pass the parallel regression assumption [3]. Also the number of turnover categories caused an empty cell issue. Due to the violation of the empty cell, and parallel regression assumption the ordered logistic regression could no longer be used. In order to solve both the parallel regression assumption, and the empty cell issue a generalised ordered logistic regression [3] is performed. This approach uses a series of binary logistic regressions to split up the ordinal variable [3, p. 63]. Since the growth in turnover consists of five values the generalised ordered logistic regression splits the data four times into two different groups. Each different splitting point is then used to cut the group of firms in two, run a binary logistic regression, and generate a beta coefficient. The four beta coefficients represent the following splitting points:

1. β^1 is calculated by comparing the firms with no turnover with the firms with turnover
2. β^2 is calculated by comparing the firms with less than €100.000 in turnover with the firms with more than €100.000 in turnover
3. β^3 is calculated by comparing the firms with less than €300.000 in turnover with the firms with more than €300.000 in turnover

4. β^4 is calculated by comparing the firms with less than €500.000 in turnover with the firms with more than €500.000 in turnover

Due to the unequal distribution of the number of firms over the five different turnover categories the first two beta coefficients are unreliable. For example the first beta coefficient compares firms with no turnover (16 firms) with the rest of the firms (88 firms), and the second beta coefficient compares the firms with less than €100.000 turnover (30 firms) with firms with more than €100.000 turnover (74 firms). The small number of firms in one of the cells of the first two beta coefficients make them unreliable. The first and second beta coefficient can therefore not be used to analyse the matching behaviour of the academic spin-off firms. The third, and fourth beta coefficient compare larger groups, and can therefore be used. The third beta coefficient compares firms with less than €300.000 (44 firms) with firms with more than €300.000 (60 firms) in turnover, and the fourth beta coefficient compares firms with less than €500.000 (56 firms) with firms with more than €500.000 (48 firms) in turnover.

The generalised ordered logistic regression solved both the empty cell issue, and the parallel regression assumption. However it did not solve the endogeneity problem which was affecting the incoming information flows. In order to analyse the influence of the endogenous variable incoming information on the results the method of instrumental variables is used with location as an instrument. The results of the IV method are shown above in model 3 in table 18, and model 6 in table 19. The results of model 3 indicate that the trend between the semipartial marketing match and the growth in turnover is unreliable. However the results of model 6 indicate that the trend between the semipartial management match and the growth in turnover is reliable.

	Model 63.1	**Model 6.2**	**Model 6.3**
	β (s.e.)	β (s.e.)	β (s.e.)
Type of outlier	Extreme growth (fte per year > 12)	Extreme resource deficiency (lacking all resources)	Non responsive diversity match ≤ -0.5
Control Variables			
Age	0.200 (0.071)***	0.191 (0.072)***	0.207 (0.072)***
Location 0 = Trondheim 1 = Delft	used as an instrument	used as an instrument	used as an instrument
Ext. att. information	β^1 = -11.732 (6.158)* β^2 = -9.589 (4.427)** β^3 = -10.028 (4.511)** β^4 = 4.294 (4.482)	β^1 = -11.611 (5.847)** β^2 = -9.360 (4.495)** β^3 = -8.817 (4.594)* β^4 = 4.722 (4.500)	β^1 = -11.621 (6.167)* β^2 = -9.747 (4.436)** β^3 = -9.927 (4.522)** β^4 = 4.541 (4.541)
Matching variable			
Semipartial management capital ranking match	β^1 = 0.087 (0.770) β^2 = 1.138 (0.725) β^3 = 2.294 (0.932)** β^4 = -2.682 (0.778)***	β^1 = 0.213 (0.775) β^2 = 1.043 (0.746) β^3 = 2.134 (0.926)** β^4 = -2.645 (0.778)***	β^1 = 0.082 (0.770) β^2 = 1.137 (0.725) β^3 = 2.300 (0.935)** β^4 = -2.724 (0.786)***
N	103	99	103
LR Chi2	55.62***	50.68***	56.35***
Pseudo R^2	0.188	0.179	0.190

Table 20: Results of the robustness check for IV generalised ordinal logistic regression between the semipartial management ranking match, and the growth in turnover

* p<0.1; ** p<0.05; *** p<0.01

Robustness The robustness of model 6 in table 19 is being checked by analysing the influence of outliers on the results. There are three types of outliers which are excluded from the model, the firm with an enormous growth of more than 12 fte per year on average, the firms who lack all resources at the same time, and the non responsive firm from table 11 in chapter 6. The results of the robustness test of model 6 are shown above in table 20. These results show that outcome of model 6 does not change much when the above outliers are removed. The model is thus robust for outliers.

Results Is noticeable that the two models which were found to have a significant trend between the match and the growth in turnover showed strongly differing beta coefficients. These matches were the semipartial marketing, and management ranking match. The huge difference between

the third beta coefficient, and the fourth beta coefficient might exist due to a shift in the approach, and effectiveness of the academic spin-off firms over growth. Because of the insignificant results of the endogeneity test for the semipartial marketing ranking match only the results of the semipartial management ranking match is analysed.

The results of the management match in table 19 show that the β coefficients start off being positive (β^3), and then become negative (β^4). The explanation for the switch from positive to a negative β coefficient is probably because pre-emptively obtaining external managerial advice is positively influencing the growth of the academic spin off firms in turnover while the firms have a turnover of above €300.000. However when the firms get a turnover of above €500.000 the firms grow so far that they might no longer want external advice, but instead use other methods to solve their managerial problems (e.g: hire a professional manager, go to training, learn-by-doing). These other methods which are substituting external information from knowledge networks are not included in the match, thus creating a low matching value. As a result the fourth beta coefficient shows a negative correlation.

The explanations for the quantitative results in this chapter are verified, and supplemented by the information obtained from the interviews. Chapter 9 compares these results with each other and check whether the results explain each other.

8.4. The results of the influence of the matches on the growth

The answer to the fifth sub research question: "How does the match between incoming information retrieved from the knowledge networks of the academic spin-off firms, and resource deficiencies influence the growth of the spin-off firms?" is explained in this section, and led to two conclusions.

Firstly the variable incoming information seems to be negatively correlated to the growth, and endogenous. These two unexpected results can be explained by reverse causality. Reverse causal-

ity means that the causal direction which was assumed is actually the other way around. Thus while we assumed that the incoming information would influence the growth, the growth actually influences the number of incoming information. As an example firms with low growth will try to improve their growth by attracting external information, while firms with a high growth don't attract so much external information.

Secondly the multi factor growth model shows a significant beta coefficient between the semi-partial matches and the growth in three cases. These cases are:

- The semipartial investment capital ranking match has a significant positive beta coefficient with the growth in fte. Being more pre-emptive in obtaining external investment capital information positively influences the growth of the firm in fte.
  - This model is sensitive to omitting firms with a large growth.
- The semipartial marketing ranking match has a significant negative beta coefficient when comparing the firms which have a turnover of less then €300.000 with firms which have more than €300.000 in turnover. However the marketing ranking match has a significant positive beta coefficient when comparing the firms which have a turnover of less then €500.000 with firms which have more than €500.000 in turnover.
  - When correcting the model for endogeneity by using the instrumental variable approach the beta coefficients become insignificant.
- The semipartial management ranking match has a significant positive beta coefficient when comparing the firms which have a turnover of less then €300.000 with firms which have more than €300.000 in turnover. However the management ranking match has a negative significant beta coefficient when comparing the firms which have a turnover of less then €500.000 with firms which have more than €500.000 in turnover.
  - This model is robust and does not change much when omitting outliers.

9. Validation and discussion

This chapter compares the quantitative results from chapter 8 with the qualitative results from the interviews. It starts off with a short recap of the two statistical significant results from the quantitative part, and interpret these results. After the quantitative results are interpreted they are compared to the qualitative results obtained from the four interviews. This chapter will finish with a discussion about the results of the validation.

9.1. Validation

The two statistical significant results from the multi factor growth model in chapter 8 are:

- A positive trend between the semipartial investment capital ranking match, and the growth in fte.
- A positive trend between the semipartial management ranking match, and the growth in turnover for the firms creating less than €500.000 in turnover, and a negative trend for firms creating more than €500.000 in turnover.

Investment capital The interpretation of the positive trend between the semipartial investment capital ranking match and the growth in fte is as follows: If a firm operates pre-emptively in obtaining information about investment capital it is more likely to acquire investment capital. The result of acquiring investment capital before the firm is lacking investment capital means that the firm is never held back financially, which increases the chances of strong growth.
The assumptions which are made in the interpretation of the statistical trend of the investment capital ranking math are the following:

- Firms which acquire information about investment capital from their knowledge networks are more likely to find willing investors or banks.
- Firms which pre-emptively acquire investment capital are more likely to experience strong growth.

The assumptions which were made to interpret the positive trend between the semipartial investment capital ranking match and the growth in fte are partly verified in appendix F. The four interviews give a strong indication that firms which are actively using their network to find information about investors are likely to find them. However no evidence for or against the positive effect of pre-emptively acquiring investment capital on the growth was found.

Management skills The interpretation of the positive trend between the semipartial management ranking match, and the growth in turnover is as follows: Firms which are using their knowledge network to attract external information about how to manage a firm are more effective at managing their firm, and thus grow faster. The change of the beta coefficient from positive to negative for firms creating more than €500.000 in turnover is caused by substitution. Firms which are larger are able to hire a professional manager, take courses, or learn the managing skills internally by doing. This substitution effect reduces the need for firms to attract external information from their knowledge networks to solve their lack of management skills. As a results the matching values become negative since the matches only compare the lack of a resource with the number of meetings a firm has with their knowledge network, it does not measure the substitution effects.

The assumptions which are made in the interpretation of the statistical trend of the semipartial management ranking match are the following:

- Firms which pre-emptively acquire information about management skills from their knowledge networks are more likely to successfully manage the firm, and thus grow faster.
- Firms with a turnover of more than €500.000 tend to substitute the way they acquire management skills. As an example instead of using their knowledge networks to acquire information to improve their management skills they hire a professional manager, or learn the management by doing.

The first assumption about the positive effect of pre-emptively acquiring information about managing a firm is not verified nor falsified in the interviews in appendix F.

The second assumption about the substitution effect is also noted in interview 2, 4, and 5 in appendix F. These three firms either have an average or a strong growth, and indicate that instead of using their external knowledge networks to obtain management skills they either hired a person to do part of the HR (interview 2), went to courses (interview 4) or learned the skills by doing (interview 5). These three ways of improving the management skills of the firm fall outside the scope of the match, and are therefore not influencing the match. The assumption that larger firms have the tendency to substitute the use of their knowledge networks with other methods of improving their management skills is thus verified.

