

SOCIAL NETWORKS' OPENNESS, UNIVERSITY ENTREPRENEURSHIP AND OPEN INNOVATION

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Abstract

Enhancing the establishment and growth of spin-off firms from university is receiving an increased attention in local and regional policy today. University spin-off firms are typically in short of resources, reason why social networks play a vital role in their early growth. There is however a lack of understanding of the profile of these networks in different segments of these firms. Building on a resource-based perspective and the concept of open innovation, we explore differences between two types of spin-off firms: highly innovative ones and medium-to-low-innovative ones. The results indicate a smaller growth among highly innovative spin-offs as an impact of among others more homogeneous and more often locally oriented networks. This situation calls for opening of the social networks and gradually growing business networks. The paper speculates on how open innovation and the specific model of living labs may be helpful in this strategy, but also how different urban areas (high versus low density) may influence such strategy.

Key words: university spin-offs, social networks, innovation strategy, open innovation, living labs, job growth, urban areas.

1. Introduction

Knowledge accumulation and spillover effects on productive capacity is a central theme in theories on endogenous economic growth (e.g. Grossman and Helpman, 1991; Aghion and Howitt, 1998). Theoretically, universities play a central role in these processes, as knowledge producers and as creators of human capital. However, for many years empirical evidence has not uniformly confirmed this role of universities as 'engines of economic growth'. Most recent evidence on the contribution of universities to economic growth in regions has been shown by Koo and Kim (2009), alongside contribution from entrepreneurial activity and human and social capital. These results may reflect that universities have become increasingly entrepreneurial since the early 1980s and even more strongly since the early 2000s (Etzkowitz, 2008; Huggins and Johnston, 2009; Kitson et al., 2009).

This development runs parallel with the increased attention from policymakers and university managers for enhancing the survival and growth of university spin-off firms since the early 2000s. The main arguments for such policy include the contribution of these firms to diffusion of new technology, improved university-business links, and in particular regions, their role in restructuring regional economies (Benneworth and Charles, 2005). University spin-off firms can be defined as a particular type of spin-offs, created for the purpose of commercially exploiting knowledge, technology or research results developed within a university (Pirnay et al., 2003).

Despite this common feature of spin-offs, they are varied in characteristics, like their relationship with university policy (Bathelt et al., 2010), single or team start, experience of entrepreneurs at start (e.g. Druilhe and Garnsey, 2004; Colombo and Grilli, 2005, 2010) as well as strategy adopted towards innovation. Another characteristic they share is, like all small high technology firms, a heavy

dependence on social networks to access external resources in their early years. Much attention has been given to growth numbers, incubation in terms of organization and support to university spin-offs, but social networks and differences in characteristics of these networks between segments of university spin-offs have seldom been studied. This despite the increasing recognition in management studies that small high technology firms need the benefits from participation in inter-firm and inter-organizational knowledge relationships, *inter alia* universities, by absorbing a wide range of specialized knowledge (Grant, 1996; Tether, 2002). In this segment of technology firms, networks give access to external resources that remain otherwise beyond reach. Since the early 1990s, models of external collaboration in R&D and the concomitant learning processes have been identified and labeled as 'open innovation' (Chesbrough 2003; Chesbrough et al. 2006). Accordingly, there is an 'outside in' element meaning that innovation in the firm benefits from external inputs and a connected 'inside out' element meaning that part of innovative activity finds the market through other firms and organizations.

The focus in this paper is on the segment of highly innovative spin-off firms. These spin-offs aim to commercialize a cutting edge technology and strongly invest in the development and market introduction of this technology. They may be the first firm entering the market (first-mover strategy) (Lieberman and Montgomery, 1988). Through investing in highly novel technologies or products, they may benefit from acquiring superior resources, particularly a unique market position, but they may also suffer from taking too high risks. By contrast, late-moving spin-offs choose to introduce renewed or improved product/services in existing markets on the basis of a relatively modest investment in research and development.

Among the policy tools used to enhance spin-off growth – and more broadly commercialization of university knowledge – we find since a few years the so-called living labs. Basically, living labs refer to a new structure of innovation in which various actors contribute to a quicker introduction to market, this through an early involvement of user-groups in design (co-design), testing and improvement of inventions in real-life situations, like hospitals, campuses, sporting stadiums, villages and city-quarters (Følstad, 2008; Ståhlbröst, 2008). Living labs are rooted in ideas on open innovation. Aside from an early involvement of user groups and a physical environment which represents the real-life environment, living labs have an open network in common that brings together stakeholders sharing the desire to support a better and quicker take-up of innovations in the market (Guldmond and Van Geenhuizen, 2012).

