CRITICAL DIVERSITY IN BOOSTING THE ROLE OF UNIVERSITIES IN THE REGIONAL ECONOMY: AN INTERNATIONAL PERSPECTIVE

Marina van Geenhuizen **

Danny Soetanto*

Abstract

Universities are increasingly seen as important players in the regional economy, among others through their contribution to the rise of new high-technology companies and mechanisms of knowledeg valorization. Regional-economic development and the creation of academic research clusters are becoming more and more mutually intertwined dynamic forces. In this paper, we argue that diversity is a major supporting condition to growth in knowledge valorization, particularly because of different needs in learning and innovation. The focus of analysis is on the growth rate of incubators in a comparative study across the developed world and on differences in growth rate between spin-off companies in a local contrasting study, i.e. concerning Delft University of Technology in Delft in the Netherlands and NTNU in Trondheim, Norway. The overall conclusion is that diversity matters in many ways in a positive sense. This holds particularly for diversity in stakeholders in the incubation initiative and for diversity in social background of partners in networks of spin-offs through which learning and innovation take place.

Despite a different incubator development in Delft and Trondheim, the growth patterns of incubated spin-off firms turned out to be roughly similar. The social networks, however, turned out to be different in structure and shape, i.e. relatively open, strong and more often outside the local in Delft, as opposed to relatively closed, weak and local-oriented in Trondheim. One characteristic is similar, that is heterogeneity in social background of partners. Of all four network characteristics studied, it is precisely this factor that tends to influence growth in the same (positive) direction in both cities. An important difference is concerned with strength of relationships: stronger relationships tend to hamper growth in Delft but tend to stimulate growth in Trondheim. As far as the role of proximity in social networks is concerned, we gained the result that employing networks over larger areas tends to enhance growth in Delft, not in Trondheim. Based on the results, we may assume that spin-offs in Trondheim have adapted themselves in gaining a quicker growth from locally available knowledge by efficiently using capabilities and support, and by stronger relations with local partners compared to Delft's spin-offs. All in all, we found more differences than similarities between the two contrasting cities in impact of the social network profile. The only similarity, however, stands clear and that is a positive influence of heterogeneous networks.

Key words: technical universities, spin-off companies, incubators, social knowledge networks, diversity, Delft University of Technology, National Technical Norwegian University.

** Delft University of Technology, Faculty of Technology, Policy and Management, OTB Research Institute.

* Delft University of Technology, Faculty of Technology, Policy and Management.

1. Valorization of Knowledge

In the era of the knowledge-based economy no country or region can improve its innovation performance and competitive position without well-performing education and research. Increasingly, universities and research institutes are assigned a third mission, and that is the valorization of knowledge. This means that universities and research institutes today are actively involved in bringing their knowledge to market.

Until a few decades ago, the idea was that a science-driven education would create good students who would apply the academic knowledge after the completion of their studies. Universities were more or less solid bastions of independent research, not directly engaged in real world applications. This traditional view on academic institutions is clearly reflected in various regional impact studies of universities where the main regional-economic effects of universities were estimated on the basis of multiplier studies related to expenditure patterns of universities' staff and students (e.g., Armstrong and Taylor, 2000). The commercial and industrial ('generative') effects, like the ones derived from knowledge valorization, were often overlooked.

In recent years, we have witnessed a much more direct involvement of academic institutions with commercialized knowledge acquisition and technology transfer (e.g. Hackett and Dilts, 2004). Universities are no longer an oasis in a rapidly changing environment; they follow a tidal movement in response to the request of society to offer not only societal relevance but also socio-economic and technological returns ('value for money'). The margins between the university systems and the commercial system sometimes have become fuzzy and sometimes very thin (Leydesdorff, 2003; Nowotny et al., 2001). At present, not only most US universities but almost all universities have moved their mission and orientation towards commercialization of their knowledge. The reasons for this development are manifold:

- A shortage of funding from the side of public bodies.
- Accountability to policy-making bodies and the public at large.
- Insufficient utilization of results of publicly financed research at universities for commercial applications (in the EU the "knowledge paradox").
- Reduction in basic research in large corporate firms with the necessary consequence that publicly financed universities are pushed in this vacant positions.
- Changes in the research system itself (e.g. biomedical technology) where academic inventions in various key sectors incorporate a potentially high economic value which through Intellectual Property Right (IPR) regulations may need to be protected and through subsequent licensing may be translated in monetary revenues.
- The rise of a knowledge-based society causing academic institutions to be much more strategic spearheads of accelerated economic growth, with the consequence that science-based clusters (e.g., science parks) around universities are arising .

As a result of all these changing circumstances, regional-economic development and the creation of academic research clusters are becoming more and more mutually intertwined dynamic forces (Etzkovitz, 2002; Feldman, 2006; de Groot, 2004; Rothaermel and Ku, 2008). In this paper we will offer some background observations, describe some empirical developments concerning the desired growth of spin-off companies from universities, and provide some strategic policy lessons and future research paths.