9.2. Discussion

The results of the validation through the interviews make the interpretations of the quantitative results more likely. However it is hard to investigate the effect of the pre-emptive, reactive or passive behaviour of the academic spin-off firms. The time between the start of the academic spin-off firms and the interviews which were held in 2013 made it harder for the firms to give specific data about their approach. This effect was especially noticeable during the interviews with the older firms.

10. Conclusion and recommendations

This chapter discusses the conclusions of this research and the recommendations which follow from this research. This chapter is structured in two parts. The first part, the conclusion explains what the results of this research are, gives suggestions for further research, and reflects on the approach which was used in this research. The second part of this chapter, the recommendations and the suggestions which follow from this research for the academic spin-off firms and the academic spin-off incubators.

10.1. Conclusion

The conclusion is divided into four parts namely: the validated results, the hypothesis, suggestions for further research, and the reflection on the used research approach.

The validated results The results of the quantitative part of this research show that acting pre-emptive as an academic spin-off firm increases the chance of experiencing a strong growth. These results as discussed in chapter 9 are:

- The positive trend between the semipartial investment capital ranking match, and the growth in fte.
- The positive trend between the semipartial management ranking match and the growth in turnover for firms creating less than €500.000 in turnover and a negative trend for firms creating more than €500.000 in turnover.

The interpretation of these results is that acting pre-emptively as an academic spin-off firm positively influences the growth of the firm. However because the focus of the match is on the incoming information from the knowledge networks of the academic spin-off firms other factors are not included in this research. Other methods of improving the human capital of the firm such as hiring an external person, or going to courses can however substitute the use of incoming information. This suspicion is strengthened by the results of the qualitative study. The larger firms indicated that they are also using other ways to improve their management skills.

Hypothesis The results of this research verify the hypothesis; "Firms which are better at matching the incoming information from their knowledge networks with their missing resources, and thus have a higher match, grow faster". ***Firms which match their incoming information from their knowledge networks in a better way grow faster.***

Suggestions for further research The suggestions for further research are shown below in bullet points. These suggestions follow from the conclusion of this research, and several discoveries during this research which were out of the scope of this research.

- Widen the scope of the matching procedure by including the substitution effects such as learn-by-doing or hiring an external manager.
- Create a database with knowledge of when the firms have meetings (in which year, before the resource deficiencies exist or after etc.). This way it is possible to analyse the preemptive behaviour of firms in more detail.
- Investigate whether lacking one resource leads to the other or whether there is a third variable causing both the lack of marketing skills and a lack of investment capital.
- Investigate whether obtaining information about one resource leads to obtaining information about a second resource, or whether there is a common cause.

Reflection on the used research approach This research has used a mixed method approach with as main research method, the quantitative approach. This method proved to be a good choice since it focusses both on which trends exist, and how these trends can be interpreted. However while the method proved helpful during this research the following alterations to the approach are proposed:

- Instead of using 4 interviews conduct more interviews to obtain in-depth information from a larger sample. However due to time limitations this was not possible in this research.
- The consequences of choosing a certain conceptual model on the assumptions of the statistical model, such as collinearity and endogeneity, should be assessed early on in the

research. During this research the failed collinearity and endogeneity assumption came to light in a later stage which caused a lot of extra work.

10.2. Recommendations

This section gives the recommendations for academic spin-off firms, and incubators such as Yes! Delft. This section is split up into two parts. It will start with the recommendations for the academic spin-off firms, followed by the recommendations for academic spin-off incubators such as Yes! Delft.

Recommendations for the academic spin-off firms The academic spin-off firms which were found to be pre-emptive in solving resource deficiencies tended to experienced a faster growth. Also the rate at which academic spin-off firms are obtaining information from their knowledge networks seems to be steered by negative growth. Thus firms which are growing slowly are trying to solve this by obtaining information from their knowledge networks.
The main recommendation which would improve the growth rate of the academic spin-off firms is be pre-emptive. ***Try to be ahead of future resource deficiencies, and solve future resource deficiencies before they emerge.***

Academic spin-off firms should analyse how the firm is developing and react to it. Each firm should ask itself what their ambitions are and how this affects their resources. For example when a firms product is ready for launch invest in marketing aimed to sell the product.
Another example is that of the management of the firms. If the ambition of a firm is to become a large firm it should take measures to ensure that the firm is managed properly. Depending on the competences of the current staff the management could be trained within the firm or should be sought outside of the firm. In any case it is wise to use the experience of other firms to learn from. The firms should tap into their network, and learn from the experiences of others.
The last example focusses on investment capital. Each firm should know how it is funded, and when they need more money. If a firm then operates pre-emptively their chances of attracting

investment capital increase, which increases the chances of experiencing a strong growth. A good way to obtain information about how the banks really operate is by attending the meetings with former high-executives from financial institutions. The firms which were interviewed mentioned "ondernemersklankbord" as a good way of obtaining insight in the way a bank operates, and how you can effectively approach banks.

Recommendations for academic spin-off incubators The recommendations for the academic spin-off incubators are related to the recommendations for the academic spin-off firms themselves. This research shows that acting pre-emptively to solve future resource deficiencies before they become a problem, increases the growth of the academic spin-off firms. In order to make sure the academic spin-off firms know when the moment is there to act pre-emptively the incubators should monitor the firms in terms of number of employees, the current capital position, the maturity of the firms product, and the current resource deficiencies of the firms. ***The incubator then uses the data of the firms to create an early warning system.***
For example if firms which are growing larger then 7 employees are starting to lack the management skills these firms should be alerted around 4 to 6 employees. By warning the academic spin-off firms about what management problems lay ahead for them, they can act pre-emptively and thereby increase their growth.

A. List of variables

Variable name	Type	Scale	Mean/ Median/ Mode	Variance (st. dev.)	Min/ Max	Calculation/ Categories (*amount of firms*)
Diversity match	independent	ratio	mean = 0.12	0.05 ($\sigma = 0.22$)	-0.66/ 0.75	= (1-$\sum {p_{information}}^2$)* - (1-$\sum {p_{resources}}^2$)**
Marketing ranking match	independent	ratio	mean = 0.10	0.70	-1 / 1	= (meetings rank) - (lack of resource rank)***
Management ranking match	independent	ratio	mean = 0.18	0.71	-1 / 1	= (meetings rank) - (lack of resource rank)***
Investment capital ranking match	independent	ratio	mean = 0.05	0.70 ($\sigma = 0.49$)	-1 / 1	= (meetings rank) - (lack of resource rank)***
Age	independent	interval	mean = 6 years	9.1	1 year/ 11 years	= 2006 − "$year_{start}$" + 1
Science base	independent	nominal	mode = non science based			1) science based(*25 firms*) 0) non science based(*80 firms*)
Phase	independent	nominal	mode = exploitation			1) exploration(*39 firms*) 0) exploitation(*66 firms*)
Location	independent	nominal	mode = Delft			1) Delft(*61 firms*) 0) Trondheim(*44 firms*)
Lacking resource	independent	ratio	mean = 0.45	0.06	0/ 1	= $\frac{\text{number of lacking resources}}{\text{number of resources}}$
Incoming information	independent	ratio	mean = 0.71	0.08	0/ 1	= $\frac{\text{number of incoming information}}{\text{number of contents of information}}$
Growth in fte's (per year)	dependent	interval	mean = 1.20 fte median = 0.40 fte	6.64	-1 fte/ 16.3 fte	= $\frac{"fte's_{2010}" - "fte's_{start}"}{age}$
log of growth in fte's (per year)	dependent	interval	mean = 0.61 fte median = 0.54 fte	0.59	-1.14 fte/ 2.87 fte	= *log*("Growth in fte's" + 1.32)
Growth in turnover****	dependent	ordinal	median = cat 4 mode = cat 5		cat 1 / cat 5	cat 1 = no turnover cat 2 = <€100000 cat 3 = €100000<€300000 cat 4 = €300000<€500000 cat 5 = ≥ €500000

Table 21: List of variables used in this research

* where (1-$\sum p_{information}$) is the diversity of incoming information using Harrison's method of diversity for categories [22, p. 1210]

** where (1-$\sum p_{resources}$) is the diversity of lacking resources using Harrison's method of diversity for categories [22, p. 1210]

*** the lack of resource rank, and meetings rank are both calculated per resource resulting in three sub matches. The rank is a percentage rank compared to the other firms of the same age, with a value of 0 (0% of the firms have less resource deficiencies or meetings) to 1 (100% of the firms have less resource deficiencies or meetings)

**** all firms started off with no turnover, thus the turnover in 2010 is the growth in number of categories

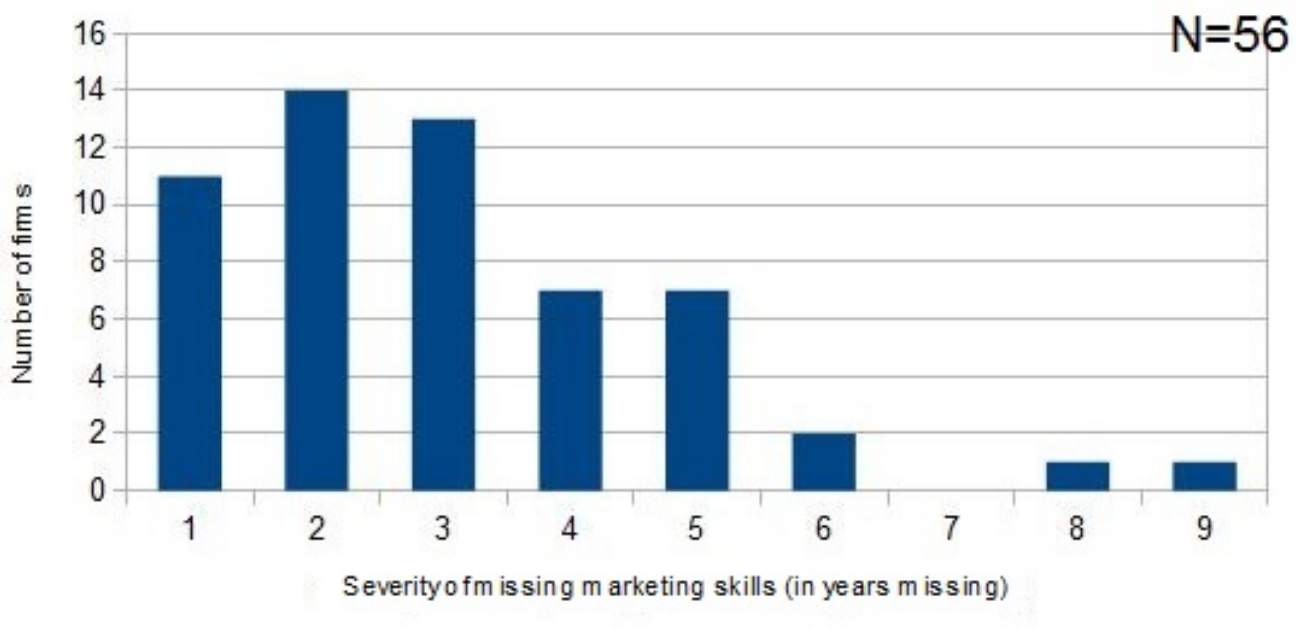
B. Resources that are missing among the academic spin-off firms

This section will give the in depth analysis of the outcomes in section 4.

