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Contrasting dynamics in global reach**

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## **Knowledge relationships of university spin-off firms: Contrasting dynamics in global reach**

**Mozhdeh Taheri and Marina van Geenhuizen**

### **Abstract**

This article provides an attempt to better understand the establishment of international knowledge relationships, including changes over time. Internationalization of young high-tech firms is strongly required given the drive for upscaling technology solutions and given the increased global spread of knowledge centers. To increase understanding, a framework of conditions of capability formation in internationalization is developed and measured using a sample of 105 university spin-off firms in Northwest Europe. In early years, 62 per cent of these firms employed knowledge relationships abroad, often crossing continents. The main capabilities in this stage tend to be connected to education (PhD) and market training, innovation activity at practical level, and diversity in preceding domestic networks. Subsequent changes on the firm level show a somewhat stronger internationalization, 74 per cent, associated with other capabilities compared to early years, mainly derived in previous internationalization, pre-start work experience and innovation activity at an advanced level. However, the results also point to a ‘problematic’ segment of firms, including shrinking patterns and persistent absence of internationalization. To summarize, we observe inertia as well as (highly) dynamic patterns of knowledge relationships abroad, with important implications for management and policy.

**Keywords:** university spin-off firms, international knowledge relationships, spatial reach, capability formation, inertia

## 1. Introduction

Internationalization of knowledge interaction and exchange offers strategic and operational benefits to young high-tech firms, particularly those in need for highly specialized knowledge and those facing small domestic markets in their attempts to scale-up and grow (De Jong and Freel 2010; EC 2014; OECD 2009). In addition, young high-tech firms are likely to enjoy scale and scope advantages in specialized value chains, by gaining more benefits from their R&D investments and by developing critical knowledge in collaborating with demanding R&D institutes, customers and suppliers overseas (Love and Ganotakis, 2012; Onkelinx et al., 2015; Raymond and St-Pierre, 2011). Accordingly, an increased attention has been given to internationalization among young high-tech firms, as stepwise paths (e.g. Johanson and Vahlne, 1997; 2009) and as radical development of ‘born-global’ firms acting international from inception (e.g. Andersson and Wictor, 2003; Cavusgil and Knight, 2015; Knight et al., 2004), and this has been followed by more refined views (e.g. Jones and Coveillo 2005; Kuivalainen et al., 2012).

Various studies indicate the importance of knowledge interaction on a *global* level today (Bolzani et al., 2015; Clercq et al., 2012; Heitor, 2015; Kuemmerle, 2002); this is because industrial competence and innovative economic activity are now widely dispersed all over the globe, whereas increased specialization and importance of niche markets have limited the availability of specialized knowledge to a few places in the world (Amin and Cohendet, 2006; Kiederich and Kraus, 2009; Teece, 1992). These places, however, are increasing in number mainly outside Europe. The OECD observes a growing role in international research activity for countries like China, Korea, Brazil and India (OECD, 2012). Today, South-Korea, the US and Japan have a lead in innovation performance over the European Union (EU), while innovation growth rates indicate that China is facing the strongest growth (8.1 per cent) (EC, 2017). This changing landscape of R&D and related innovative businesses may urge young high-tech firms in Europe (small economies) to establish international knowledge relationships quicker and with an increasing spatial reach, thereby enabling to upscale their activity (Anyadike-Danes et al., 2015). In addition, the world is facing a massive move of population to cities, in developing

countries (United Nations, 2017). The fast growing urbanization in developing economies calls for innovative infrastructure and construction solutions, increasingly in the face of needs for resilient and healthy cities (OECD, 2018). The demand for new solutions pushes (engineering) firms to build international knowledge relationships with partners on-site abroad, like in design and implementation of housing projects, sustainable energy production, water management works, port development, waste water treatment, etc.