2. Universities, spin-off processes and learning

Universities have a longstanding tradition as a knowledge creator, but not as a wealth creator. As indicated above, this position of universities has changed. Indeed, universities are often nowadays involved in what is named knowledge valorization, or in other words adding value to new knowledge in the process of transforming it into a new product, process or organizational principle to be introduced to market (PriceWaterhouseCooper, 2007). Although knowledge valorization as a process may inhibit cyclic developments and sometimes chaotic characteristics, most authors to date use a chain model of valorization activity. Accordingly, the chain starts with the idea of researchers to bring an invention to market and ends – if successful - with the actual introduction in the market. Knowledge valorization is a relatively new term covering activities that are basically not new (see, e.g. Charles and Howells, 1992 on the state of university – business activity in the early 1990s in Western Europe). What is new today is that knowledge valorization is increasingly recognized to be the third mission of universities including the establishment of budgetted valorization centres or institutes, and that the actors involved recognize that knowledge valorization has a multidimensional and complex character, and is differentiated in types of learning. The latter is connected with the fact that knowledge may have various "carriers" like codified sources, labour force endowed with skills and experience, patents, machines and instruments, etc. As a result, knowledge valorization deals with manifold activity like contract-research commisioned by large firms, licensing of patented knowledge to firms, activity of spin-off firms engaged in furher development and testing of a university invention, etc. , but also with the flow of graduates into the labour market (e.g., d'Este and Patel, 2007). One of the most visible (not necessarily most important) modes of knowledge valorization is the establishment and growth of university spin-off firms.

There are several reasons for a strong orientation of a university and city/region on potential benefits from enhancing spin-off processes. Shane (2004) distinguishes the following elements:

- University spin-offs create local economic development (through innovation, application of advanced technology and stimulation of an R&D climate).
- Spin-offs generate economic value (through financial assets), accelerate access to commercialized knowledge and the creation of a business climate.
- Spin-offs create employment in terms of skilled labor, but also indirect labor market effects.
- Spin-offs induce private investments in university technologies (through commercial initiatives such as patenting and licensing).
- Spin-offs call for new research initiatives (through a successful commercialization of an invention there will be a call for new inventions in a competitive environment).
- Spin-offs are breeding ground for young talent (e.g., by offering internships and training facilities to students).

It is thus evident that modern universities are nowadays operating in a completely different force field compared to a few decades ago. Two aspects are noteworthy here. First, the orientation of university research towards market value calls for a new regulatory system (witness the Bay-Dole Act in the US) in which the new force field of publicly founded research institutions is set out. And second, the development of a successful spin-off policy puts high demands on local and regional public authorities to orient regional development initiatives (e.g., infrastructure, suprastructure, incubators) towards promising R&D initiatives geared to the application of new knowledge in the area concerned. Overall, university-industry-government relations, also named Triple Helix, can be seen as adaptive networks that change over time in response to different dynamics in their environment. The networks fulfill three core functions, i.e. knowledge production, wealth generation and governance (control). One of the clearest changes over time is a blurring of the edges between the functions of each of the three actors. Thus, in Western Europe and North America, universities have become more entrepreneurial, whereas large companies have started knowledge production-based education in campuses hosting training in specific academic fields; and governments are increasingly engaged in enhancing the knowledge-based economy by improving conditions for entrepreneurial innovation. There seems no end in the above changes, meaning a continued integration and hybridization of functions in the coming years, although the starting point and pace of changes may differ across countries (Viale and Etzkowitz, 2005).

Regional development policies to enhance knowledge valorzation may be relatively general in aim by encompassing different high-technology areas, like micro-electronics, optronics, nanotechnology, informatics and computational science and biotechnology, or specifically focusing on one or two related areas like biotechnology. But it needs to be mentioned that learning models are quite different between sectors, leading to different needs of spin-offs in these sectors (Asheim et al., 2007). For example, in life-sciences and material science learning deals with formal scientific models that can be universily applied using highly codified knowledge. In contrast, in mechanical engineering (e.g. medical instruments and mechatronics) the learning is mainly based on problem-solving using large amounts of tacit knowledge (connected with practical skills) in a context-specific way.

We now turn to our empirical study to show how regional (local) initiatives to nurture academic spin-off companies may differ in design and in results.

3. Incubators in a Global Comparison

Theoretical ideas

Incubators are perceived in this paper as organizations that create a supportive environment for firms to get started and to survive the first years. Incubator organizations as part of a university usually employ one or a few buildings in which they offer cheap and flexible rooms and supporting (secretarial) services, while some offer rooms spread over various on campus faculty buildings. A new development is the networked incubator, particularly the non-physical version or virtual incubator, merely working as an electronic network organization (Hansen et al., 2000). By nature, incubators support start-ups on a temporary basis, e.g. three or four years. We examine, based on results of a study of the literature, six factors that may influence the growth rate of incubators, i.e. variety in the involvement of stakeholders, the overall incubation strategy and the model of support, the age of the incubator as an organization, the entrepreneurial culture in the area and the level of urbanization of the region.

Incubators differ in the kind of stakeholders involved in the establishment and management, leading to differences in creative atmosphere and richness of resources. We may observe incubators mainly organized by a university or research institute, as well as incubators that internalize the triadic relationships between the university, government and industry and the hybridization of their roles (Etzkowitz, 2002; Leydesdorff, 2003). The involvement of different stakeholders – as opposed to the involvement of merely the university – implies a potential access to more varied networks and resources and the ability to better respond to heterogeneity in learning and needs for resources among incubated start-ups (Bølllingtoft and Ulhøi, 2005; Druilhe and Garnsey, 2005). Thus, we may assume that the multiple stakeholder model brings about a more dynamic growth compared with the single stakeholder model. The next two institutional factors represent choices made by incubator organizations and their stakeholders, that is, the overall incubation strategy and the model of support. Hannon and Chaplin (2003) identify two incubation strategies in the United Kingdom, i.e. pure incubators and flagship models. The pure incubators are traditionally established by universities and seek to exploit university potentials by nurturing firms that commercialize research results. The flagship model, on the contrary, originates also from initiatives by local/regional governments, or real estate developers, and tends to be more profit-oriented due to higher initial investment and running costs. More recently, besides the flagship strategy, incubators are emerging that also employ a certain level of profit-seeking and invite start-ups from outside the university to join the incubation program. We expect the latter incubators to grow faster than the traditional ones, because they face an inflow of more varied knowledge and face participation in more diversified networks. With regard to the model of support, we argue the following. Conventional support mainly deals with the provision of tangible assets, e.g. room and basic office services, laboratory facilities and financial support. However added-value support includes support in connecting start-ups to relevant networks, like business angel networks, and new methods in business mentoring and training to increase the spin-offs capability to survive. Value-added support may also include help in exit strategies. We may assume that an emphasis on value-added support accelerates the growth of incubated start-ups, thus increasing the number of incubated start-ups per year.