Given the above missing understanding and insights, we respond to the following research challenge. Studies of university spin-offs have primarily discussed the incubation process in terms of organization, process and financial aspects, and only a limited amount of research has examined social and network aspects related to business incubation (Totterman and Stern, 2005). One exception is Walter et al. (2006) who focused on the impact of network capability (to develop and utilize) relationships together with entrepreneurial orientation on performance. Despite a growing interest in the role of business incubators as creators and supporters of functional business networks (Aernoudt, 2004; Bøllingtoft and Ulhøi, 2005), the question what types of social networks bring benefits to the growth of spin-off firms has remained largely unanswered, particularly with regard to different levels of innovativeness of these firms and the general trend for open innovation.

The contribution of this paper is to fill the knowledge gaps in three ways. First, to picture differences between highly innovative spin-offs and other spin-offs with regard to social networks. Second, to explore how social networks play a role in the growth of highly innovative spin-offs, and third, to examine policy implications of the results with an emphasis on potential benefits from open innovation and living labs. The paper is structured as follows. Section 2 highlights various theoretical viewpoints on innovation strategy and social network formation, as well as open innovation and living labs. The next section (3) is concerned with methodological aspects of the empirical study,

including the variables and statistical model, and characteristics of the sample. The results of the comparative analysis of resource deficiency and characteristics of the social networks are next (section 4) and this is followed by the results of two estimations of growth models for highly innovative firms, with a focus on social network profiles (section 5). Section 6 presents a discussion of the results in the light of policy practice, particularly what advantages open innovation and 'living labs' might provide for highly innovative spin-offs. The paper draws on a previous study and is an elaboration of it (Soetanto and van Geenhuizen, 2011).

2. Innovation Strategy, Open Innovation and Social Networks

2.1 Resource-based theory

Resource-based theory indicates that young high technology firms need to access external resources in order to fulfill their chosen product-market strategy, including level of innovativeness and type of market entry (e.g. Barney 1991; Barney et al. 2001; Barney and Clark 2007). At the same time, young high technology firms need to develop particular capabilities through learning, and one of these capabilities is to establish and maintain useful social networks through which external resources can be accessed (Hughes et al. 2007). Social networks provide entrepreneurs with avenues for negotiation and persuasion, and enable them to gather a variety of resources (e.g., market information, social support, venture funding and other financial resources) held by other actors (Nicolaou and Birley 2003).

Birley (1985) observes an extensive use of social networks in the early stages of the venture generation process, which in the case of university spin-offs may include family, friends, previous colleagues and employers, and former professors. In the current paper, social networks are defined as networks of important '*partners*' that potentially provide valuable resources for firms' growth. As young spin-offs often lack critical resources, especially market-related knowledge and skills, they attempt to fill resource-deficiency by seeking a solution through 'partners' in social networks and emerging business networks. As most highly innovative spin-off firms are engaged in 'secret' knowledge that is not (yet) protected and at the same time can take only small risks, it remains to be seen to what extent open innovation and participation in living labs could be a solution for them.

2.2 Open Innovation and Living Labs

R&D and the concomitant learning processes increasingly take place in networks beyond the boundaries of a single firm with knowledge institutes, customers, suppliers, etc. as important partners in collaborative learning, a phenomenon captured by the term of open innovation (Chesbrough 2003, Chesbrough et al. 2006). Advantages of open innovation for firms may encompass cost reduction (search costs and costs to access new knowledge) and a stronger competitiveness due to, for example, a more diverse knowledge supply and a better match with customers' needs. However, managing the concomitant networks and relationships seems to be an art in itself, it is not about just giving up control and hoping for the best but about carefully implementing mechanisms to govern, shape, direct, and if necessary constrain external innovators. Thus, successful spin-offs are those that invest in effective relationships with suppliers, sub-contractors, knowledge-intensive business services firms, experts/advisors and universities and/or research institutes (Hughes et al. 2007; Belussi et al., 2010), using a strategic selection and selective maintaining of such relationships leading to a different emphasis on open innovation.

Open innovation, in fact, means 'relatively open' innovation and is a phenomenon on a spectrum that runs from somewhat open to entirely open (Dahlander and Gann, 2010). In addition, openness refers to different aspects of relationships, like knowledge flow, accessibility of the network for outside partners, number of relationships and extent in which partners are connected with each other and with other networks. This means that firms, dependent on their needs and strategy can be

open and relatively closed at the same time. Open innovation has been studied mostly among large firms, meaning that open innovation among SMEs is not well understood. One exception is the study by van der Vrande et al. (2009). They find that medium-sized firms are more engaged in open innovation than small firms, and that most of SMEs that are involved in open innovation do so for market reasons, e.g., to learn about customer specification and to learn about competitors. There also seem to be limits to open innovation in terms of organization (managing external contact) and cultural issues.