Internationalization, be it in relation with R&D institutes, customers, suppliers or other players in value chains, requires an appropriate level of resources and capabilities among the firms involved. Knowledge relationships are conceived as relatively stable relationships through which important knowledge concerning R&D and business activity is developed and exchanged. Our analysis puts an emphasis on firm behavior connected with dynamic capabilities. These capabilities enable to build, integrate and reconfigure competences in order to deal with rapidly changing environments and adjustment to new circumstances (Cohen and Levinthal, 1989; Escribano et al., 2009; Muzzi and Albertini, 2015; Teece et al., 2007). The concept we address (but remains outside the empirical study) is (global) corporate mind-set. It refers to capabilities and competences of firms in combining awareness of and openness to diversity across global cultures and markets, and encompasses ways of past and current learning to think, act and operate according to the firms' organization (e.g. Felicio et al. 2016; Torkkeli et al., 2018).

Different capabilities seem connected to different paths of actual internationalization. Two contrasting views on young high-tech firms have been highlighted in literature. In one view, young firms are facing low capabilities causing a high vulnerability (also indicated as liability of newness and 'foreignness') and preventing a quick response to opportunities abroad. Accordingly, firms follow a stepwise pattern using experiential learning, such as in building cognitive bridges (e.g. Johanson and Vahlne, 1997; 2009). In a contrasting view, young firms benefit from a relatively large flexibility in decision-making, responsive learning and quick adjustment, and 'go abroad' immediately after inception (Boccardelli and Magnusson, 2006; Cavusgil and Knight, 2015; Oviatt and McDougall, 1994; Teixeira and Coimbra, 2014; Zaheer, 1995; Zahra et al., 2006). Such contrasting views on internationalization but also the identification of various new paths, in-between and changes from one type to the other, have attracted increasing attention in

research (e.g. Jones and Coveillo, 2005; Knight and Liesch, 2016; Kuivalainen et al., 2012; Vanninen et al., 2017). However, it is not clear to what extent differentiation and dynamic changes, like in speed of internationalization and coverage of continents, do occur and which firm conditions determine the newly emerging patterns.

In responding to this knowledge gap, the article ‘breaks’ with static snapshot research. Rather, it pictures dynamics in internationalization and seeks to understand the relation with formation of firm capabilities, for example, derived from experience in domestic social networks and experience in early steps in internationalization (Johanson and Martín-Martín, 2015; Saarenketo et al., 2004; Zhou et al., 2007). Using a dynamic approach, the article responds to several calls for more empirical research, particularly on the dynamics of early internationalized firms (post-start) while using quantitative approaches (e.g. Johanson and Martín-Martín, 2015; Madsen and Servais, 1997; Torkkeli et al., 2012). To our knowledge, there has been no research using larger samples that enables a quantitative approach to changes in international knowledge relationships of the specific category of university spin-offs, as well as the role of conditions in capability building. In addition, studies on internationalization of university spin-off firms through knowledge networks are rare. For example, Teixeira and Coimbra (2014) focus on speed of internationalization through exports and foreign direct investment, but not through knowledge networks. In addition, Bjørnåli and Aspelund (2012) and Taheri and Van Geenhuizen (2011) use a capability (competence) approach but measure international knowledge networks at one point in time, excluding changes. The current study aims to cover the above knowledge gap in picturing changes in internationalization patterns, as well as to identify connected conditions of firm capability formation using a quantitative modelling approach.

Against this backdrop the research questions are as follows: 1) What are the patterns of international knowledge relationships and which continents are involved in rather early versus later internationalization? Which are the changes over time? 2) To what extent are early international relationships connected to capability-related conditions and what differences do exist with later internationalization?