In managing an incubator, experience and professionalism in selection, monitoring and coaching of start-ups seem critical (Smilor et al., 1988). A study in the US shows that it takes several years for incubators to become mature, in terms of gaining the capability to organize themselves efficiently, access the most fertile networks and produce independent and viable firms on a continuous basis (McKinnon and Hayhow, 1998) Although learning is not a linear process, it increases with age. Accordingly, we may assume that the growth of incubators is stronger with increasing age. With regard to influence of entrepreneurial culture, we argue the following. An important dimension of entrepreneurial culture is uncertainty avoidance (Hofstede, 1991). Countries facing high levels of uncertainty avoidance generally show a tight regulation of entrepreneurship and an accepted resistance to enter new, risky avenues. By contrast, in countries with low levels of uncertainty avoidance, there is room for differentiation, experimentation and risk-taking in business operations. The latter entrepreneurial climate is also believed to stimulate incubator organizations to be more active and creative in searching for new possibilities of supporting their ventures. All this may lead to a more dynamic growth of incubators. The last factor to be considered here is concerned with differences in the urban environment of the incubators, particularly the spatial concentration of human capital and knowledge. Jacobs (1961) draws attention to metropolitan cities in attracting and mobilizing talented and creative people. In a similar vein, a growing stream of more recent research has focused on factors that attract talented people (Glaeser et al., 2001; Florida, 2002). This has led to the understanding that metropolitan cities providing a high diversity in amenities, entertainment, art facilities and lifestyle, have important advantages in attracting and keeping talented and creative people and in strenght of entrepreneurial communities. Therefore, we assume that incubators in metropolitan cities grow relatively fast; this in contrast with incubators in rural areas and peripherally located regions.

Note that – with regard to the model of incubators - capacity indicators like size of the buildings and budgets of incubator organizations remain beyond our analysis because we focus on strategic factors. For the same reason, operational details like access criteria and time-length of incubators' support fall outside the study.

A differentiated growth of incubators

The selection of incubators took three specific requirements into consideration. First, to be a technology-related incubator; this type of incubators supports mainly technology-based start-ups and employs institutional links with and/or is located close to a university or research center. Secondly, to face a similar time-frame; incubators in the 1980s cannot be compared with those in the 1990s because of the potential influence of different macro-economic factors. And thirdly, to face particular characteristics in one (or more) of the six determining factors of growth of incubators. Our main data sources were paper journals, conference proceedings, annual reports of incubators, and incubators' websites. As a result of the above selection process, we established a set of 40 incubators (base population) in various developed countries For various testing procedures we have drawn 10 random samples from this population (see for more details, Soetanto and Van Geenhuizen, 2007).

The data concerning the incubators are largely qualitative in nature. Hence, a special statistical technique is required to arrive at testable solid results. We made use of rough set analysis to identify the strength of the above six factors in explaining differences in growth of incubators in various developed countries. Growth, measured as an average number of new spin-offs (entrants) per year in the years 1998-2002, varied between – 3.0 and + 7.0. The frequency distribution allowed for a division of the incubators into two classes, i.e. those experiencing a relatively strong growth and those experiencing a relatively weak growth.

Rough set analysis enables the transformation of an imprecise or incomplete (fuzzy) collection of data, both quantitative and qualitative, into structured knowledge (Pawlak, 1991). Unlike conventional methods that are based on statistical assumptions, this analysis makes the only assumption that the value of the determining factors can be categorized. In particular, rough set analysis is able to incorporate different measurement scales and different degrees of measurement accuracy, and proved proved to be successful as a tool of analysis in different areas (e.g. Goh and Loaw, 2003; Nijkamp et al. 2002; Van Geenhuizen and Nijkamp, 2007). In rough set analysis, the dependent variable is named the *decision* attribute (in our study, growth of incubators) and the independent (explanatory) variables are named *condition attributes* (in our study, model of stakeholders' involvement, type of urban location, risk avoiding attitude, model of support, incubation strategy and age of the incubation organization). Rough set analysis produces a set of *decision rules*, presented in an ''IF condition(s) … THEN decision'' format. Condition attributes that are in the so-called *core* have the strongest explanatory power; these are indispensable in explaining the variation in the decision attribute. All other condition attributes appear at a lower frequency in the rules. In general, a high frequency rate of individual condition attributes in the decision rules means that these attributes stand out in a more pronounced way than others. In addition, the *coverage* indicates the strength of the rules based on the rate in which objects in a subset with the same decision attribute support the decision rule. In our study, the rough set estimations were conducted using ROSE2 software (Predki and Wilk, 1999) (note 1). In our analysis of 10 samples (each of approximately 25 incubators) derived from the base population of 40 incubators, seven strongest rules could be identified concerning a weak growth and five strongest rules could be identified concerning a strong growth (Table 1). We used two measures in exploring the explanatory power of the rules, (1) the frequency of individual condition attributes in the strongest rules and (2) the frequency of the strongest rules in the samples.