Living Labs, as it started to emerge around 2000, can be seen as a user-centric research and development approach in which new technologies are co-created, tested, and evaluated in the users' own (private) real-life context. Key is the purposeful engagement of customers in commercialization processes and practices (Thomke and von Hippel 2002; Bogers et al. 2010; Priem et al. 2012). Customers include individuals, like patients, public organizations like municipalities, but also small and large firms. Living labs can be seen as networks/platforms and delimited physical places where a set of enabling stakeholders have settled a public private partnership (or the like) including universities, research institutes, public entities, firms and individuals. Most experience so far is in healthcare, wireless communication, and in energy saving in connection with building and architecture. Although the idea is that living labs are firmly anchored in local communities, there may be various important links on a distance between user groups, universities and large firms (communities of practice, other living labs) to increase learning from practice and to make use of the diversity of global technical knowledge. Accordingly, living labs may also emerge as networked living labs connecting different places across Europe.

Living labs today are a popular policy tool and thought to be helpful in bringing new technology to market, enhancing new entrepreneurship and increasing the innovative level of existing small and medium-sized enterprises. Initiatives to establish a living lab or a network of living labs are mushrooming today. In The Netherlands six living labs are recently being established with subsidy of the Ministry of Economic Affairs, among others in Delft, Leiden and Rotterdam. One of the fields here is innovation in healthcare, in collaboration with *Medical Delta* hosted at TU Delft (Livinglab, 2010). Further, Amsterdam is involved in ICT-focused *Apollon* (Advanced Pilots of Living Labs Operating in Networks), including cities like Helsinki and Barcelona, and cooperation with Philips and Nokia and various universities (Aimsterdam, 2010). The mushrooming of living labs can be further illustrated with the city of Helsinki, where one finds seven registered living labs (Lepik et al., 2010). Living labs as organizational structures provide coordination activity and services to enable users to take active part in design and testing of inventions.

Due to their recent emergence, living labs have not yet been evaluated rigorously, in terms of reaching goals in bringing inventions quicker and better adjusted to user needs to the market. The aims of living labs tend also to be somewhat fluid. There is not much understanding of the appropriate spatial scales, ways of inserting living labs in existing regional networks and schemes of support/incentives, and ways to connect the local with the global. In addition, organizational learning is different between sectors and value chains (Asheim et al., 2007) but there is not much experience with designing different living lab models to respond to this diversity. The same holds for differences between regional innovation needs, particularly given different levels of absorptive capacity of the stakeholders involved, the last including university spin-off firms (Hussler et al., 2010).

However, what has become apparent from a scan of the literature (Guldmond and Van Geenhuizen, 2012) is a set of critical factors, without which living labs would not work. These include 1) a close and interactive involvement of users, based on a sufficient match between research/development issues and user's needs and abilities, 2) adequate physical environment and functionalities (and management) of the networks to reach the collective aim of stakeholders, 3) business models that allow for openness and neutrality, 4) a set of legal issues that need to be settled, including liability,

intellectual ownership. Despite all the knowledge gaps, one of the intriguing questions is to what extent living labs - as a new methodology using sets of more formal knowledge networks - might be able to resolve unfulfilled resources needs and to 'correct' undesirable aspects of social network profiles of young university spin-off firms.

2.3 Dimensions of Social Networks

We focus on the structural and relational dimension of networks, as well as the dimension of social background of network partners and the spatial dimension.

Structural Positions: Tightness of Networks

Studies on the influence of network structure on new firms' performance are not conclusive. Several studies stress that linkages with tight networks are more advantageous in the early years of firm growth (Gulati, 1995) while others emphasize the importance of being connected to loose networks (McEvily and Zaheer, 1999). According to Granovetter (1992) firms enjoy large advantages if they have partners who are connected in sparse (loose) networks, or according to the *current* paradigm, some kind of open innovation networks. A loose network structure brings on benefits from diversity of information and brokerage opportunities created by lack of connections between separate clusters in the networks. This leads into a concept named *Structural Hole* (Burt, 1992). Actors who occupy brokerage positions between clusters have better access to information.

Tight networks are described as networks in which all partners are connected to each other. If business partners know each other well, network membership will reduce risk and enhance the opportunity of building cooperation and getting access to resources from other partners connected in the network. Partners in tight networks are familiar with each other's interests and build trust and credibility on each other. Therefore, tight networks are beneficial for the transfer of complex (fine-tuned) and tacit knowledge, and for performing joint problem solving (Coleman, 1990; Uzzi, 1996). Tight networks may however also cause disadvantages. The autonomy of the members is heavily restricted, since each decision to be taken by them is subject to the acceptance and the influence of all interconnected contacts (e.g. Gargiolo and Benassi, 2000).

If we focus on highly innovative spin-offs (HIS), we may assume that tight networks are beneficial for these firms because of the strong need for technological learning and tacit knowledge as a vehicle in this learning. Tight networks also provide a certain protection and exclude partners that are mainly connected with other networks. Open innovation, because of the need for protection of inventions and for prevention of spread of secret information into other networks, seems to bring many risks and is therefore not adequate. If these firms move to the market, the situation might change (van der Vrande et al., 2009).