Drawing on interview data concerning 105 university spin-off firms in Northwest Europe in

2006 and an update among the same firms in 2012, the article makes the following three contributions to the literature on university spin-off firms. Firstly, it provides a deeper picture of patterns of internationalization including different changes in spatial reach of knowledge relationships. Secondly, the contribution is also theoretical, namely by providing evidence of the enhancing role of capabilities derived in domestic networks, specifically diversity in the social circles involved, and of capabilities developed in being present abroad in early internationalization. These results support the importance of learning theory and information diversity (Clercq et al., 2012; Onkelinx et al., 2016). A third contribution is to the debate on the ‘liability’ of young high-tech firms. There appears no one typical development path, rather, three different paths can be observed, including one in line with ‘liability of newness’.

The article unfolds as follows. Theory and hypotheses are discussed in Section 2. Methodological aspects are explained in Section 3. Next is the analysis of the changing pattern in knowledge relationships (Section 4) while the results of exploration of the role of conditions of capability formation are discussed in Section 5. The article ends with a summary and implications of the results, including practical ones (policy), and with some future research paths.

## **2. Theory and hypotheses**

### *2.1 Introduction*

In literature on firms’ performance and growth, focal attention has been given to absorptive capacity and dynamic capabilities providing certain firms with competitive advantage in skills and accumulated knowledge over other firms in dealing with changes. Absorptive capacity is seen as connected to a set of dynamic organizational capabilities (Cohen and Levinthal, 1989; Nooteboom, 2009; Teece, 2007; West and Noel, 2009; Zahra et al., 2006). These capabilities enable firms to recognize and acquire new knowledge that is useful in responding to changes in the business environment, and subsequently assimilate that knowledge in (re)formulation of internationalization strategies and/or operations, like in selecting a mode of organization for sales, the countries and partners involved, and in gaining the financial investment needed (Raymond et al., 2014; Sapienza et al., 2005, 2006; Yu et al., 2011). The theoretical approach of global mind-set (GM) exclusively focuses on internationalization, which includes both

capabilities/competences and firms' internationalization behaviour, in a broader context of attitudes and strategies towards global operations (Javidan and Bowen 2013; Nielsen, 2014; Rogers and Blonski, 2010). A global mind-set is regarded to reside both in individuals (leaders) and organisations (teams), with emphasis on combining openness and awareness about diversity (distances) across cultures and geographic markets, and on building cognitive bridges (capabilities) in exploiting opportunities of such diversity in actual internationalization. Originated in strategy studies of large corporations (Levy et al., 2007; Nielsen, 2014), the concept of global mind-set has more recently also been applied in studies of SMEs (Felício et al., 2016; Torkkeli et al., 2018).

In studies on firm behaviour, focal attention has also been given to the evolutionary character of formation of capabilities. Accordingly, part of the capabilities roots back to what has been developed in the past and cannot easily be changed 'overnight' (Grandi and Grimaldi, 2003; Madsen and Servais, 1997; Pettersen and Tobiassen, 2012; Rasmussen et al., 2014). Past development may refer to teams at university and domestic social networks. Firms with stronger capabilities are not only better equipped to identify and gain external knowledge that is valuable wherever in the world it is, but also to learn to overcome barriers hindering the establishment of relationships abroad, producing that valuable knowledge (Rogers and Blonski, 2010). In practical literature, barriers to internationalization are often grouped into three main categories (BIS, 2010; OECD, 2009), first, resource barriers, like shortages in investment capital, management skills, reputation; secondly, cultural barriers, like difficulty to adjust to cultural norms in doing business and in daily management; and thirdly, institutional (legal) barriers, like in dealing with different financial and tax-related regulation, intellectual ownership and standardisation issues (Oviatt and McDougall, 1994; Prashantham, 2005).

As we study spin-off firms at two points in time, we may observe that relatively weak primary knowledge relationships aimed for opportunity recognition abroad, change into secondary relationships developed for exploitation of international opportunities (Hite and Hesterley, 2001; Styles and Genua, 2008). Such development tends to come with different barriers requiring the formation of distinct firm capabilities, like in dealing with cultural (language) barriers compared to complicated legal barriers. While we focus in this study on conditions in which firms'

capabilities may grow and become elaborated (in short: capability-formation conditions), we do not include a direct view on the kinds of barriers involved.