With regard to the first measure, the frequency of each *condition attribute* in the strongest rule was divided by the total number of strongest rules in that class of growth (weak or strong). For example, regarding a weak growth, the model of stakeholders' involvement (C1) faces a frequency rate of 43% ($3/7 * 100\%$).

Table 1. Frequency of individual condition attributes in the strongest rules*

Weak growth (strongest rules)	C1	C2	C3	C4	C5	C6
Frequency of appearance (%)	43.0 (3/7)	29.0 (2/7	43.0 (3/7)	57.0 (4/7)	43.0 (3/7)	14.0 (1/7)

Strong growth (strongest rules)	C1	C2	C3	C4	C5	C6
Frequency of appearance (%)	60.0 (3/5)	60.0 (3/5)	20.0 (1/5)	0	40.0 (2/5)	20.0 (1/5)

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

On the basis of these outcomes, various condition attributes have a strong classificatory power:

1. conventional support (C4) for weak growth (57%); this confirms our idea of a modest impact of support that is merely tangible and fails to train individual start-ups in strengthening business capabilities;
2. multiple stakeholders' involvement (C1) for a relatively strong growth (60%); this also confirms our expectations, in that the involvement of different stakeholders in steering the incubator introduces a favorable diversity of resources, including networks and knowledge flows;
3. location in non-metropolitan areas (C2) for a relatively strong growth (60%); different from the previous outcomes, this outcome cannot confirm our expectations.

There may be two explanations for the last, unexpected, result. First, in Europe, particular non-metropolitan areas receive targeted regional development assistance from the EU and the country, causing the establishment and operation of incubator facilities to be less costly, a situation that enables the supply of a wider range and higher intensity of support to spin-offs. Secondly, in dense metropolitan areas the incubation process may work rather spontaneously, particularly in older city quarters on the fringe of the central business district with plenty supply of cheap accommodation, thereby reducing the role of incubators and causing them being almost redundant. With regard to the remaining attributes - risk avoiding attitude, incubation strategy, and age of the incubator organization – we note a minor importance (Table 1).

Next, we examined the pattern of strongest rules as combinations of particular condition attributes. The focus was on the frequency in which the *strongest rules* (top three for each sample) appear in the 10 samples. Two strongest rules appeared in more than three samples with one of them appearing in a majority of the samples (6 out of 10) (Table 2). These rules include (1) the combination of the model of stakeholder involvement (multiple) with urban conditions (non-metropolitan areas) (C1 & C2), and (2) the model of support provided to the start-ups combined with the type of incubation strategy (value-added support and a limited profit-focused strategy) (C4 & C5), and refer both to strong growth.

Note that the validity of the outcomes of this analysis depends on how well the selected incubators represent the different types of incubators in developed countries. In any case, the analysis is rather robust because the prediction accuracy of the rules, measured as the share of correctly predicted cases using new samples, turned out to be around 75% (Soetanto and Van Geenhuizen, 2007). We now move to a detailed analysis of growth of academic spin-off companies, in two of the studied incubators, i.e. Delft University of Technology (in the city of Delft, the Netherlands) as a slowly growing incubator and National Technical Norwegian University (in the city of Trondheim, Norway) as a quickly growing incubator.

Table 2. Frequency of appearance of the strongest rules in the 10 samples

Strongest rules (a)	Frequency in the 10 samples (%)	Strong growth	Weak growth
C1 & C2	60.0 (6/10)	3	3
C4 & C5	40.0 (4/10)	2	2
C1 & C5	30.0 (3/10)	1	2
C1 & C6	20.0 (2/10)	0	2
C2 & C5	20.0 (2/10)	2	0

(a) C1-C6: The condition attributes (model of stakeholders' involvement, level of urbanization, uncertainty avoiding attitude, model of support, incubation strategy, and age of incubator).

4. Growth of Spin-offs in Two Contrasting Cities

Theoretical ideas

In general, the connection between the growth of incubators in terms of numbers of new entrants and the growth of spin-offs in terms of employment lies in the fact that incubators grow more quickly in throughput if the incubated firms grow more quickly and qualify for an early exit from the incubator (shorter stay). We now turn to individual spin-offs in Delft and Trondheim to explore whether differences in growth can be attributed to factors representing diversity in the business environment and in socioeconomic networks.

On the basis of the literature, we have focused on four socioeconomic aspects of knowledge networks: tightness, strength, heterogeneity and spatial proximity of network partners. Note that the literature is not conclusive on whether particular network characteristics (like rather loose relationships or a strong heterogeneity of the social background of network partners) contribute to growth. For example, some scholars adhere the idea that tight networks are beneficial for the transfer of complex and tacit knowledge, development of trust and comfort, and joint problem solving (Coleman, 1990; Uzzi, 1996). By contrast, Granovetter (1973) argues that loose networks cause benefits from diversity in knowledge flow and brokerage opportunities created by a lack of connections. In addition, Marsden (1987) shows that partners integrating different spheres of society facilitate more efficient actions than partners that are similar in background. In this latter respect, there is more or less consensus in the literature: the more heterogeneous the partners, the more variety in the resources (including knowledge) captured by spin-off companies and the better the performance.

With regard to spatial proximity in the networks, we may forward the following viewpoints. Local (regional) networks, according to proximity approaches, yields the benefits of knowledge spillovers (avoided costs of knowledge exchange) and local learning through frequent interaction in person and high levels of trust (Audretsch, 1998; Maskell and Malmberg, 1999), but the dominant mode of learning and innovation (scientific, engineering like and artistic) may play a role (e.g. Asheim et al., 2007). Following Camagni (1991), it seems that close proximity between spin-offs and network partners supports the gaining of new knowledge (reduction of uncertainty) thereby enhancing growth of spin-offs. On the other hand, local networks may also produce the above-indicated disadvantage of strong ties preventing new knowledge to be recognized and absorbed by the spin-offs.