Relational Quality: Strength of Relationships

Strength refers to the quality or value of the relationships as appreciated by partners in the network. It varies according to the time invested herein, seen from the long-term and seen from intensity of interaction. Granovetter (1995) defines the strength of relationships on time and emotions invested in a relationship, as well as reciprocity between the partners. This type of relationship is important for entrepreneurs trying to market an unproven product yet facing limited resources. In such a highly uncertain situation, entrepreneurs will heavily rely on learning and support from close friends or family members. Highly innovative spin-offs, particularly first-movers, typically work under highly uncertain conditions and accordingly may depend on close relationships with partners.

The theory of social networks, however, also presents a contradictory argument. Granovetter (1973) argues that new information is obtained through casual acquaintances rather than through strong personal relationships. Since strongly connected partners are likely to interact frequently, much information that circulates is the same. Conversely, *weak ties* often include links with partners who

move in social circles other than those of the focal persons. Weak ties are an important source of information about activities, resources and opportunities in distant parts of the social system, and are often more important in spreading new information or resources because they tend to serve as a bridge between otherwise disconnected social networks. Accordingly, it is through weak ties that spin-offs can recognize novel information, which leads them to new resources and exploiting new business opportunities.

It is difficult to say whether weak ties are more important in the growth of highly innovative spin-offs compared to other spin-offs. We may speculate that in the first years when capital is scarce but investments are high, these spin-offs avoid weak ties, just to prevent that knowledge on the invention leaks away into wider parts of the network.

Social Background of Network Partners

With regard to the social background of network partners the following is found in the literature. Marsden (1987) shows that partners from a diverse social background - integrating several spheres of society - facilitate more beneficial actions than partners from a similar social background. Accordingly, with regard to spin-offs' growth, the more heterogeneous the partners, the larger the variety of resources, such as know-how, information and expertise. Heterogeneity in partners' backgrounds increases the likelihood of obtaining valuable information and knowledge, guiding spin-offs more quickly to different resources. A positive influence of relatively heterogeneous networks, connecting the spin-off with diverse circles, could recently be proved for spin-off growth (Soetanto and Van Geenhuizen, 2009).

Regarding the innovation strategy, we may speculate that highly innovative spin-offs – due to their strong technology focus - employ more homogeneous partners and benefit from them, like from the research group at university where the founders originate and research groups abroad known from conferences.

Spatial: Proximity of Partners

In studies of network creation, networks are assumed not to randomly link individuals. Rather, people interact most frequently with those in close geographic proximity provided that they also share common backgrounds, interests and affiliations (Gertler, 2003; Boschma, 2005). To put it in a slightly different way, a network that is clustered in space provides larger opportunities for partners to actively interact and to benefit from knowledge spillovers (e.g. Audretsch, 1998; Camagni, 1991). Accordingly, entrepreneurs in locations densely populated with specialists in their field often form networks that contain many close, casual, and indirect ties with colleagues. These networks convey information about new technological developments, unresolved technical puzzles, and emerging market opportunities. In this case, highly innovative spin-offs may receive more benefits from partners that are located in close proximity than medium/low innovative spin-offs.

The literature, however, once more, gives some contradictory arguments. First, a predominantly local orientation bears the risk of lack of diversity of information. Ideally, therefore, local and global relations are coupled (Bathelt et al., 2004). In the management-oriented literature (e.g. Amin and Cohendet, 2005) it is emphasized that spatial proximity does not matter: highly innovative firms step into knowledge relations contingent upon their individual needs and specialization, and contingent upon their capability to identify new knowledge. Accordingly, the scale of interaction that is useful varies from local to global, and is not limited to the local and to benefits from the local (Van Geenhuizen, 2008). Regarding highly innovative spin-offs, we may speculate that they - in order to remain in the forefront of technology - focus both on local and on global relationships.

Overall, we may assume that with regard to open innovation the social networks and emerging business networks of highly innovative spin-offs show some 'selected openness', meaning open if the rich information is needed, but closed if leakage of not protected knowledge is envisaged.

3. Methodological Aspects of the Study

The study draws on a survey of university spin-offs of Delft University of Technology (Delft, the Netherlands) and Norwegian University of Science and Technology (Trondheim, Norway). The population of spin-offs from these universities was delineated using three criteria, i.e., located in Delft/Trondheim or surrounding area, survived in 2006 (as the first round of survey was conducted), not older than approximately 10 years (Note 1) and use of at least one type of support from the university or incubation organization. However, as both universities have not formally maintained any record and information about their spin-offs, we managed to obtain data about university spin-offs through direct interviews.

The interviews were conducted on incubator managers, professors, and university officers through whom we could identify and develop a database of university spin-offs. In the second round, data were collected using a semi-structured questionnaire in face-to-face interviews with the principal managers of the spin-offs, often the founder/entrepreneur. During the interviews, the latter were asked whether they knew other spin-offs. Through this process, a list of spin-offs was built. This approach has resulted in 100 valid questionnaires.

In this study, Ordinary Least Square (OLS) regression analysis was used. To explore the role of social network profile on the growth of HIS, the analysis contained two steps. First, a linear regression analysis of resources and capability level among highly innovative (HIS) was performed. The second analysis aimed to estimate a model of growth focusing on the social network profile, aside from resources and capability level. Thus, two models were generated: model 1 explored the influence of resources and capability variables on growth, while the additional impact of different network profiles was explored in model 2.