## *2.2 Conditions of capability formation*

We analyze the reach (scale) in internationalization and changes herein, and explore the role of capability-related conditions among spin-off firms (Figure 1). The ‘unobserved variable’ is global mind-set that integrates behavior, global knowledge and cognition, including the building of capabilities (Felício et al., 2016; Levy et al., 2007). With regard to conditions of capability formation, we follow the theoretical idea (‘upper-echelon’ theory) that in new ventures like spin-off firms - given the absence of hierarchical structures in early years - coordination and strategic planning are mainly performed by the founding team, while team decisions in the initial stages may also condition the creation of capabilities and access to resources at subsequent stages (e.g. Agarwal et al., 2004; Colombo and Grilli, 2005, 2010; Delmar and Shane, 2006; Fern et al., 2012; Huynh et al., 2017; Rasmussen et al., 2014). We address five conditions concerning the founding team, namely, participation in training, team size and experience in pre-start work and in a PhD study. In addition, internationalization is seen as related to a broader complex of learning through innovation activity and concomitant application fields which already started in founders’ projects at university (Felício et al., 2016; Rasmussen et al., 2014). These can be highly applied like in engineering or more fundamental like in material science and biotechnology. This difference is included in the framework as level of innovation. Next, capability formation through networks is part of the framework by including domestic networks with regard to size and partner composition (diversity) (e.g. Lavie, 2006; Hayter, 2015; Milanov and Fernhaber, 2014; Parida et al., 2016). And finally, later internationalization is seen as partially ‘inherited’ from the past, through already developed capabilities and routines at the time, but also as causing the need for the creation of new capabilities, like in dealing with foreign systems of standardization and intellectual ownership issues. At a glance, the previously indicated conditions seem to have developed prior to the establishment of international knowledge relations, but we cannot exclude anticipation to particular steps of internationalization, like in a purposeful formation of a founding team with experience abroad. The last situation would implicate reversed causality in the relationships, and accordingly, we phrase our hypotheses using the term ‘association’.



Drawing on literature on accumulated competences in firms' founding teams (Ensley and Hmieleski, 2005; Visintin and Pittino, 2014), we assume that various founding team characteristics influence the building of capabilities in developing international knowledge relationships. Participation in training on market potentials/marketing skills enables founders to better identify and acquire new knowledge abroad, and overcome various barriers (Love and Roper, 2013; Teixeira and Coimbra, 2014). Targeted training provides better capabilities through which firms can position themselves internationally, in terms of value proposition and relevant market segments (niches) and partners, and find ways to deal with cultural differences and specific local demand (Escribano et al., 2009; Mohr et al., 2014). The relationship may also be the other way around, in that actual internationalization efforts may reveal lack of capabilities that are subsequently solved by means of training. Accordingly, the following hypothesis is phrased:

Hypothesis 1. Participation in market training is positively associated with spatial reach in international knowledge relationships.

We also take size of the founding team into account. It seems that larger founding teams have more capacity to develop adequate skills in searching for the right partners, selecting the best matching knowledge domains and mode of internationalization, e.g. being present on site (or not) (Colombo and Grilli, 2010; De Jong and Freel, 2010; Styles and Genua, 2008; Xia, 2013). Accordingly we phrase:

Hypothesis 2. Size of the founding team is positively associated with spatial reach in international knowledge relationships.

With regard to pre-start business experience, accumulated business skills, like in sales, management and market understanding are important in acquiring new knowledge internationally, eventually through strategic alliances and sales agreements in an industry that is familiar to a founder (e.g. Bjørnåli and Aspelund, 2012; Colombo and Grilli, 2005, 2010; Pettersen and Tobiassen 2012; Visintin and Pittino, 2014; Zhang et al., 2006).