Regarding the two different types of support (conventional support and value-added support combined with conventional support, as discussed in the first part of this paper) we expect that spin-offs that experience a balanced mix of conventional support and value added support grow quicker compared with spin-offs that experience a poor mix. In the remaining section, we will explore and test the above ideas and assumptions.

A similar growth, but different networks

The study draws on a survey of university spin-offs of TU Delft (Delft, the Netherlands) and NTNU (Trondheim, Norway). We delineated the population of spin-offs on the basis of three criteria, i.e., located in Delft or Trondheim or surrounding area, survived in 2006, an age not older than 10 years, and use of at least one type of support from the university or incubation organization. We approached all firms in this population and obtained a response rate of 78% for TU Delft (59 cases out of 76) and 55% for NTNU Trondheim (41 cases out of 74). Data were collected using a semi-structured questionnaire in face-to-face interviews with entrepreneurs. Our database only includes spin-offs that survived, meaning that non-survivors fall outside the analysis, a common situation in this type of research. Of course, this situation calls for an investigation of bias due to excluding non-survivors (e.g. through using Heckman selection model) because the aim of the research is to identify factors influencing growth. However, in the European Union in general, survival rates of university spin-off firms are rather high. Mustar et al. (2007) assess that 75% of the spin-offs are still alive after six years. In-depth interviews in Delft and Trondheim confirm the findings by Mustar et al., indicating a rather small potential bias in the results due to excluding non-survivors.

We measured the dependent variable, job growth, as average annual job growth in 1996-2005. Despite the difference in incubator growth, the growth rate of individual spin-off firms from TU Delft and NTNU Trondheim appear to be almost similar, i.e. modest over the past years (1996-2005). Almost 60% experience a very small growth or fails to grow, i.e., 1 full-time equivalent (fte) or less per year. Only a good 20% grow with >1.5 fte or more per year. Spin-offs from TU Delft and NTNU Trondheim face an almost equal average annual growth, witness 0.87 and 0.90 fte respectively. This pattern fits into the general slow growth in the European Union, i.e. 80% of survivors (after six years) have less than 10 jobs (Mustar et al. 2007). Below, we explain how the factors influencing growth of spin-offs were measured. The various independent variables representing the components of the growth model were measured as follows (details are in Soetanto and Van Geenhuizen, 2009).

- *age* as number of years since establishment;
- strategy, resources/capabilities, support: *risk-avoidance* in strategy as a composite indicator reflecting differences in risks between manufacturing and services and different innovation intensity; *general capability* as a composite indicator reflecting differences in pre-entry experience of the entrepreneurs and in capacity related to the type of start (team start or single start); *resource deficiency* as an indicator concerning the number of missing key resources, and *richness of support* as an indicator reflecting the amount of value added support;
- networking: *tightness* (density) of network based on the amount of existing versus potential relations; *strength of relationship* as a composite indicator reflecting frequency of interaction, duration of the relationship and the quality of the relationship; *heterogeneity of partners* based on the share of heterogeneous partners in all partners; and, *spatial network orientation* as the number of external partners versus the number of local partners (E-I index).

In measuring networks we used the so-called *ego-centric* approach, by focusing on individuals (the entrepreneurs) rather than on complete networks (sociocentric approach in network analysis). Accordingly, the interviews served to identify and characterise the partners in networks qualified by the entrepreneur as important in knowledge exchange and in learning on business matter.

Delft and Trondheim can be described as contrasting cities as follows. Delft is located in a highly urbanized area in the western part of the Netherlands (Randstad), while Trondheim is in the centre of Norway, at a distance of several hundred kilometres from other cities, like Bergen and Oslo. Delft has a population of almost 95.000 and Trondheim of 162.000 (municipal level, in 2006). Delft is in-between the agglomeration of The Hague (approximately 600.000 inhabitants), the administrative capital of the Netherlands, and the agglomeration of Rotterdam (1.000.000 inhabitants), the international centre of port activities and petro-chemical complex. Regarding the region, South-Holland is a service-economy with specialization in trade and transport, business services, and administrative services. The economy of South-Trøndelag is also a service-economy, but its specialization is the public sector (education and research). On a lower level, primary industries (fishing, forestry and energy) are also important. The support policies concerning establishment and growth of spin-offs have been somewhat different in the past years (Note 2).

No big differences can be observed between spin-offs in Delft and Trondheim in terms of sector and technology. A small share is involved in research/development in manufacturing activity, witness 18.7% in Delft and 24.4% in Trondheim, including new materials, sensor technology, optronics and biotechnology. With regard to services, a larger share in Trondheim is involved in informatics and engineering, testing, optimization and simulation, etc. (63.4 versus 49.1%) and this seems related to the relatively strong energy sector in the region (oil and gas, and sustainable energy).

Despite a broadly similar growth, there are clear differences in the profile of the social networks employed. Spin-offs in Trondheim tend to perform in a tighter network than those in Delft, witness an average score of 0.67 versus 0.51 (Table 3). Thus, in Trondheim a larger number of partners is connected with each other, meaning that the networks are less open than those in Delft. At the same time, it appears that the relationships with individual partners are stronger in Delft compared with Trondheim, witness a score of 2.29 versus 1.92. Both differences are statistically significant. Remarkably, the two cities do not differ in heterogeneity of partners' background. Regarding the spatial orientation, Delft's networks have a relatively strong focus on external relations in the larger metropolitan area. The emphasis in Trondheim on its city-region may be explained by the relatively high threshold for meeting face-to-face outside this region, namely travelling by plane (e.g., to Bergen, Oslo or Stavanger).