HIS were defined as those ones that have spent at least 35% of their turnover (or income) on research and development. We took average annual job growth as an indicator for growth. In the regression analysis, we used age (in years) and location (a dummy variable indicating Delft or Trondheim) as control variables. Social networks were measured using the so-called *ego-centric* approach, focusing on individuals as focal nodes rather than on networks as a whole. The focal nodes are the founders/entrepreneurs and we identified the partners with whom they interacted and discussed business affairs on a regular basis

Next in this section we briefly examine growth of mainly highly innovative spin-offs in the sample (Table 1). The sample encompasses 52 HIS and 48 MLIS. With regard to job growth, HIS stay behind MLIS, witness 0.7 versus 1.0 full-time equivalent (fte) on average per year. Overall, the spin-offs' growth is modest and fits into the pattern sketched by Mustar et al. (2007) for the European Union. The relatively slow growth of HIS may follow from their specific R&D strategy, in which new projects are undertaken in networks with the university or large firms. The relatively slow growth of HIS could also be seen in relation to the age structure: HIS are younger than MLIS with 54% in the category younger than 4 years (25% among MLIS).

Table 1. Growth among highly innovative and medium/low innovative spin-off firms a)

	HIS	MLIS
Sample size	52	48
Average Growth (jobs)	0.7 (S.D: 0.73)	1.0 (S.D: 0.88)
	t-test: 1.69*	
Age b)		
- Less than 4 years	28 (54%)	12 (25%)
- 4 years and more	26 (46%)	36 (75%)

a) HIS: highly innovative spin-offs; MLIS: medium/low innovative spin-offs.

b) The age of 4 tends to be 'critical' in that obstacles to growth decrease substantially in number after this age has been reached (Soetanto, 2009; see, also Van Geenhuizen and Soetanto, 2009).

Source: Adapted from Soetanto and Van Geenhuizen (2011).

In exploring the growth models, the focus is on various characteristics of the social networks. However, several other factors will be explored as they may influence the growth as well (Soetanto and Van Geenhuizen, 2009): *age* of the spin-offs, referring to an increase of accumulated knowledge/experience and growth of learning abilities as they get older; *location* of the spin-offs, referring to different location characteristics, i.e. highly urbanized area versus an isolated city, including differences in information density (knowledge spillovers); these variables act as control variables in the models.

Further we include resources and capabilities of the spin-offs, referring to three different factors: shortage of resources (*resource deficiency*), presence of capabilities (*capability level*), and resources gained through support received from university or incubation organization (*basic support or value added support*). Most importantly, we are interested in the question how the growth of highly innovative spin-off firms can be understood by the profile of their social networks.

4. Resource Deficiency and Social Networks

University spin-off firms are usually short of resources. In some cases, this may take such proportions that the firms' survival and growth are in danger. Therefore, we next examine which obstacles to growth are faced most frequently in our sample. We limit ourselves to the five most frequently observed obstacles (Table 2). Highly innovative spin-offs suffer most from lack of marketing knowledge (57.7% of all HIS spin-offs), lack of investment capital (46.2%) and problems in dealing with uncertainty and risk (40.4%).

This profile of resource deficiency complies with an image of HIS spending most of their time and resources to research and development, thereby still neglecting the market and skills to enter the market, and requiring large amounts of investment capital. In addition, these firms are facing manifold uncertainty, like concerning the technology and the market, and dealing with uncertainty is seen by the spin-offs as problematic.

Table 2. Obstacles to growth (current and past)

Categories		Highly innovative spinoffs	
		Freq.	% ^{a)}
Market-related knowledge	Marketing knowledge	30	57.7 (1)
	Sales skills	19	36.5 (5)
	Forecasting future markets	15	28.9
Financial	Cash flow	20	38.5 (4)
	Investment capital	24	46.2 (2)
Management	Management overload	14	26.9
	Problems with uncertainty	21	40.4 (3)
All obstacles ^{b)}		143	
Average number of obstacles (all) per firm		3.4	
Average number of main obstacles per firm ^{c)}		0.6	

a. Share of spin-offs facing the obstacle.

b. This refers to all obstacles (incl. regulation, location problem, etc.).

c. This refers to market-related, financial and management obstacles.

Source: Adapted from Soetanto and Van Geenhuizen (2011)

We now proceed with a descriptive analysis of the social networks of HIS compared with those of MLIS. Differences between the profiles are significant for two characteristics, i.e. homogeneity of partners (social background) and local orientation (Table 3). As expected, HIS with their technology focus, interact with relatively homogeneous partners. However, unlike our expectations, HIS employ a relatively strong local orientation in their networks. We may explain the last situation with the higher levels of risk HIS deal with and their relatively younger age, urging a stronger reliance on trustworthy networks with the local university and local experts in the technology field concerned. Also, unlike our expectations, tightness of networks and strength of relationships of HIS compare are similar to networks of MLIS.