Distributions of severity of missing resources

This section will cover the distribution of the severity of each lacking resource. Figures 5, 6, and 7 give a graphical representation of the distribution of the severity of missing resources. After each distribution plot a table containing the frequencies, and the results of the Shapiro-Wilk and Shapiro-Francia tests for normality are shown.

Figure 5: Severity of missing marketing skills

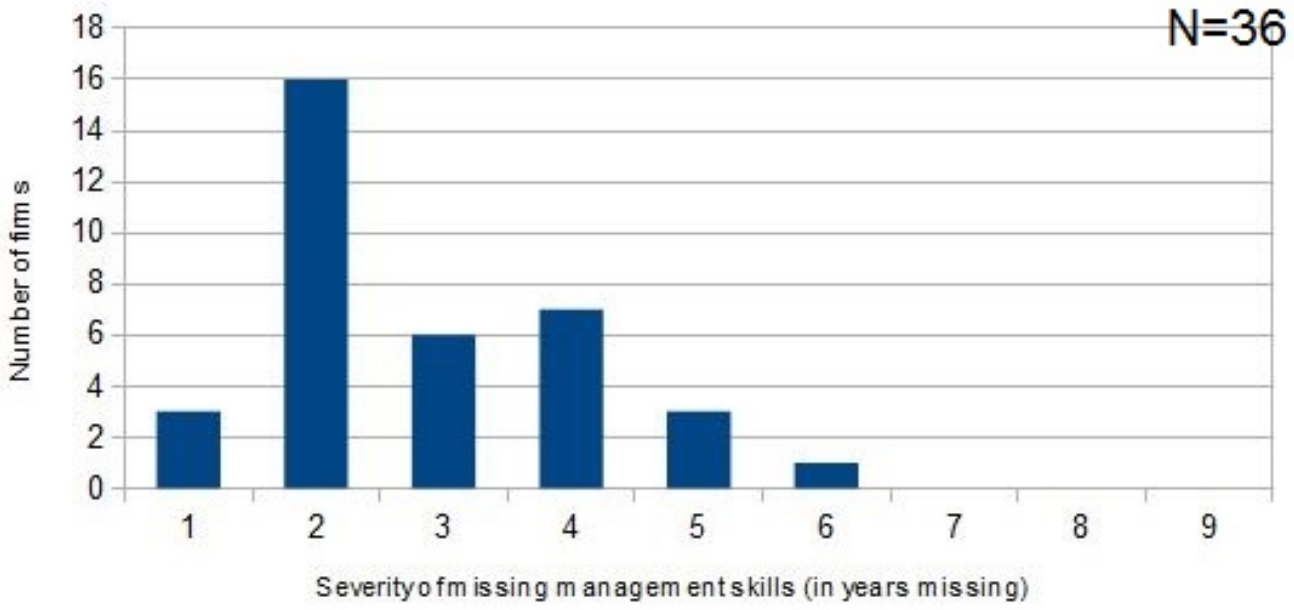


Severity of missing marketing skills (in years):	1	2	3	4	5	6	7	8	9
Number of firms:	11	14	13	7	7	2	0	1	1
N=	56								
Shapiro-Wilk test for normal data prob>z	0.00071								
Shapiro-Francia W' test for normal data prob>z	0.02433								

Table 22: Severity of missing marketing skills

The data from table 22 show the outcomes of the Shapiro-Wilk test, and Shaprio-Francia W' test for normal data. Since both test are below the significance threshold of 5% the data is assumed to be normally distributed.

Figure 6: Severity of missing management skills

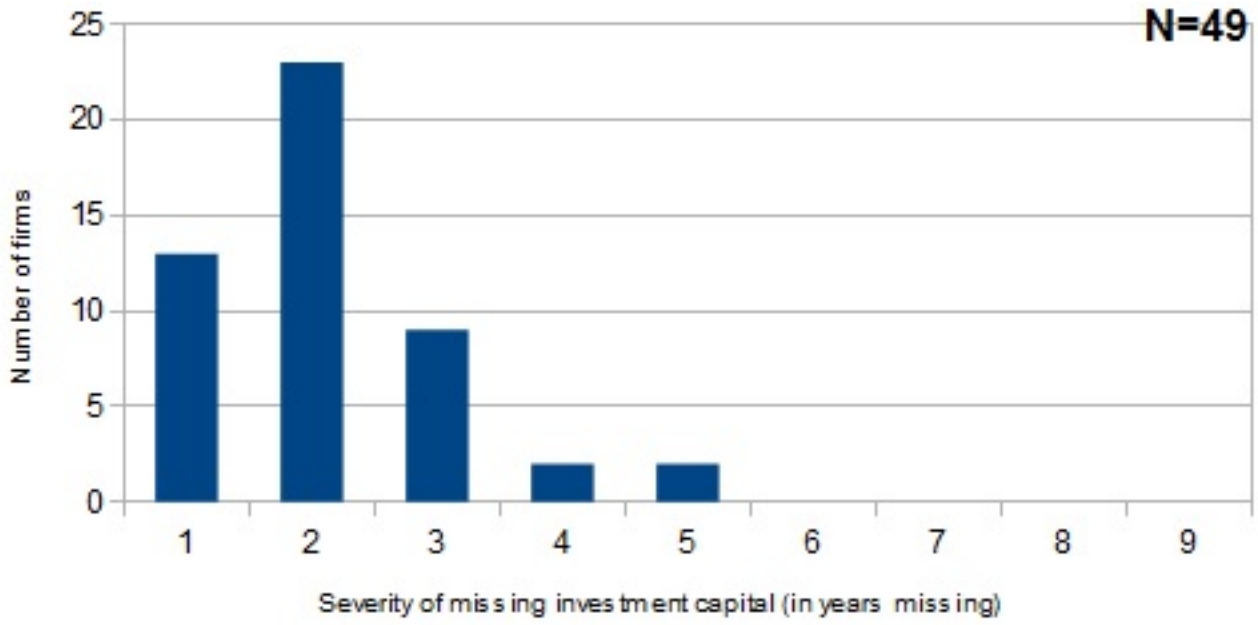


Severity of lacking management skills (in years):	1	2	3	4	5	6	7	8	9
Number of firms:	3	16	6	7	3	1	0	0	0
N=	36								
Shapiro-Wilk test for normal data prob>z	0.12027								
Shapiro-Francia W' test for normal data prob>z	0.42954								

Table 23: Severity of missing management skills

The data from table 23 show the outcomes of the Shapiro-Wilk test, and Shaprio-Francia W' test for normal data. Since both test are above the significance threshold of 5% the data is assumed not to be normally distributed.

Figure 7: Severity of missing investment capital



Severity of lacking investment capital (in years):	1	2	3	4	5	6	7	8	9
Number of firms:	13	23	9	2	2	0	0	0	0
N=	49								
Shapiro-Wilk test for normal data prob>z	0.00266								
Shapiro-Francia W' test for normal data prob>z	0.14396								

Table 24: Severity of missing investment capital

The data from table 24 show the outcomes of the Shapiro-Wilk test, and Shaprio-Francia W' test for normal data. Since the Shapiro-Francia W' test is above the significance threshold of 5% the data is assumed not to be normally distributed.

Comparing the results from table 2 and figures 5, 6, and 7 it marketing strikes out in terms of average severity and distribution. It has the highest average severity but also the broadest distribution of all three resources. This could be an indicator that the problem of a lack in marketing skills occurs random over time.

The same can not be said about a lack of management skills. 16 of the firms experiencing management skills lack the skill for two years, while only 3 firms lack it for one years and 6 lack the resource for 3 years. This could be an indication that a lack of management skills does not occur random over time but occurs after a given time period. This conclusion sounds

logical since the spin-off firms tend to start with little employees and grow over time. After a certain amount of time most firms will cross an invisible line after which management becomes increasingly important to keep the firm running.

The third graph about investment capital shows a similar picture. Firms who lack investment capital often lack it for two years, and never longer then four years. It is logical that there is a maximum to the amount of years a firm lacks investment capital. During a lack of investment capital the firm slowly loses money, which eventually results in bankruptcy.

Statistical difference in firms lacking a resource

This section will focus on the question whether the three types of resources statistically differ in terms of average duration.a Due to the non-normal distributions and unequal variances between groups it is impossible to use an ANOVA test. Therefore the Kruskal-Wallis test is used to investigate whether the three groups statistically differ from each other.

resource	Obs	Rank Sum
Investment	49	2768.50
Management	36	2818.00
Marketing	56	4424.50

chi-squared = 9.470 with 2 d.f.
probability = 0.0088

chi-squared with ties = 10.183 with 2 d.f.
probability = 0.0061

Table 25: Results of the Kruskal-Wallis test checking whether the severity of the missing resources statistically differs between the resources

The results from the Kruskal-Wallis test (as shown in table 25) show that at least one of the groups is statistically different. Therefore the Kruskal-Wallis test is performed three more times to investigate each pair of resources. When comparing the results of the Kruskal-Wallis tests (as shown below in table 26) with the earlier results from table 2 it becomes clear that the resource investment capital is lacking statistically shorter then Marketing, or Management.

	Marketing skills	Management skills	Investment capital
Marketing skills	=	=	≠
Management skills	=	=	≠
Investment capital	≠	≠	=

Table 26: Results of the Kruskal-Wallis tests for all sets of two resources ("=" means no statistical difference, and "≠" means a statistical difference)

Occurrence of firms lacking resources

This section graphically shows when firms start to lack resources and when it stops. The figures 8,9,10 show when firms respectively lack marketing skills, management skills, and investment capital. The colours represent the type of firm based upon the "newness" of the firm as devised by Taheri M., and van Geenhuizen M. [23].