Table 3 Profile of the social networks

	TU Delft		**NTNU Trondheim**		**Mann-Whitney or Chi ^{2} test**
	Mean	**SD**	**Mean**	**SD**	
Social characteristics					
Tightness (network)	0.51	0.30	0.67	0.31	-2.50*
Strength (relationships)	2.29	0.33	1.92	0.38	5.08**
Heterogeneity (partners)	0.49	0.16	0.48	0.19	0.39
External (non-local) orientation	-0.21	0.55	-0.47	0.39	-2.72**

*p<0.05 ** p<0.01

The model developed in this study is tested using ordinary least square regression analysis. We discuss the outcomes for the pooled data, Delft and Trondheim in the remaining section. Descriptive statistics of the independent variables are in Annex 1. We mention the following similarities and differences for the pooled data and for the two cities with regard to the effects of the various factors on growth (Table 4). With regard to the control variables, we do not find a significant effect of age in the three models. Further, we do not observe a significant influence of location in the pooled data. In contrast, we find that resource deficiency has a significant and negative influence in the three models, indicating that this deficiency is a relatively strong hampering factor for growth.

Table 4. OLS regression analysis on employment growth of university spin-offs

	Beta coefficients a		
Control variables	**Pooled data**	**TU Delft**	**NTNU Trondheim**
Age	0.04 (0.10)	0.11 (0.14)	-0.01 (0.09)
Located in Delft (dummy)	-0.03 (0.07)		
Resource deficiency	-0.20** (0.12)	-0.14* (0.16)	-0.19* (0.16)
Resources/capabilities/strategy			
Riskprofile of strategy (dummy)	0.06 (0.05)	-0.02 (0.09)	0.14 (0.07)
Capability level (dummy)	0.15** (0.06)	0.07 (0.09)	0.29** (0.08)
Richness of incubation support	0.19* (0.03)	0.09 (0.05)	0.24* (0.05)
Social network profile			
Tightness	-0.18** (0.08)	-0.18* (0.12)	-0.08 (0.13)
Strength	-0.01 (0.24)	-0.31** (0.24)	0.20* (0.27)
Heterogeneity of partners	0.30** (0.19)	0.19* (0.25)	0.28** (0.20)
External orientation	0.18* (0.07)	0.20* (0.07)	0.01 (0.13)
N	100	59	41
F	35.90**	28.54**	33.79**
R^2	0.78	0.77	0.84
Root MSE	0.23	0.21	0.19

*p<0.05 ** p<0.01

a) within brackets is the standard error.

A remarkable difference between the two cities is that the general capability level and richness of support have a positive and significant effect on growth for Trondheim but not for Delft. This would mean that particularly in Trondheim spin-offs benefit from diversity in experience and diversity in support. Regarding the network profile, the largest difference between the two cities is concerned with strength of relationships. The effect for Delft is negative and significant, whereas the effect for Trondheim is positive and significant. This would suggest that stronger relationships hamper growth in Delft but contribute to growth in Trondheim. In addition, tightness of networks and external orientation seem to work differently in Delft compared to Trondheim (the same signs but only significant effects for Delft). The spatial dimension reveals that employing more external networks enhances growth in the pooled data and Delft, but not in Trondheim. In contrast, heterogeneity of partners works the same in all three models (a positive and significant effect): the more heterogeneous the relationships the quicker the growth. All in all, the above results would suggest that growth of spin-off firms in Delft is stronger influenced by the network profile than growth of spin-off firms in Trondheim.

We may summarize the previous findings, particularly in view of impacts of diversity as follows:

- Two factors in the resources/capabilities/strategy set indicating benefits from diversity (capability level and richness of support) are positive and significant for Trondheim, but not for Delft.
- Heterogeneity in partners’ social background is positive and significant in all models.
- Other diversity-related characteristics of the network profile work differently in Delft compared to Trondheim.

5. Concluding Remarks

The empirical research of this study was carried out on two levels, 1) incubators in various countries and 2) spin-off firms in two contrasting cities facing a different growth of incubators, viz. Delft in the Netherlands and Trondheim in Norway. Our findings on the level of incubators suggest that a diversity of stakeholders tends to contribute to fast growth of incubators, apparently due to a relatively high diversity in resources disclosed by diverse stakeholders. In addition, incubators in non-metropolitan (peripheral/rural) areas tend to grow more quickly than those in large metropolitan areas. This pattern points to more favorable conditions in non-metropolitan areas, including benefits from national and/or EU policies. Overall, the combination of a differentiated stakeholder involvement and location in non-metropolitan areas turned out to produce the most powerful explanation of a relatively strong growth of incubators. In second place, but clearly less strong in explanation (in this case of weak growth) was the combination of conventional support and a focused strategy of the incubators (merely research commercialization) representing low levels of diversity. Aside from the location of the incubator, the institutional aspects of incubators as an outcome of Triple Helix processes tend to play a substantial positive role in growth. Diversity and hybridization manifest themselves in a mix of stakeholders and hybrid activity, a certain shift towards a profit-focused strategy, and extending conventional support with support to improve entrepreneurial performance. These findings may be helpful in designing policies on technology incubators.