Table 3. Profile of social networks

	Tightness	Strength	Homogeneity of partners	Local orientation
HIS (52)	Mean: 0.51 S.D: 0.36	Mean: 2.15 S.D: 0.37	Mean: 0.56 S.D: 0.20	Mean: 0.87 S.D: 0.79
MLIS (48)	Mean: 0.59 S.D: 0.36	Mean: 2.13 S.D: 0.42	Mean: 0.49 S.D: 0.14	Mean: 0.64 S.D: 0.88
Significance test	-0.78	-0.23	-1.97**	-1.53*

* p<.10; ** p<.05

Source: Adapted from Soetanto and Van Geenhuizen (2011).

We now examine the pattern of spatial orientation of the social networks in more detail (Table 4). Local/regional is defined as within a travel time of 30 minutes from Delft and from Trondheim. As previously indicated, HIS clearly have a more local/regional orientation than MLIS. Although for both categories of spin-offs the social networks are in majority local/regional, almost 70% of HIS' networks are local/regional compared to 57% of MLIS', a difference which is significant. Networks of MLIS cover also wider areas with 17% of the networks developed in the country and 26.3% developed internationally.

Table 4 Spatial orientation in social networks of HIS and MLIS a)

	HIS (52)	MLIS (48)	t-test
Local/regional	69.7	56.7	-1.84**
National	8.0	17.0	1.08*
International	22.3	26.3	0.87

* p<.10; ** p<.05

a) based on average percentage share of each category (local/regional, national and international) in each spin-off firm's network.

Source: Adapted from Soetanto and Van Geenhuizen (2011).

5. Influence of Social Networks on Growth

We explore in this section to what extent the previously discussed social network profiles influence the growth of spin-offs, aside from the capability level, resource deficiency, and support received. We use OLS (Ordinary Least Square) regression analysis (note 2).

The model (full) on the influence of social networks on *job growth* is defined as:

$$\text{Job growth} = \beta_0 + \beta_1\text{age} + \beta_2\text{location} + \beta_3\text{capability level} + \beta_4\text{resource deficiency} + \beta_5\text{VAsupport} + \beta_6\text{tightness} + \beta_7\text{strength} + \beta_8\text{homogeneity} + \beta_9\text{local orientation} + e$$

Where

Job growth is the average yearly growth since establishment (in full time equivalent)

Age is measured as the number of years since establishment (years)

Location is a binary variable: Trondheim = 0 and Delft = 1

Capability level is a composite indicator reflecting pre-entry work experience and capacity from single/team start, measured as a binary variable: high level = 1; 0 = otherwise

Resource deficiency is measured as the share of missing main resourcing in all three main resources (min: 0; max: 1)

VAsupport is measured as the share of value-added support in all support measures enjoyed by the firm (min: 0; max: 1)

Tightness (density) is the quotient of the total number of ties of the network relation and the total number of partners per spin-off (min: 0; max: 1)

Strength is a composite indicator reflecting frequency of interaction, duration of the relationship, and respondent's assessment of quality of the relationship (min: 0; max: 1)

Homogeneity is measured as the share of homogeneous partners in all partners of the network (min: 0; max 1)

Local orientation is the quotient of the number of local/regional partners (reach within 30 minutes traveling) and number of non-local/regional partners (beyond this reach) (min: -1; max: 1)

e is the error term.

We estimate two models, a partial (firm characteristics) and full (also including social network profile) model both for HIS. Table 5 shows that the two models pass the statistical F test, and the R-square (the goodness of fit) of the models shows a relatively high value. One of the pitfalls in estimating regression models is the existence of multicollinearity among independent variables. To check the multicollinearity, the so-called variance inflation factor (VIF) was used (note 3).

In model 1 focusing on resources and capabilities, all three beta-coefficients turn out to be significant and show signs as expected. Thus, the capability level and value added support tend to have a positive impact on growth, whereas deficiency of resources tends to have a negative impact. In the full model (model 2), three out of four beta-coefficients of network characteristics are significant. By inserting social network characteristics in the model, R^2 improves considerably, i.e. from 0.46 to 0.69. This indicates an important influence of the social network profile on growth.

Noteworthy is that the beta-coefficient of age and location is found not to be significant in the full model including social network variables. The influence of a young/older age on growth may be compensated by network characteristics. In addition, being located in Delft or in Trondheim tends to have no influence on spinoff growth. There is however a different sign between model 1 and model 2, which may indicate that social networks tend to interact with high or low information density in the urban environment.