Figure 8: Occurrence of lacking marketing skills

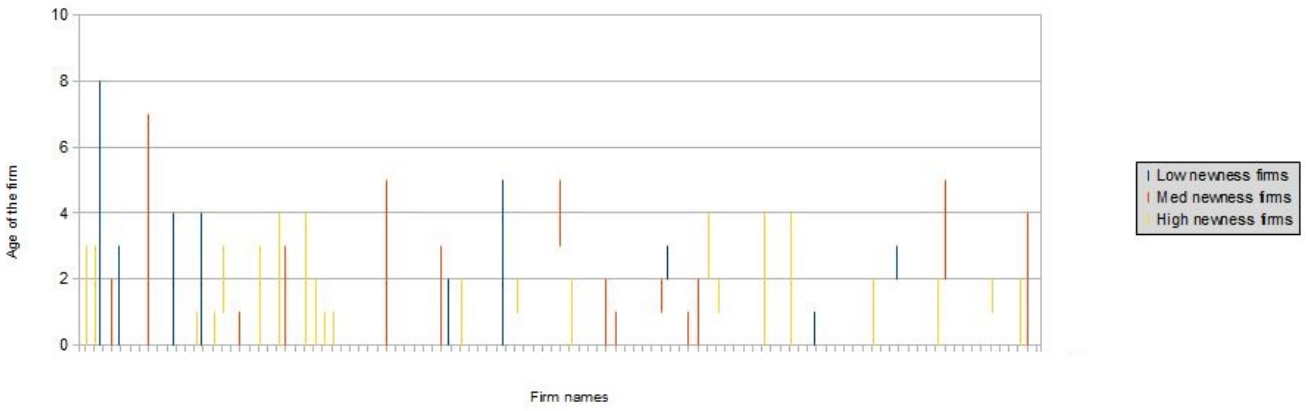


Figure 9: Occurrence of lacking management skills

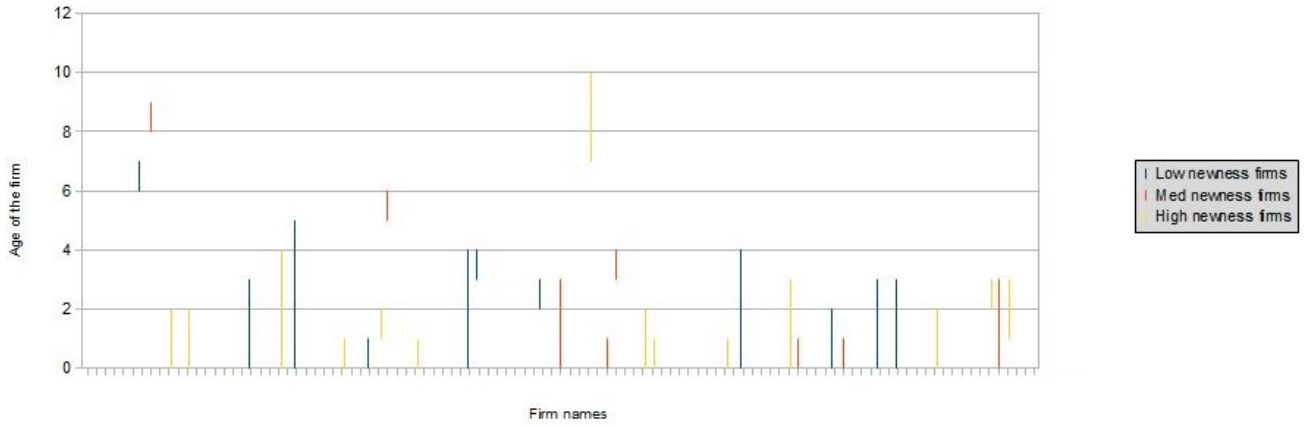
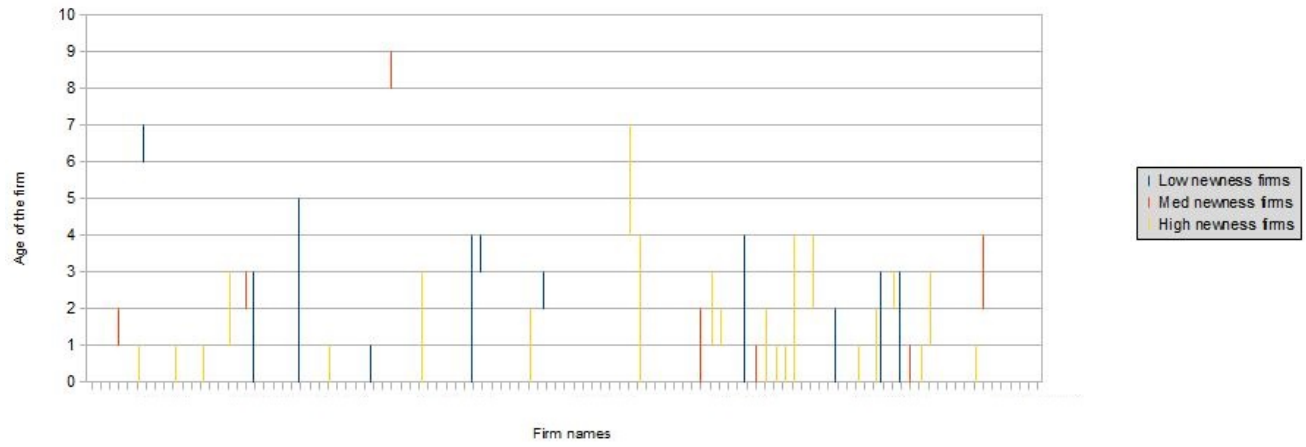


Figure 10: Occurrence of lacking investment capital



C. The contents of information that circulate through the knowledge networks of the academic spin-off firms

This section will give the in-depth analysis of the statistical methods used in section 5.

ANOVA to test for statistical differences between the number of firms obtaining content, per content

In order to check whether there is a statistical difference in the number of firms obtaining certain content from their knowledge networks a ANOVA test is used. The results from the ANOVA test are shown below in table 27.

Analysis of Variance

Source	SS	df	MS	F	Prob > F
Between groups	6.27301587	2	3.13650794	16.63	0.0000
Within groups	58.8571429	312	.188644689		
Total	65.1301587	314	.207420888		

Bartlett's test for equal variances: chi2(2) = 15.1298 Prob>chi2 = 0.001

Table 27: ANOVA checking whether there is a statistical difference in the % of firms obtaining certain content from their networks

Analysing the results from the ANOVA in table 27 it is noticeable that the probability is 0.0000, meaning that the null hypothesis, which states that all three groups are equal is rejected. Because of the rejection of the null hypothesis the alternative hypothesis, which states that at least one group is statistically different is accepted. In order to check which groups are statistically different a Bonferroni test is conducted. The results of the Bonferroni test are shown below in table 28. The Bonferroni test shows there is in fact a statistical difference between financial related meetings, and information about marketing, and managerial advise, but the groups information about marketing, and managerial advise don't statistically differ.

Row Mean- Col Mean	Investme	Manageme
Manageme	.209524 0.002	
Marketin	.342857 0.000	.133333 0.081

Table 28: Bonferroni checking which types of content statistically differ

Multicollinearity test between reputation of persons and the number of meetings

In order to rule out multicollinearity between the reputation of the person with who is met and the number of meetings with this persons two tests are performed: a linear regression analysis, and the Pearson's correlation coefficient is calculated.

The results from the linear regression analysis are shown below in table 29 and indicate no correlation since the significance of the linear regression analysis is above 5%. Also the beta coefficient is almost zero, indicating no correlation.

Source	SS	df	MS
Model	7.55260904	1	7.55260904
Residual	878.347391	371	2.36751318
Total	885.9	372	2.38145161

Number of obs	= 373
F(1, 371)	= 3.19
Prob > F	= 0.0749
R-squared	= 0.0085
Adj R-squared	= 0.0059
Root MSE	= 1.5387

meetings	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
rep	.2908579	.1628465	1.79	0.075	-.0293601	.6110758
_cons	1.391216	.1264781	11.00	0.000	1.142512	1.63992

Table 29: Linear regression between the reputation of the person met, and the number of meetings with these persons

In order to be sure that no multicollinearity exists the Pearson's correlation coefficient is also

calculated and shown in table 30. Because of the low Pearson's correlation coefficient of 0.09 (which has a two tailed significance of 0.075, which is insignificant at a 0.05 level) it can be assumed that there is no multicollinearity.

```
. correlate rep meetings
(obs=373)
```

	rep	meetings
rep	1.0000	
meetings	0.0923	1.0000

Table 30: Pearson's correlation coefficient between the reputation of the person met and the number of meetings with these persons

ANOVA and Kruskal-Wallis test between the number of meetings per type of content

This section will analyse whether there is a statistical difference between the number of meetings per type of content. First the number of meetings in total per type of content will be analysed, however since the variances of the three types of content are not homogeneous the ANOVA test can not be used. Instead the Kruskal-Wallis test will be used. The results from the Kruskal-Wallis test as shown below in table 31 shows that the three groups do not statistically differ from each other ($p > 0.05$).

content_high	Obs	Rank Sum
Investment capital	55	5450.50
Management	77	8611.00
Marketing	91	10914.50

```
chi-squared =     3.577 with 2 d.f.
probability =     0.1672

chi-squared with ties =     3.645 with 2 d.f.
probability =     0.1617
```

Table 31: Kruskal-Wallis test used analyse whether there are significant differences between the amount of meetings per content

While there are no significant differences in number of meetings per content in total there might be statistical differences when taking the reputation of the person with who is met in account. In order to be able to use an ANOVA the dataset needs to be normally distributed, and the variances of the different groups need to be homogeneous. To check these assumptions the Shapiro-Francia W' test for normality, and Barlett's test for equal variances is used. The results from the Shapiro-Francia W' test for normality range between 0.00001 and 0.00032, which is far below 0.05, the groups are therefore considered to be normally distributed. The result from the second test; Barlett's test (as shown in table 32 and 33) ranges between 0.167, and 0.195 which is higher then 0.05. The variances of the groups are therefore assumed to be the same.

The results from the two ANOVA's (as shown in table 32 and 33) show that there is also no statistical difference between the number of meetings per content of information, when taking the reputation of the person who is met into account.