Despite the different incubator development in Delft and Trondheim, the growth patterns of incubated spin-off firms turned out to be roughly similar. The social networks, however, turned out to be different in structure and shape, i.e. relatively open, strong and more often outside the local in Delft, as opposed to relatively closed, weak and local-oriented in Trondheim. One characteristic is similar, that is heterogeneity in social background of partners. Of all four network characteristics studied, it is precisely this factor that tends to influence growth in the same (positive) direction in both cities. An important difference is concerned with strength of relationships: stronger relationships tend to hamper growth in Delft but tend to stimulate growth in Trondheim. As far as the role of proximity in social networks is concerned, we gained the result that employing networks over larger areas tends to enhance growth in Delft, not in Trondheim. Futher, the outcomes indicate that spin-offs in Trondheim have adapted themselves in gaining a quicker growth from locally available knowledge by efficiently using capabilities and support, and by stronger relations with local partners compared to Delft’s spin-offs. All in all, we found more differences than similarities between the two contrasting cities in impact of the social network profile. The only similarity, however, stands clear and that is a positive influence of heterogeneous networks.

Note 1. We followed two steps in the application of rough set analysis. First, we reduced the base-sample of 40 incubators to 25 incubators by random sampling; the latter number can be handled more easily. We worked with 10 samples of this size. Secondly, we measured *accuracy* connected with the decision rules as a standard routine by ROSE2 and as an additional step to assess the prediction power of the decision rules, using samples not used before (*prediction accuracy*). The accuracy of the core attributes and of all attributes turned out to be 75 and 76% respectively, and the prediction accuracy amounted to 73%.
Note 2. Delft University of Technology adopted a policy to support academic entrepreneurship in 1998. The initiative was built on a national program named 'Technostarters' and provided a set of support from which academic entrepreneurs could select, such as a loan (without interest), use of laboratory/office room at the faculty building or other university premises. So far, the policy could be labelled as "low selective" (Clarysse et al., 2005) meaning that it tended to create as many spin-offs as possible, and these were likely to be less-innovative. To strengthen the initiative, in 2005, TU Delft established a close collaboration with the Municipality of Delft and set up the incubator program YES!Delft. This program offers a broad set of support, including a mix of conventional and additional value-added support, while using more stringent rules for access. NTNU Trondheim never adopted an explicit policy in supporting university spin-offs. However, through a collaborative effort between the university and a private company Leiv Eriksson Nyfotek a business incubator named Gloshaugen Innovation Center (GIC) was established in 2000, providing office space and shared services. Being incubated in this center entitles spin-offs to gain a grant from the national support program (Innovation Norway). Besides providing basic support, GIC also offers a range of services for somewhat lower prices than in the market, including business counselling, legal service, book keeping, public relations, etc. GIC also employs experienced "network-connecting persons" as managers of the incubators. It seems that NTNU used a more selective model than TU Delft.
Note 3 To check for multicollinearity, the so-called variance inflation factor (VIF) was used. High VIFs are an indication for the presence of multicollinearity. In the regression analysis, the VIFs found in the estimates ranged from 1.24 to 1.58, meaning that no multicollinearity problems occurred.

Annex 1 Descriptive statistics (independent variables)

	Pooled data	Delft	Trondheim
Age of spin-offs, average (SD)	5.1 (3.02)	5.8 (2.97)	4.2 (2.87)
Risk-avoidance	0: 52 (52.0%) 1: 48 (48.0%)	0: 29 (49.2%) 1: 30 (50.8%)	0: 23 (56.1%) 1: 18 (43.9%)
General capability	0: 70 (70.0%) 1: 30 (30.0%)	0: 43 (72.9%) 1: 16 (27.1%)	0: 27 (65.8%) 1: 14 (34.2%)
Resource-deficiency, average (SD)	2.74 (1.43)	2.56(1.33)	3.00(1.55)
Richness of support, average (SD)	0.69 (0.87)	0.41 (0.62)	1.09 (1.02)
Tightness, average (SD)	0.58 (0.32)	0.51 (0.30)	0.67 (0.31)
Strength, average (SD)	2.14 (0.39)	2.29 (0.33)	1.92 (0.38)
Heterogeneity, average (SD)	0.49 (0.17)	0.49 (0.16)	0.48 (0.19)
External orientation, average (SD)	0.84 (1.09)	1.15 (1.31)	0.40 (0.37)

References

Armstrong, H. and J. Taylor. (2000) *Regional Economics and Policy*, Oxford, Blackwell Publishers, 3rd ed.

Asheim, B., Coenen, L. en Vang, J. (2007) Face-to-face, buzz and knowledge bases: sociospatial implications for learning, innovation and innovation policy, *Environment and Planning C: Government and Policy* 25: 655-670

Audretsch, D B. (1998). "Agglomeration and the Location of Innovative Activity", *Oxford Review of Economic Policy,* 14, 18-29.

Bølllingtoft, A. and J P. Ulhøi. (2005). "The networked business incubator – leveraging entrepreneurial agency?", *Journal of Business Venturing,* 20, 265-290.

Camagni, R. (1991). "Local Milieu, Uncertainty and Innovation Networks: Towards a Dynamic Theory of Economic Space", in: Camagni, R., (Ed.), *Innovation Networks : Spatial Perspectives,* pp. 121-144. London: Belhaven Press.

Charles, D. and J. Howells, (1992). *Technology Transfer in Europe: Public and Private Networks*, London, Belhaven Press.

Coleman, J.S., (1990). *Foundations of Social Theories*, Cambridge, MA: Harvard University Press.

D'Este, P. en Patel, P. (2007) University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy*, 36: 1295-1313.

Druilhe, C. and Garnsey, E., (2004). "Do Academic Spin-Outs Differ and Does it Matter?", *Journal of Technology Transfer*,. 29, 269-285

Etzkovitz, H., (2002). "Incubation of incubators: innovation as a triple helix of university-industry-government networks", *Science and Public Policy*, 29, 115-128.