Table 5. OLS regression analysis of growth of highly innovative spin-offs

	Highly innovative spin-offs	
	1	2
	Beta coefficient	Beta-coefficient
<i>Control variables</i>		
Age of spin-offs	.28**	.09
Location	-.09	.15
<i>Resources/capabilities</i>		
Capability level	.34**	.07
Resource deficiency	-.21*	-.18**
Value added support	.29**	-.01
<i>Network profile</i>		
Tightness of network		-.25*
Strength of relationships		.07
Homogeneity of partners		-.18*
Local orientation		-.22*
N	51	51
F	9.80***	12.81***
R^2	.46	.69

* $p < 0.10$ * * $p < 0.05$ *** $p < 0.0$

If we focus on network characteristics in the full model (model 2), the following trends become clear. Tightness of networks tends to influence growth in a negative manner while strength of relationships has apparently no influence on growth. Both homogeneity of partners and a dominance of local partners tend to influence growth in a negative manner. The last observation is important because the network profile of HIS compared to MLIS just indicated a relatively high level of homogeneity and of local partner dominance (Table 3).

6. Implications

The findings of this study can be used to improve policy in supporting entrepreneurship that originates at university. First, there is a need for increasing awareness of the significance of social networks, particularly their profile. This is to be done preferably at universities and in incubation centers. Secondly, there is a need to provide training of spin-off firms in *network management*, including the identification of adequate network partners, establishment of relationships with them, and the evaluation of the networks e.g. finding out whether the relationships are worth to be continued after a time. This training support needs to focus on highly innovative spin-offs in order to resolve their specific shortage in marketing knowledge and investment capital. Adapting their knowledge networks to include more *non-local* partners and partners with a *larger variety* in social circles, should be one of the aims of such specific support. For example, leading professors at university could give access to their international business networks. Furthermore, training in network support preferably also aims at reducing the tightness of social networks or preventing increase of it and make the networks more open, meaning to select partners that are not connected with other partners in the network.

We now reflect on what living labs might improve in the resource position and in networks of university spin-off firms. We focus on HIS because these are central in many new incubation programs at university but tend to show relatively slow growth. Our reflections contain some speculation because the concept of living labs is still fluid and might be implemented with different features (Lepik et al., 2010). Table 6 shows what benefits living labs may produce given the short resources and necessary aims of network management. With regard to resources, many improvements can be foreseen. Marketing knowledge may be gained as early as the stages of creation and prototyping, based on co-design with user groups. In addition, co-design, if performed with large, financially strong, partners may open the way to models of co-financing and a more fair distribution of financial risk over the partners. Moreover, uncertainty in terms of the market may decrease as a result of co-design and participation of particular user groups with changing needs.

With regard to the profile of the networks, the following can be speculated. Living labs may play an important role in increasing the heterogeneity of networks through connecting spin-off firms to various stakeholders and segments of value chains. By contrast, whether living labs can respond to needs for a national and international focus and needs for a more open structure, remains to be seen. For widening the spatial focus, this depends on how well local living labs are connected with living labs in other cities and abroad. Due to different national cultures, living lab concepts abroad may be different (Lepik et al., 2010). In principle living labs can open the structure of social networks of spin-off firms and link them through particular partners to other networks. However, if secret knowledge is involved that is not protected, living labs should be able to respond to the need for *selective* openness with ownership of results protected by contracts (e.g. Dahlander and Gann, 2010). Such needs may be contrary to the general business model of living labs and pressure to be open. There is not much experience here, meaning that in future research living labs need to be monitored with special attention to dealing with intellectual ownership of small high technology firms.

Table 6. Potential benefits from participation of highly innovative spin-off firms in living labs (LL)

Important aspects for HIS	Impact	Remarks
<i>Perspective of missing resources</i>		
Marketing knowledge	Benefit	-Early connection with customers and their needs.
Investment capital	Benefit	-Co-design opens up new models of financing R&D (particularly if large firms and public authorities act as co-designers).
Skills to deal with risks and uncertainty (financial, market)	Benefit	-Co-financing reduces financial risks. -Co-design might come with reduction of market risks through early connection with customers and their (changing) needs.
General	Benefit	-Value chains created by LL offer many opportunities to fill resources needs
<i>Perspective of network needs</i>		
Need for stronger national and international focus	<i>Question mark</i>	-LLs work basically in <i>local</i> communities, thus benefits depend on how well LLs and their value chains are connected nationally and globally.
Need for more heterogeneous networks	Benefit	-LLs typically include a variety of stakeholders and the value chains involved are typically varied in partners.
Need for less tight (open) network structure	<i>Question mark</i>	-May only work if secret knowledge is protected and 'leakage' towards other networks can be prevented.
General: need for 'selected' openness	<i>Question mark</i>	-May only work if the general pressure of LLs for openness can be fine-tuned in responding to specific wishes for closed relations

A final point to be raised is whether living labs due to their needs for local network embeddedness and physical accommodation can flourish in all places. Spatial innovation theory suggests that the potentials for open innovation are not the same for all urban areas, like in large metropolitan areas and places with less urban density. The question whether and how urban qualities influence the potentials for open innovation has been addressed only recently (Isaksen and Onsager, 2010; Martin and Moodysson, 2012). An important influence seems beyond doubt the presence of various advantages in large cities, such as access to a rich variety of venture capital, skilled labor, specialized suppliers, and customer groups, including launching customers, meaning that large cities enhance open innovation *within* the city and region. This is also true for living labs as a specific tool in open innovation. Living labs in large city areas tend to benefit from both localization and agglomeration advantages.