Analysis of Variance

Source	SS	df	MS	F	Prob > F
Between groups	8.10522614	2	4.05261307	1.43	0.2409
Within groups	622.368227	220	2.82894649		
Total	630.473453	222	2.83997051		

Bartlett's test for equal variances: chi2(2) = 3.5754 Prob>chi2 = 0.167

Table 32: ANOVA used analyse whether there are significant differences between the amount of meetings per content, for meetings with persons of low reputation

Analysis of Variance

Source	SS	df	MS	F	Prob > F
Between groups	1.00215372	2	.501076862	0.16	0.8509
Within groups	682.342829	220	3.10155831		
Total	683.344983	222	3.07813055		

Bartlett's test for equal variances: chi2(2) = 3.2702 Prob>chi2 = 0.195

Table 33: ANOVA used analyse whether there are significant differences between the amount of meetings per content, for meetings with persons of high reputation

D. The growth pattern of spin-off firms, regarding employment and turnover

This section will give an in-depth overview of chapter 7. This section will consists of the statistical tests which were used, the results of these tests, and an analysis which ordinal analyses the fte growth and turnover growth, with regard to each other.

Fte growth distribution of the academic spin-off firms

Table 34 shows the results of the Shapiro-Francia W' test for normal data. Since the probability value of 0.00001 is far below 0.05 the firms fte growth is assumed to be normally distributed.

Shapiro-Francia W' test for normal data

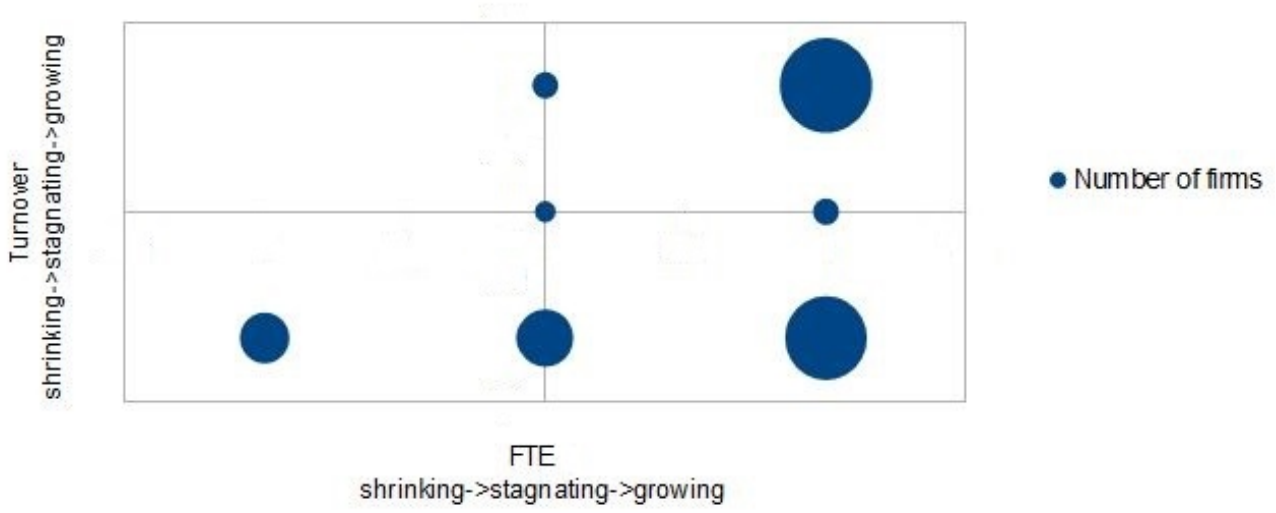
Variable	Obs	W'	V'	z	Prob>z
fte_growth	105	0.59555	38.316	7.229	0.00001

Table 34: Shapiro-Francia W' test for normal data

Growth of the academic spin-off firms ordinal analysed

The size of the firms is measured in both 2006, and 2011 (with restrospect to 2010), and is measured in both; fte number (ratio level), and annual turnover (ordinal level). In order to create a better insight into how the firms perform a graphical ordinal representation has been created. The size of the dots in figure 11 represent the number of firms (the larger the dot, the more firms). Furthermore the axis represent the fte growth (on the x-axis), and the turnover growth (on the y-axis).

Figure 11: The growth of the academic spin-off firms inbetween 2006 and 2010 ordinal represented



When looking at figure 11 it is peculiar to see that around 30% of the firms experience a decreasing turnover but an increasing amount of fte. This effect could be explained by firms who are hiring people to further develop their product, while they aren't selling any yet (and thus have none or little turnover).

E. The influence of the match on the growth of the firms

This appendix will give the raw statistical data which analyses the trends between the matches and the growth of the firms. The results of these statistical tests will be used in chapter 8 to analyse the effect of the matches on the growth of the firms.

Spearman's rank correlations between all variables

This subsection is will analyse the Spear's rank correlation coefficients between all variables. The results of this analysis give a first glance of the correlations between variables, and will later on be used to check for multicollinearity.

In the correlation matrix (table 36) it is noticeable that the correlation between the growth of the firms in both fte growth, and turnover is negatively correlated with the number of contents of incoming information. This negative correlation coefficient is unexpected and could be caused by reversed causality. While there might be the effect of the number of contents of incoming information on growth there could also be the effect of growth on the number of contents of incoming information. If a firm is having trouble growing these firms might be more motivated to use external information in the hope to grow the firm. In order to check whether this might be the case the number of contents of incoming information will be checked for endogeneity.

When analysing the correlation between the matches and the number of contents of incoming information, and the severity of the lack of resource (table 35) is noticeable that these variables are strongly correlated. The strong correlation between these variables is due to the way the matches are calculated. In order to measure the direct effect of the match on the growth without the indirect effects of the lack of resources, and the incoming information a semipartial match will be calculated. These three semipartial matches are calculated by taking the residuals of the OLS between each match, and the lack of resources, and incoming information separately. The resulting semipartial match (table 36) is uncorrelated with the lack of resources and the

externally attracted information.

Key	
rho	
Number of obs	
Sig. level	

	Diversity match	Marketing ranking match	Management ranking match	Investment capital ranking match	Lack of resources	Incoming information
Diversity match	1.0000 105					
Marketing ranking match	0.4737 105 0.0000	1.0000 105				
Management ranking match	0.5494 105 0.0000	-0.0027 105 0.9784	1.0000 105			
Investment capital ranking match	0.5019 105 0.0000	0.1637 105 0.0952	0.1006 105 0.3073	1.0000 105		
Lack of resources	-0.7225 105 0.0000	-0.4214 105 0.0000	-0.3187 105 0.0009	-0.3144 105 0.0011	1.0000 105	
Incoming information	0.6265 105 0.0000	0.2270 105 0.0199	0.4476 105 0.0000	0.5052 105 0.0000	-0.0154 105 0.8762	1.0000 105

Table 35: Spearman's rank correlation matrix of the original matches, the lack of resources, and incoming information

When further analysing the control variables it is noticeable that the all firm profile variables are correlated with each other except the location and science base. Because of the risk of a multicollinearity bias in the results a thorough analysis of the effects of the control variables on each other needs to happen before running the final model.

Key	
rho	
Number of obs	
Sig. level	

	Log of the growth in fte	Growth in turnover	Age	Science base	Location	Phase	Lack of resources	Externally attracted information	Semipartial diversity match	Semipartial marketing ranking match	Semipartial management ranking match	Semipartial inv. cap. ranking match
Log of the growth in fte	1.0000 105											
Growth in turnover	0.7207 104 0.0000	1.0000 104										
Age	0.2055 105 0.0354	0.3389 104 0.0004	1.0000 105									
Science base	0.0300 105 0.7615	-0.0484 104 0.6255	-0.2724 105 0.0049	1.0000 105								
Location	0.2553 105 0.0086	0.1915 104 0.0514	0.2811 105 0.0037	-0.1144 105 0.2453	1.0000 105							
Phase	-0.1422 105 0.1478	-0.2438 104 0.0126	-0.6003 105 0.0000	0.2182 105 0.0254	-0.2260 105 0.0204	1.0000 105						
Lack of resources	-0.2208 105 0.0236	-0.1598 104 0.1051	-0.1735 105 0.0767	0.0631 105 0.5227	-0.1876 105 0.0553	0.1749 105 0.0743	1.0000 105					
Externally attracted information	-0.2040 105 0.0368	-0.2133 104 0.0297	-0.1170 105 0.2345	0.0035 105 0.9714	-0.2050 105 0.0359	0.0094 105 0.9245	-0.0154 105 0.8762	1.0000 105				
Semipartial diversity match	-0.0579 105 0.5574	0.0416 104 0.6746	-0.0749 105 0.4474	-0.1314 105 0.1815	-0.0956 105 0.3321	0.1090 105 0.2684	0.2574 105 0.0080	-0.1836 105 0.0608	1.0000 105			
Semipartial marketing ranking match	-0.0282 105 0.7751	-0.0188 104 0.8497	-0.0654 105 0.5072	-0.1579 105 0.1077	-0.0490 105 0.6193	0.0810 105 0.4116	-0.0321 105 0.7450	-0.0105 105 0.9151	0.0624 105 0.5268	1.0000 105		
Semipartial management ranking match	-0.0840 105 0.3940	-0.1219 104 0.2177	-0.0307 105 0.7562	-0.1059 105 0.2824	0.0863 105 0.3813	0.0449 105 0.6494	0.0010 105 0.9916	-0.0238 105 0.8093	0.0396 105 0.6884	-0.3907 105 0.0000	1.0000 105	
Semipartial inv. cap. ranking match	0.0781 105 0.4281	0.0203 104 0.8378	-0.1418 105 0.1489	0.1968 105 0.0442	0.0217 105 0.8263	0.0619 105 0.5308	0.0045 105 0.9633	0.0292 105 0.7675	-0.1048 105 0.2875	-0.1586 105 0.1062	-0.2774 105 0.0042	1.0000 105

Table 36: Spearman's rank correlation matrix (NOTE: since there was one firm with no turnover data this firm is not included in the correlation with the growth in turnover)

The effects of the control variables on the growth in fte

This subsection will analyse the trend of the controlling variables with the transformed growth in fte, and multicollinearity bias. This section will start with an explanation of how and why the growth was transformed, followed by the results of the multi factor growth model between the controlling variables and the transformed growth in fte.

The original growth in fte was measured as an average growth from the start of the academic spin-off firm until 2010. However the limited possibility to get a negative growth figure, and the unlimited possibility to get a positive growth figure (as explained in chapter 7) creates a bias. In order to overcome this bias the difference between the lowest growth figure (-1 fte per year), and the highest growth figure (16.3 fte per year) needed to be dealt with. In other words the skewness of the distribution needed to be fixed. The second problem with the growth in fte was the huge amount of firms having a growth just above 0, making the growth in fte distribution leptokurtic.
In order to minimise the effects of both problems the growth in fte was transformed by using a natural logarithmic transformation. The choice for the log base e instead of the suggested log base 10 was used to further decrease the kurtosis of the distribution [25], and [26] cited in [27].