Feldman, M. and J. Bercovitz (2006). Entrepreneurial universities and technology transfer: a conceptual framework for understanding knowledge-based economic development, *Journal of Technology Transfer* 31, 175-188.

Florida R. (2002). "The economic geography of talent", *Annals of the Association of American Geographers* 92, 743-755.

Geenhuizen, M. van. (2003). "How can we reap the fruits of academic research in biotechnology? In search of critical success factors in policies for new-firm formation." *Environment & Planning C*, 21, 139-155.

Geenhuizen, M. van, and D.P. Soetanto. (2004). "Academic Knowledge and Fostering Entrepreneurship: An Evolutionary Perspective". In: Groot, H. Nijkamp, P. and R. Stough (eds) *Entrepreneurship in the Modern Space-Economy: Evolutionary and Policy Perspectives.* London, Edward Elgar, pp. 252-268.

Geenhuizen, M. van, Soetanto, D, and P. Nijkamp (2007) Diversity as a Critical Element in Stimulating the Regional Economic Role of Technical Universities, *Studies in Regional Science* , 37 (2): 501-518

Glaeser, E.L., Kolko, J, and Sainz, A. (2001). "Consumer city", *Journal of Economic Geography* 1, 27-50.

Goh, C., and Law, R. (2003). "Incorporating the Rough Sets Theory Into Travel Demand Analysis", *Tourism Management* 24, 511-517.

Granovetter, M. (1973). "The Strength of Weak Ties", *American Journal of Sociology*, 78(6), 1360-1380.

Hackett, S.M and Dilts, D.M., (2004). "A Systematic Review of Business Incubation Research", *Journal of Technology Transfer* 29, 55-82.

Hannon, P.D. and Chaplin, P. (2003). "Are incubators good for business? Understanding incubation practice – the challenges for policy", *Environment & Planning C: Government and Policy* 21, 861-881.

Hansen, M.T., Chesbrough, H.W., Nohria, N and Sull, D.N. (2000). "Networked incubators. Hothouses of the new economy", *Harvard Business Review* 78 (5), 74-84.

Hofstede, G. (1991). *Culture and Organizations: Software of the Mind*, British Library, London.

Jacobs, J. (1961). *The death and life of great American cities*. Random House, New York.

Leydesdorff, L. (2003), "A Methodological Perspective on the Evaluation of the Promotion of University-Industry-Government Relations", *Small Business Economics*, 20, 201-204.

Marsden, P.V. and Campbel, K.E. (1984), "Measuring Tie Strength", *Social Forces*, 63(2), 482-501.

Maskell, P. and Malmberg, A. (1999). "Localised learning and industrial competitiveness", *Cambridge Journal of Economics*, 25: 167-185.

McEvily and Zaheer, A. (1999) "Bridging ties: A source of firm heterogeneity in competitive capabilities", *Strategic Management Journal*, 20: pp. 1133-1156.

McKinnon, S, and S. Hayhow. (1998). *State of Business Incubation Industry,* National Business Incubator Association (NBIA), Ohio.

Nijkamp, P., Rodenburg, C.A. and Wagendonk, A.J. (2002). "Success factors for Sustaining Urban Brownfield Development: A comparative case study approach to polluted sites", *Ecological Economics* 40, 235-252.

Nowotny, H., Scott, P. and M Gibbons. (2001), *Re-Thinking Science. Knowledge and the Public in an Age of Uncertainty*. Cambridge: Polity Press.

Pawlak, Z. (1991). *Rough sets: Theoretical Aspects and Reasoning About Data*, Kluwer Academic, Dordrecht, The Netherlands.

Predki, B., and Wilk, S. (1999), "Rough Sets Based Data Exploration using ROSE system". In : Ras, Z.W., Skowron, A. (eds.), *Foundation of Intelligent Systems. Lecture Notes in Artificial Intelligence 1609*, Springer, Berlin.

Rickne, A. (2006) Connectivity and Performance of Science-based Firms, *Small Business Economics* 26, 393-407

Rothearmel, F.T. and Ku, D. (2008) Intercluster innovation differentials: The role of research universities. IEEE. Transactions on Engineering Management.

Saxenian, A. (1994). *Regional Advantage*, Harvard University Press, Cambridge, Mass.

Shane, S. (2004), *Academic Entrepreneurship: University Spinoffs and Wealth Creation*, Edward Elgar, Cheltenham.

Smilor, R.W., Gibson, D.V. and Kozmetsky, G. (1988). "Creating the Technopolis: High Technology Development in Austin, Texas", *Journal of Business Venturing* 4, 49-67.

Soetanto, D. and Geenhuizen, M. van. (2007), "Technology Incubators and Knowledge Networks. A Rough-set Approach in Comparative Project Analysis", *Environment and Planning B (Planning and Design)* 34; 1011-1029.

Ubbels, B., and P. Nijkamp. (2002), "Unconventional funding of urban public transport", *Transportation Research Part D* 7, 317-329.

Uzzi, B. (1996), "The Sources of Consequences of Embeddedness for the Economic Performance of Organizations: the Network Effects" *American Sociological Review* 61, 674-698.

Viale, R, and H. Etzkowitz. (2005), "Third Academic Revolution: Polyvalent Knowledge: the "DNA" of the Triple Helix," Presentation at the 5th Triple Helix Conference, The Capitalization of Knowledge, May 18-21 2005, Fondazione Rosselli, Turino, Italy.

West, G.P. and T.W. Noel (2009) The impact of knowledge resources on new venture performance, *Journal of Small Business Management*, 47 (1), 1-22.