Small cities in rural areas, by contrast, lack such spatial advantages. This may cause living labs to be more closed with stronger local relations. At the same time, however, these living labs may collaborate with more distant living labs outside the region in order to compensate for local knowledge deficiencies. Thus, the last situation may go along with spatially networked living labs supported through virtual teams and virtual cooperation tools. However, particularly in these situations, secret knowledge seems to be more difficult to protect and therefore living labs in small cities in rural areas may be less useful as an 'environment' for highly innovative spin-off firms. Needless to say that the influence of urban area on open innovation in general and living labs in particular deserve attention in future research.

8. Concluding Remarks

This study was concerned with highly innovative spin-off firms from universities, their lack of resources and the profile of their social networks in filling these resources. The study produced first results of a comparative analysis of differences in network characteristics between highly innovative and medium/low innovative spin-off firms, and results of an analysis of influence of network characteristics among highly innovative spin-offs on job growth. It gave also an early assessment whether highly innovative spin-offs might benefit – given their specific needs and networks - from an increasingly popular instrument in open innovation, i.e. living labs. Living labs basically work with user-involvement in the creation, validation and testing of new products and services, in an interactive way and in a real-life everyday context. The results indicated that highly innovative spin-offs are in short of marketing knowledge, investment capital, and skills to manage uncertainty. In addition, their social networks tended to be relatively strongly focused on small (homogeneous) circles and on local partners. We also found that social networks tend to play an important role in job growth of highly innovative spin-offs, with negative influence of homogeneous networks and local network orientation, but also of relatively tight networks.

In a next step in the paper, benefits from living labs were explored for highly innovative spin-offs' needs for resources and for network changes. The overall conclusion was that from the perspective of resources, participation in living labs may accelerate highly innovative spin-offs on their way to market and to strong growth. From a network perspective, this also holds for the need for more heterogeneous networks. However, it remained to be seen whether highly innovative spin-offs can make their networks more open by connecting with other networks through living labs. If new knowledge is not protected, openness can only be selective and living labs should be able to respond to that.

Further implications of this study should be seen in connection with the selections made in the design of the study. We limited our sample to rather young spin-offs with a maximum age around 10 years. It is reasonable to assume that social networks develop a stronger business component as spin-offs grow older, meaning that the results of the current study would only have further implications for relatively young spin-offs. In addition, the sample was taken at technical universities in the Netherlands and Norway. The results would have further implications for technical universities that have recently developed a stronger focus on highly innovative spin-offs in incubation programs, particularly in countries sharing innovation systems with averse against risk-taking and a moderate popularity of entrepreneurship.

Note 1. Bias as a result from excluding firms that died is expected to be low. In a previous study it was found that around 80% of the spin-offs in Delft have survived the first ten years. In addition, simulation studies could prove that firms that have died in this period do not differ significantly from the ones that survived (Van Geenhuizen and Soetanto, 2009).

Note 2. Using OLS regression analysis calls for a check on heteroscedasticity, or having a non-constant variance of the residuals. Such situation would imply that a better prediction can be obtained for some units than for other. To check this issue, we run Breusch-Pagan/Cook-Weisberg test. Overall, the test shows that all models reject the presence of heteroscedasticity.

Note 3. The variance inflation factor (VIF) is the reciprocal of tolerance. Large VIFs are an indication for the presence of multicollinearity. For the linear regression, the VIFs found in the estimates ranged from 1.28 to 1.56, meaning that no multicollinearity problems occurred.

Note 4. The models potentially suffer from the so-called endogeneity problem. In this case, we are particularly interested in the loop of causality between the independent and dependent variables. As the dependent variable is job growth and independent variables are network characteristics, there is a possibility that job growth is determined by network characteristics or the other way around. If there is a bi-directional causality between the dependent variable and independent variables, then OLS regression analysis may not be appropriate to apply. In order to test the presence of endogeneity, we employed an approach suggested by Hausman (1978). Overall, we did not find an endogeneity problem. The results also indicate that OLS can be used in this analysis.

We followed a procedure that corresponds to Two-Stage Least-Squares regression. We first properly identified and estimated a first-stage regression of the suspected endogenous variables (i.e., strength of ties). In the next stage, we ran another regression and included the residual from the previous regression. Using the results from both regressions, we performed a Wu-Hausman test. The following table shows the results from the test. Overall, we did not find any potential endogeneity problem. The finding also indicates that OLS can be used in this analysis.

	Wu-Hausman F test	P-Value
Tightness of network	2.73157	0.09912
Strength of ties	2.74613	0.09749
Homogeneity of partners	2.77812	0.09705
Local orientation	2.73786	0.09860

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