After the growth has been transformed it is now possible to analyse the trends between the controlling variables, and the transformed growth. This analysis will be performed by using a bidirectional elimination approach. The steps of this stepwise regression are shown below. The results are shown in table 37.

1. Use all firm profile variables as independent variables in the OLS regression and check the variance inflation factors, the combination age, and phase cause a large variance inflation factor.

2. Take age, or phase out of the model to check which variable has the least influence on the transformed growth. Phase has almost no influence and is taken out of the OLS regression.

3. Include the lack of resources, and externally attracted information separate in the OLS regression to analyse their separate trends.

4. Include both lack of resources and externally attracted information in the model.

	Firm profile	**without phase**	**with lack of res.**	**with ext. attracted inf.**	**All control without phase**
	β (s.e.)	β (s.e.)	β (s.e.)	β (s.e.)	β (s.e.)
Control Variables					
Age	0.055 (0.031)*	0.051 (0.026)**	0.048 (0.026)*	0.047 (0.025)*	0.044 (0.025)*
Science base	0.228 (0.176)	0.231 (0.175)	0.231 (0.174)	0.215 (0.172)	0.215 (0.172)
Phase	0.047 (0.185)	-	-	-	-
Location	0.373 (0.152)**	0.369 (0.151)**	0.342 (0.153)**	0.317 (0.151)**	0.286 (0.152)*
Lacking resources	-	-	-0.358 (0.296)	-	-0.379 (0.291)
Externally attracted information	-	-	-	-0.525 (0.259)**	-0.537 (0.259)**
N	105	105	105	105	105
F	3.39***	4.54***	3.78***	4.53***	3.99***
R^2	0.119	0.119	0.132	0.153	0.168
Adjusted R^2	0.084	0.093	0.097	0.120	0.126
Root MSE	0.738	0.734	0.733	0.723	0.721
NOTE	non nor. resid.^{clt}	non nor. resid.^{clt}	non nor. resid.^{clt}	non nor. resid.^{clt} Ext. att. inf. is endogenous^{end}	non nor. resid.^{clt}

Table 37: Results of the stepwise regression analysis of the control variables versus the transformed growth of the firms in fte (the growth of the firms was transformed by "transformed growth" $= log($"growth in fte" $+ 1.32)$)

* p<0.1; ** p<0.05; *** p<0.01

^{clt} The results of the normality tests indicate non-normal residuals. However since the sample size is reasonably large [13], the mean of the distribution is approximately zero, and the tail of the residual distribution is limited the central limit theorem states that normality can be assumed [14, p. 184].

^{end} Externally attracted information has been checked by using a DWH test, and using the location as an instrumental variable. The test was found significant on a 95% confidence interval.

The following assumptions have been checked: linearity, collinearity, homoscadasticity, the normality of residuals, and endogeneity.

The effect of the matches on the growth in fte

This subsection shows the statistical results of the OLS regression analysis with the matches, and controlling variables as independent variables, and the transformed growth in fte as dependent variable. The following assumptions have been checked: linearity, collinearity, homoscadasticity, normality of residuals, and endogeneity.

	Control variables & match	**Significant controll variables & match**
	β (s.e.)	β (s.e.)
Control Variables		
Age	0.044 (0.025)*	0.039 (0.025)
Science base	0.227 (0.174)	-
Phase	-	-
Location	0.291 (0.153)*	0.310 (0.152)**
Lacking resources	-0.378 (0.292)	-
Ext. att. information	-0.535 (0.260)**	-0.539 (0.261)**
Matching variable		
Semipartial diversity match^{spc}	0.361 (0.720)	0.234 (0.717)
N	105	105
F	3.34***	4.11***
R^2	0.170	0.141
Adjusted R^2	0.119	0.107
Root MSE	0.723	0.728
NOTE	non nor. resid.^{clt}	non nor. resid.^{clt} Ext. att. inf. is endogenous^{end}

Table 38: Results of the stepwise regression analysis of the semipartial diversity match (without the indirect effect of the lacking resources, and externally attracted information) versus the transformed growth of the firms in fte (the growth of the firms was transformed by "transformed growth" = log("growth in fte" + 1.32))

* p<0.1; ** p<0.05; *** p<0.01

^{spc} without the indirect effect of the lacking resources, and externally attracted information

^{clt} The results of the normality tests indicate non-normal residuals. However since the sample size is reasonably large [13], the mean of the distribution is approximately zero, and the tail of the residual distribution is limited the central limit theorem states that normality can be assumed [14, p. 184].

[end] Externally attracted information has been checked by using a DWH test, and using the location as an instrumental variable. The test was found significant on a 95% confidence interval.

	Control variables & match	**Significant controll variables & match**
	β (s.e.)	β (s.e.)
Control Variables		
Age	0.043 (0.026)*	0.039 (0.025)
Science base	0.205 (0.175)	-
Phase	-	-
Location	0.285 (0.153)*	0.305 (0.152)**
Lacking resources	-0.380 (0.292)	-
Ext. att. information	-0.539 (0.260)**	-0.542 (0.261)**
Matching variable		
Semipartial marketing ranking match[spc]	-0.050 (0.170)	-0.083 (0.168)
N	105	105
F	3.31***	4.15***
R^2	0.169	0.142
Adjusted R^2	0.118	0.108
Root MSE	0.724	0.728
NOTE	non nor. resid.[clt]	non nor. resid.[clt] Ext. att. inf. is endogenous[end]

Table 39: Results of the stepwise regression analysis of the semipartial marketing ranking match (without the indirect effect of the lacking resources, and externally attracted information versus the transformed growth of the firms in fte (the growth of the firms was transformed by "transformed growth" $= log($"growth in fte" $+ 1.32)$)

* p<0.1; ** p<0.05; *** p<0.01

[spc] without the indirect effect of the lacking resources, and externally attracted information

[clt] The results of the normality tests indicate non-normal residuals. However since the sample size is reasonably large [13], the mean of the distribution is approximately zero, and the tail of the residual distribution is limited the central limit theorem states that normality can be assumed [14, p. 184].

[end] Externally attracted information has been checked by using a DWH test, and using the location as an instrumental variable. The test was found significant on a 95% confidence interval.

	Control variables & match	Significant controll variables & match
	β (s.e.)	β (s.e.)
Control Variables		
Age	0.041 (0.025)	-
Science base	0.196 (0.172)	-
Phase	-	-
Location	0.312 (0.153)**	0.395 (0.148)***
Lacking resources	-0.373 (0.290)	-
Ext. att. information	-0.532 (0.258)**	-0.563 (0.260)**
Matching variable		
Semipartial corr. of the management ranking match^{spc}	-0.220 (0.173)	-0.257 (0.173)
N	105	105
F	3.62***	5.37***
R^2	0.181	0.138
Adjusted R^2	0.131	0.112
Root MSE	0.718	0.726
NOTE	non nor. resid.^{clt} Ext. att. inf. is endogenous^{end}	non nor. resid.^{clt} Ext. att. inf. is endogenous^{end}

Table 40: Results of the stepwise regression analysis of the semipartial management ranking match (without the indirect effect of the lacking resources, and externally attracted information versus the transformed growth of the firms in fte (the growth of the firms was transformed by "transformed growth" $= log($"growth in fte" $+ 1.32)$)

* p<0.1; ** p<0.05; *** p<0.01

^{spc} without the indirect effect of the lacking resources, and externally attracted information

^{clt} The results of the normality tests indicate non-normal residuals. However since the sample size is reasonably large [13], the mean of the distribution is approximately zero, and the tail of the residual distribution is limited the central limit theorem states that normality can be assumed [14, p. 184].

^{end} Externally attracted information has been checked by using a DWH test, and using the location as an instrumental variable. The test was found significant on a 95% confidence interval.

	Control variables & match	**Significant controll variables & match**
	β (s.e.)	β (s.e.)
Control Variables		
Age	0.048 (0.025)*	0.046 (0.025)*
Science base	0.169 (0.173)	-
Phase	-	-
Location	0.267 (0.152)*	0.287 (0.150)*
Lacking resources	-0.375 (0.289)	-
Ext. att. information	-0.538 (0.257)**	-0.537 (0.257)**
Matching variable		
Semipartial inv. cap. ranking match^{spc}	0.272 (0.177)	0.304 (0.175)*
N	105	105
F	3.76***	4.96***
R^2	0.187	0.166
Adjusted R^2	0.138	0.132
Root MSE	0.716	0.718
NOTE		non nor. resid.^{clt}

Table 41: Results of the stepwise regression analysis of the semipartial investment capital ranking match (without the indirect effect of the lacking resources, and externally attracted information versus the transformed growth of the firms in fte (the growth of the firms was transformed by "transformed growth" $= log($"growth in fte" $+ 1.32)$)

* p<0.1; ** p<0.05; *** p<0.01

^{spc} without the indirect effect of the lacking resources, and externally attracted information

^{clt} The results of the normality tests indicate non-normal residuals. However since the sample size is reasonably large [13], the mean of the distribution is approximately zero, and the tail of the residual distribution is limited the central limit theorem states that normality can be assumed [14, p. 184].

The effect of the matches on the growth in turnover

This subsection whows the statistical results of the ordered logistic regression with the controlling variables, and the match as independent variables, and the growth in turnover as dependent variable.

	All control variables & match	**Significant controll variables & match**
	β (s.e.)	β (s.e.)
Control Variables		
Age	0.190 (0.070)***	0.211 (0.066)***
Science base	0.127 (0.456)	-
Phase	-	-
Location	0.350 (0.400)	-
lacking resources	-0.908	-
Ext. att. information	-1.184 (0.689)*	-1.230 (0.676)*
Matching variable		
Semipartial diversity match^{spc}	2.148 (2.025)	1.493 (1.937)
N	104	104
LR Chi2	19.11***	16.59***
Pseudo R^2	0.064	0.056
NOTE		

Table 42: Results of the stepwise ordered logistic regression analysis of the semipartial diversity match versus the growth of the firms in turnover

* p<0.1; ** p<0.05; *** p<0.01

^{spc} without the indirect effect of the lacking resources, and externally attracted information

The parallel regression assumption has been checked by using the "omodel logit" test of Rory Wolfe, and the "brant" test of Scott Long & Jeremy Freese.

	All control variables & match	**Significant controll variables & match**
	β (s.e.)	β (s.e.)
Control Variables		
Age	0.195 (0.074)***	0.195 (0.067)***
Science base	-0.155 (0.483)	-
Phase	-	-
Location	β^1 = 0.430 (0.680) β^2 = 0.953 (0.553)* β^3 = 0.804 (0.515) β^4 = -0.833 (0.528)	-
lacking resources	β^1 = 1.130 (1.480) β^2 = 0.232 (1.038) β^3 = 1.195 (1.060) β^4 = -2.245 (1.086)**	-0.834 (0.759)
Ext. att. information	β^1 = -3.079 (1.412)** β^2 = -2.595 (1.012)** β^3 = -2.855 (0.951)*** β^4 = 0.640 (0.950)	-1.13 (0.698)
Matching variable		
Semipartial marketing ranking match^{spc}	β^1 = -2.036 (0.944)** β^2 = -1.204 (0.684)* β^3 = -1.482 (0.678)** β^4 = 1.765 (0.673)***	β^1 = -1.525 (0.753)** β^2 = -0.859 (0.579) β^3 = -0.797 (0.563) β^1 = 0.876 (0.554)
N	104	104
LR Chi2	55.33***	28.59***
Pseudo R^2	0.186	0.096
NOTE	failed to satisfy the parallel regression assumption^{par}	failed to satisfy the parallel regression assumption^{par}

Table 43: Results of the stepwise ordered logistic regression analysis of the semipartial marketing ranking match versus the growth of the firms in turnover (NOTE: due to the small size of only 14 firms in turnover category 1 & 2 the first two β coefficients are unreliable)

* p<0.1; ** p<0.05; *** p<0.01

^{spc} without the indirect effect of the lacking resources, and externally attracted information

^{par} Due to failing to satisfy the parallel regression assumption a generalized ordered logistics regression has been used [3]

The parallel regression assumption has been checked by using the "omodel logit" test of Rory Wolfe, and the "brant" test of Scott Long & Jeremy Freese.

	All control variables & match	Significant controll variables & match
	β (s.e.)	β (s.e.)
Control Variables		
Age	0.188 (0.073)**	0.201 (0.071)***
Science base	-0.067 (0.461)	-
Phase	-	-
Location	β^1 = 1.131 (0.696) β^2 = 0.974 (0.502)* β^3 = 1.050 (0.509)** β^4 = -0.568 (0.510)	β^1 = 1.328 (0.687)* β^2 = 1.094 (0.494)** β^3 = 1.146 (0.502)** β^4 = -0.432 (0.497)
lacking resources	-0.839 (0.795)	-
Ext. att. information	-1.098 (0.727)	-
Matching variable		
Semipartial management ranking match^{spc}	β^1 = -0.019 (0.767) β^2 = 0.989 (0.719) β^3 = 2.250 (0.946)** β^4 = -2.769 (0.809)***	β^1 = 0.084 (0.771) β^2 = 1.129 (0.725) β^3 = 2.262 (0.929)** β^4 = -2.667 (0.775)***
N	104	104
LR Chi2	59.11***	55.70***
Pseudo R^2	0.198	0.187
NOTE	failed to satisfy the parallel regression assumption^{par}	failed to satisfy the parallel regression assumption^{par}

Table 44: Results of the stepwise ordered logistic regression analysis of the semipartial management ranking match versus the growth of the firms in turnover. (NOTE: due to the small size of only 14 firms in turnover category 1 & 2 the first two β coefficients are insignificant)

* p<0.1; ** p<0.05; *** p<0.01

^{spc} without the indirect effect of the lacking resources, and externally attracted information

^{par} Due to failing to satisfy the parallel regression assumption a generalized ordered logistics regression has been used [3]

The parallel regression assumption has been checked by using the "omodel logit" test of Rory Wolfe, and the "brant" test of Scott Long & Jeremy Freese.

	All control variables & match	**Significant controll variables & match**
	β (s.e.)	β (s.e.)
Control Variables		
Age	0.199 (0.071)***	0.220 (0.067)***
Science base	0.012 (0.459)	-
Phase	-	-
Location	0.265 (0.397)	-
lacking resources	-0.810 (0.763)	-
Ext. att. information	-1.210 (0.670)*	-1.231 (0.683)*
Matching variable		
Semipartial inv. cap ranking match^{spc}	0.341 (0.477)	0.372 (0.469)
N	104	104
LR Chi2	18.47***	16.62***
Pseudo R^2	0.0619	0.056
NOTE		

Table 45: Results of the stepwise ordered logistic regression analysis of the semipartial investment capital ranking match versus the growth of the firms in turnover. (NOTE: due to the small size of only 14 firms in turnover category 1 & 2 the first two β coefficients are insignificant)

* p<0.1; ** p<0.05; *** p<0.01

^{spc} without the indirect effect of the lacking resources, and externally attracted information

The parallel regression assumption has been checked by using the "omodel logit" test of Rory Wolfe, and the "brant" test of Scott Long & Jeremy Freese.

F. Interviews

Interview 1

- Type of firm: Engineering
- Growth: weak
- Marketing match: low
- Management match: high
- Investment capital match: high
- Age: 13 years (in 2013)

Marketing The firm uses the business network of the owner to acquire orders. After a while the firm also hired a salesperson on a performance base to acquire new orders. About one third of the orders flow through him, and about one third of the orders are direct orders from clients who know the reputation of the owner. The owner got most of his orders through the his own business network which he acquired during his previous job.

Management The firms management structure is on a project base. For each job a set of self-employed workers with a performance contract are put together to complete the job. This makes employees a more expensive but reduces the risk of losing money through sickness. Also because the employees are now responsible for their own pension this reduces the amount of work for the owner. This structure has been chosen after experiencing other ways of managing the firm. The founder has a engineering degree.

Investment capital The firm did not need external investment capital, and financed itself through own capital, and loans at the bank. In order to get a better insight in the decision making procedures of the banks the owner used the network of the "Ondernemersklankbord" to get valuable information from old directors of banks, and other companies. The firm did have half a fte in permanent service. This proved to be to risky because the employee also needed pay when he or she was sick. In order to avoid this risk the firm chose to not hire any permanent employees. In stead self-employed workers were hired, which got paid per job.

Interview 2

- Type of firm: Health care
- Age: 4 years (in 2013)
- Growth: strong
- This firm was not in the database

Marketing The firm started marketing their product from the start. The marketing can be split up in several phases, at first they marketed the idea, vision and the firm's name. By doing so they created network who supported their product. For example firms could endorse the existence of the problem which their product should reduce. In order to get the marketing going they used the network which they created through entrepreneurial contests. The advantage of the marketing in the early phase was that they attracted a launching customer. The launching customer showed to the rest of the world that the problem existed and that the product was promising. The effect of this trust was later on causing the fast growth of the firm's turnover.

Management The firm currently employs eight employees. The two founders are currently operating as the salesperson, and CEO. They hired a person to do part of the HR tasks in the firm. Every two weeks they have a meeting in which everyone tells what they are doing. They hired an external team coach for a day to map everyone's strengths, so that everyone does what he or she is best at. Both the two founders have a business degree.

Investment capital The firm used social media, the news, network meetings, Yes Delft its network, firms at Yes Delft, and entrepreneurs contest to pitch its product and thereby make the product known. Especially at the start they got useful information about the existence of these meetings from Syntens, a governmental organisation focused at boosting innovativeness in the Netherlands. They also used New Venture, an enterpreneurs contest as a way to let the world know their product by pitching it. The intention of going to these meetings is to let investors, and buyers know what your firm is about. After two years the firm hired a communications employee which role it was to keeping up the network and the communications

surrounding it. The communications employee made sure a newsletter was made to inform interested firms, a business plan was written to compete in entrepreneurial competitions, create presentations for possible buyers, and interview possible buyers to map their preferences. This method worked really well, and created a huge network. The creation of this network of interested firms contributed greatly to the growth of the firm.

Interview 3

- Type of firm: Software
- Age: 4 years (in 2013)
- Growth: average
- This firm was not in the database

Marketing The firm started marketing their services right after it started to acquire order. In order to obtain these orders the owners first used their own network at social meetings. During these social events they would meet acquaintances which knew someone who was probably interested. This quickly resulted in orders. Next to their own personal network the firm also used the demand for software of firms at Yes! Delft to obtain orders. An other effective way through which the firm obtained orders is through pitching their service at network meetings.

Management The management approach of the firm is to let everyone know what they should do on a macro management level. An example is that the management of the firm monitors whether the product is still aligned with the wishes of the buyer. According to the owner and CEO the engineers often want to build to advanced software packages, which is not demanded by the buyer and therefore makes the software unnecessary expensive. The management style of the firm is after the business structure of Valve.

Investment capital The firm is completely self funded because it does not need to invest much in hardware to perform its business. It might be that in the future projects might arise which need a lot of marking to become successful. If so the firm will look at the options at that time.

Interview 4

- Type of firm: Aviation/ space technologies
- Growth: average
- Marketing match: low
- Management match: high
- Investment capital match: high
- Age: 8 years (in 2013)

Marketing In order to sell their products the firm used either to cold sell their product to possibly interested firms, however this did not work well. In order to get the firms interested in buying their technology they needed to know someone inside the buying firm, or someone who knows someone inside the firm. Network meetings help a great deal to find those persons.

Management The company is structured flat, and there are projects which are run by project managers. The two owners are purely managing the firm, and obtaining subsidies. They did not have a managing background but in stead went to a lot of courses, used their network to learn management skills, and used a coach to coach them and their firm.

Investment capital The two investors which were attracted to fund the firm were found through the Yes! Delft network. These investments have contributed to the growth of the firm. In addition they also made it possible to further develop their own products and patents without the need for the firm to perform consultancy work.

Answers per e-mail

One firm did not have time for a face-to-face interview but send the answers to the questions instead.

- Type of firm: Aviation/ space technologies
- Growth: strong
- Marketing match: low
- Management match: low
- Investment capital match: average
- Age: 8 years (in 2013)

Marketing The firm started marketing activities focused at selling their services and future products at the start of the firm. Due to the high-tech nature of the sector, and the technical nature of the product the firm is selling the meetings were quite personal. By having a lot of meetings between the employees of the firm, and the possible buyers the firm learned how to sell its products. This self learning technique started to generate more turnover, and more employees after 6 months.

Management The firm started off with four employees which were basically all directors. However this gradually changed to the current situation, which is two directors, middle-management, and in total around 40 employees. In order to facilitate the growth the firm changed from a flat organisational structure, to a hierarchical organisational structure, to a matrix/ project structure. The firm learned to change its organisational structure by doing, and is only currently focussing on training and external advice to improve the organisation.

Investment capital In order to get information about investment capital the firm used the bank, venture capitalists, and advisor's in its network. Until now this strategy did not result in investors actually investing in the firm. It did however create an ongoing dialogue between the investors and the firm.

G. Literature study

G.1. Search method

To identify what research has been done surrounding open innovation, firm performance and spin-off firms it is necessary to find related articles. In order to find the relevant articles Google Scholar, Scopus and Web of Science were used to search for articles. All three of the search engines were used because their databases do not contain the same articles. Using the three databases therefore broadens the amount of articles which can be found. Also in a later stadium it gives the possibility of indicating which article is more and which is less important (if articles are in all 3 databases they are probably more important). To reduce the amount of unrelated articles, the keywords needed to be in the titles of the articles. The number of hits per search criteria and database are shown in table 46.

The research objective is to determine the effect of open innovation on the firm performance of academic spin-off firms. Therefore the keywords open innovation, spin-off and firm performance are important to search for. Since the research is about how open innovation influences firm performance the combination of the two will also be used to search. The same applies to open innovation and spin-off firms. Since the research will be focussing on academic spin-off companies the combination of open innovation and spin-off will also be used to search. Also since some articles use cooperative R&D as a synonym for open innovation the term cooperative R&D will also be used as a keyword.

In order to properly select articles out of the results the following selection procedure was used. First the articles were reordered in order of times cited. After the articles were reordered the titles and abstracts of the first 40 articles would be assessed on usefulness. The selected articles can be found in table 47 and the detailed information about the selected articles can be found in section G.2.

search Criteria	**comments**	**number of hits** Scholar/ Scopus/ Web of Science
"open innovation"	Good for finding general articles about Open Innovation	2620/ 492/ 327
"open innovation" "firm performance"	Good for finding articles linking open innovation to firm performance	5/ 2/ 2
open innovation performance	Good for finding different effects of open innovation on performance	53/ 21/ 15
"cooperative R&D"	Used to find articles using the synonym cooperative R&D instead of open innovation	158/ 72/ 57
"open innovation" spin-off	Good for finding articles that examine open innovation in spin-off firms	4/ 1/ 1

Table 46: Number of hits per database

search Criteria	**selected Articles**
"open innovation"	- Beyond high tech: early adopters of open innovation in other industries - Towards a Theory of Open Innovation: Three Core Process Archetypes - Open R&D and open innovation: Exploring the phenomenon
"open innovation" "firm performance"	- Open innovation and firm performance in small-sized R&D active companies in the chemical industry: the case of Belgium - Outbound open innovation and its effect on firm performance: Examining environmental influences
open innovation performance	- Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms
"cooperative R&D"	- Cooperative R&D and firm performance
"open innovation" spin-off	- Open innovation among university spin-off firms: what is in it for them, and what can cities do?

Table 47: Articles found per search criteria

The selected articles are important either because they are often cited or because their subject is close to the research subject and are therefore useful for the research. After the articles were selected a short summary and useful features were determined see section G.2.

The literature on which my research was build are shown below in section G.2. The search method used to find these articles can be found in appendix G.1. Some articles might be added

during the research, and were therefore not necessarily found by using the keywords in appendix G.1.

G.2. Selected articles

Beyond high tech: early adopters of open innovation in other industries

Chesbrough, H., Crowther A.K. 2006, Beyond high tech: early adopters of open innovation in other industries. *R&D Management*, 36 (3), pp. 229-236.

database	times cited
Schollar	432
Scopus	162
Web of Science	109

Table 48: Times cited per database

Short Summary: The article describes how the early adopters of open innovation in non high-tech industries use open innovation. Their research was conducted among big companies with revenues of around $1-$5 billion. In their research they focussed on both inbound and outbound open innovation. After interviewing the companies they determined key success factors, showed successful practices and adoption challenges of the companies [29].

Useful features: It is useful to know that research has been done in both high-tech and non high-tech industries. It is interesting to know that open innovation is being adopted in both high- and low-tech industries. It is also interesting to know what the success factors for open innovation are in low-tech industries.

Cooperative R&D and firm performance

Belderbos, R., Carree, M., Lokshin, B. 2004, Cooperative R&D and firm performance. *Research Policy*, 33, pp. 1477-1492.

database	times cited
Schollar	485
Scopus	155
Web of Science	134

Table 49: Times cited per database

Short Summary: The article of R. Belderbos shows what the effects of open innovation are on firm performance. They used 2 consecutive CIS surveys conducted in 1996 and 1998 to come up with 2353 innovating firms. They analyse what cooperation with competitors, suppliers, customers and universities does to the overall firm performance and find that all 4 factors positively influence firm performance [30].

Useful features: The paper has an interesting and useful finding about companies selling products and services new to the market and collaboration with universities. It states that collaborating with an university in this field has an positive effect on product sales. "cooperation with universities and research institutes and again competitor cooperation positively affects growth in sales per employee of products and services newto the market. New product sales are furthermore stimulated by incoming knowledge spillovers (not due to collaboration) from customers and universities and research institutes." [30, p. 1488]

Towards a Theory of Open Innovation: Three Core Process Archetypes

Gassmann, O., Enkel, E. 2004. Towards a Theory of Open Innovation: Three Core Process Archetypes. *R&D management conference*

database	times cited
Schollar	232
Scopus	-
Web of Science	-

Table 50: Times cited per database

Short Summary: The paper by O. Gassmann is about dividing the open innovation process

into three archetypes.

- "Outside-In process: Integrating external Knowledge, Customers and Suppliers" [31, p. 7]
- "Inside-Out process: Bringing ideas to market, selling/licensing IP and multiplying technology" [31, p. 7]
- "Coupled Process: couple outside-in and inside-out process with complementaries" [31, p. 7]

After defining the three archetypes the article explains what the effects on a company are if a company chooses to adopt one of the three processes. [31]

Useful features:This paper is focussing on open innovation within SME's and not on collaboration with universities. It does give insight in the general concept of open innovation by creating a new theory.

Open innovation among university spin-off firms: what is in it for them, and what can cities do?

van Geenhuizen, M., Soetanto, D.P. 2012. Open innovation among university spin-off firms: what is in it for them, and what can cities do?. *The European Journal of Social Science Research*, 25 (2), pp. 191-207.

database	times cited
Schollar	-
Scopus	0
Web of Science	0

Table 51: Times cited per database

Short Summary: The paper investigates which types of open innovation are enhancing the growth of academic spin-off firms. It does so by analysing both surveys and in depth inter-

views. [1]

Useful features: Although the paper isn't cited the paper is still of use since it uses the spin-off firms in their research.
The paper gives insight in the effectiveness of open innovation. "model estimation of growth revealed trends of negative influence of dense networks and strong relationships, and positive influence of heterogeneous partners and an orientation outside the local boundaries." [1, p. 203]

Open innovation and firm performance in small-sized R&D active companies in the chemical industry: the case of Belgium

Teirlinkck, P., Poelmans, E., 2012. Open innovation and firm performance in small-sized R&D active companies in the chemical industry: the case of Belgium. *Journal of Business Chemistry*, 9 (3), pp. 117-131.

database	times cited
Schollar	0
Scopus	-
Web of Science	-

Table 52: Times cited per database

Short Summary: The paper is about the use of open innovation by Belgian small-sized enterprises in the chemical industry. In its analysis the paper looks at the openness of the firm versus the firm performance, absorbtive capacity, company age, long term orientation and Formal R&D Management [32].

Useful features: Despite not having any citations the paper is still useful because it is about small enterprises, which is close to start up firms. The paper is about SME's in the chemical sector of Belgium. However the findings correspond to those of the other papers. Firms making use of open innovation outperform firms which don't make any use of open innovation.

Open R&D and open innovation: exploring the phenomenon

Enkel, E., Gassmann, O., Chesbrough, H., 2009. Open R&D and open innovation: exploring the phenomenon. *R&D Management*, 39 (4), pp. 311-316.

database	times cited
Schollar	246
Scopus	101
Web of Science	51

Table 53: Times cited per database

Short Summary: This article combines the findings of some of the most active authors in the field of Open Innovation. [33, p. 313]

Useful features: The paper is a special issue in which several papers are being discussed. The paper gives an overview of past research in the field of open innovation.

OPEN FOR INNOVATION: THE ROLE OF OPENNESS IN EXPLAINING INNOVATION PERFORMANCE AMONG U.K. MANUFACTURING FIRMS

Laursen, K., Salter, A., 2006. OPEN FOR INNOVATION: THE ROLE OF OPENNESS IN EXPLAINING INNOVATION PERFORMANCE AMONG U.K. MANUFACTURING FIRMS. *Strategic Management Journal*, 27, pp. 131-150.

database	times cited
Schollar	1149
Scopus	422
Web of Science	-

Table 54: Times cited per database

Short Summary: The paper examines the relation between the firms external search strategies and innovative performance. [34, p. 131] In its analysis the paper focusses on two new concepts:

- Search breadth: "the number of different search channels that a firm draws upon in its innovative activities" [34, p. 135]

- Search depth: "the extent to which firms draw intensively from different search channels or sources of innovative ideas" [34, p. 136]

Useful features: The paper shows a new concept, bread and depth and uses this to examine the effect of those variables to innovative performance. A second interesting aspect of the paper is the size of the database (2707 firms).

BENEFITS FROM LEARNING NETWORKS IN OPEN INNOVATION. SPIN-OFF FIRMS IN CONTRASTING CITY REGIONS

van Geenhuizen, M., Soetanto, D.P. 2013. BENEFITS FROM LEARNING NETWORKS IN OPEN INNOVATION. SPIN-OFF FIRMS IN CONTRASTING CITY REGIONS. *Forthcoming in European Planning Studies*.

Short Summary: The paper examines the difference between spin-off firms in a metropolitan area (TU Delft) and isolated area (Trondheim). In the comparison the paper looks at the density of the networks, strength of ties, heterogeneity, and the external orientation of the spin-off firms. The paper then compares these characteristics of spin-off firms to the growth of the spin-off firms.

Useful features: The useful features of the paper are that it determines the effect of using open innovation on the growth of the spin-off firms. The paper also gives insight in how to use certain variables.

Network Learning: Exploring Learning by Interorganizational Networks

Knight, L. 2002. Network Learning: Exploring Learning by Interorganizational Networks *Human Relations*, 55 (4), pp. 427-454.

Short Summary: This paper analyses four concepts; networks, organizational learning, interorganizational learning, and learning networks. The paper then continues with an exploratory study about learning in networks.

Useful features: Useful features of this paper is the explanation of the concept of interorganizational learning.

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