Hypothesis 3. Pre-start working experience in the founding team is positively associated with spatial reach in international knowledge relationships

Regarding experience through PhD education among founders, a PhD study provides firms with stronger capabilities to identify and overcome barriers like cultural (language) barriers and institutional barriers (Bolzani et al. 2015; Liu, 2012; Taheri and van Geenhuizen, 2011). A PhD education may help to present the firm abroad, negotiate and create trust, and handle potential legal conflicts. Accordingly, we phrase the following set of hypotheses:

Hypothesis 4. PhD education in the founding team is positively associated with spatial reach in international knowledge relationships.

Some literature also points to innovation activity as a source of capabilities in internationalization (Castellacci, 2010; Mohr et al., 2014; Rasmussen et al., 2014). We distinguish between two broad types of innovation, the one at advanced (scientific) level requiring interaction with top research groups at universities and research institutes in the world, and the one at a practical (engineering) level. The environment of the first is often turbulent and faced with technological uncertainty, requiring capabilities to closely interact with highly specialized international research groups and knowledge services, eventually in co-creation (Mohr et al., 2014). The environment of the second, is different in that it requires capabilities in new working and management practices in specific cultural settings, in adapting to working in large consortia while responding to local customer demand, and in adapting to new (extreme) weather conditions. In this context, we mention the character of our sample, namely, drawn from two technical universities, it includes a substantial number of spin-offs from engineering schools like civil or mechanical engineering and architecture and planning. Founders graduated from such schools have often already developed specific capabilities during practical work or traineeship at Master level abroad. We expect that practical types of innovations – in the early years of spin-offs' life – are already close to the market and customized on-site, mainly in developing countries in Asia and Africa. Therefore, we phrase:

Hypothesis 5. Practical innovation at modest/low level of newness is positively associated with spatial reach in international knowledge relationships.

With regard to domestic networks, young firms develop supporting capabilities through interaction in social network relations in the home country (Johanson and Vahlne, 2003, 2009;

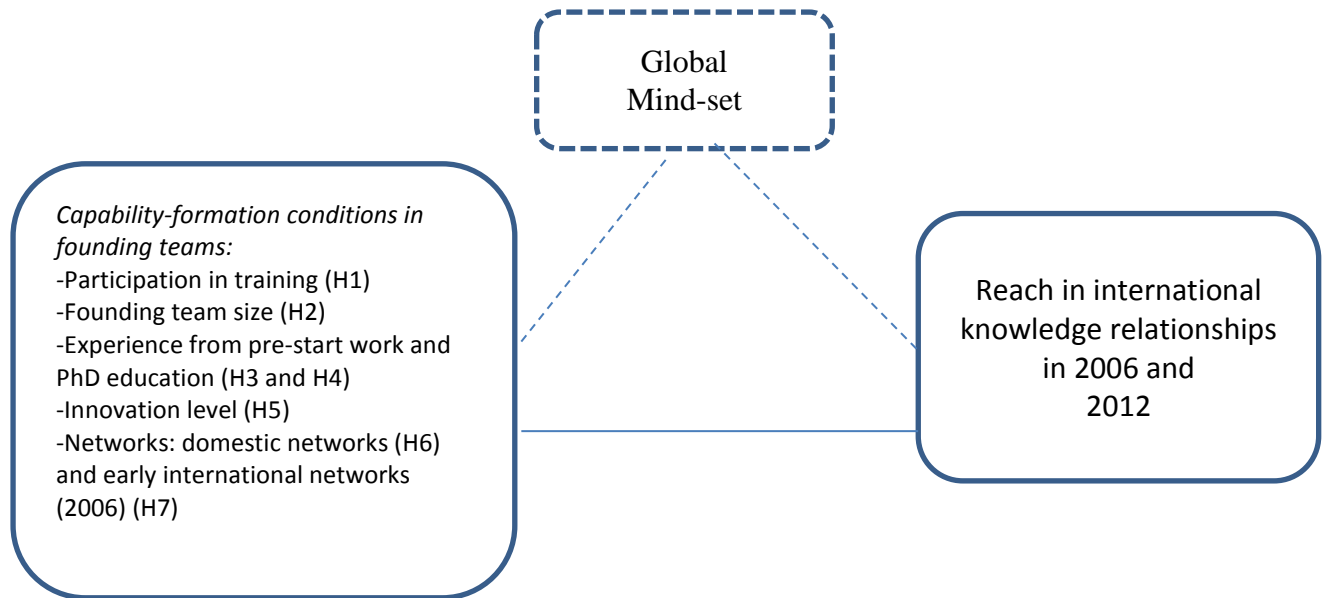
Milanov and Fernhaber, 2014). The idea is that the larger the domestic network, the more powerful capabilities tend to be in connecting domestically with firms abroad, but with larger size, management challenges may emerge (Taheri et al., 2018). In particular, networks outside academic circles, including e.g. launching customers, governments at various level and investors, and networks outside the own region may contribute to positive performance of spin-offs (Hayter, 2015; Huynh et al., 2017; Parida et al., 2016). The concomitant diversity in information provides a broader learning that goes beyond existing cognitive horizons, e.g. in culture and institutions, and may 'prepare' better for dealing with opportunities in complex settings abroad (e.g. Johansson and Vahlne, 2009; Torkelli et al., 2012; Onkelinx et al. 2016; Oxtorp, 2014). In addition, acting in domestic networks, provides capabilities of the firm in presenting itself and in negotiation of deals and agreements (Ott, 2016) including how to maintain networks that are beneficial. At the same time, we may assume some causal relations the other way around, in that far reaching international relationships may reinforce domestic networks of spin-offs due to their increased credibility. Accordingly:

Hypothesis 6. Domestic (social networks) networks, that are larger and more diverse, are positively associated with spatial reach in international knowledge relationships.

With regard to later internationalization, prior international networking experience provides capabilities that make later international knowledge relationships more efficient and better to manage. Spin-offs have already learned how to select, and connect and negotiate with new partners abroad, and how to integrate internal knowledge with knowledge from foreign partners (Ott, 2016; Raisch et al., 2009). Born globals may easily take further steps and expand their network (Johanson and Martín-Martín, 2015). However, a larger reach in internationalization (new continents) may require formation of more advanced capabilities, including new skills and understanding about country-specific situations of marketing and branding, standardization, intellectual ownership, and regulation on operation of an office or manufacturing site (BIS, 2010; OECD, 2009). Overall, as capability formation takes time (and use of other resources) (Teece, 2007; Oxtorp, 2014) we may assume some inertia in developing later internationalization, causing reach to remain close to the previous one.

Hypothesis 7. Early international knowledge relationships in terms of spatial reach and presence abroad are positively associated with spatial reach in later internationalization's knowledge relationships.

Figure 1. Research framework (parts in dashed lines are beyond empirical study)



### 2.3 Control factors

We control for influence of the local/regional economic specialization on young high-tech firms' internationalization behavior, by including location (Andersson et al., 2013; Colovic and Lamotte, 2014). In particular, we assume that spin-offs in clusters specialized in international oil/gas production or in a small regional economy have developed stronger capabilities given the need to employ international knowledge relationships in other continents; this in contrast to more diversified and larger regional economies, both of which are represented in our sample. Further, we include two control factors that are connected to initial entrepreneurial orientation (EO) of firms, in particular avoidance of or preference for risk-taking. First, the difference between science-based and market-based industry (Pavitt, 1984; Tidd et al., 2005), because science-based firms tend to be globally oriented in learning while firms in sectors pushed by market demand, adaptive learning is important which tends to benefit more from local face-to-face interactions

(Asheim et al., 2007; Liao et al., 2003). And secondly, the early vision on future growth, as this may determine the intention to become a large (international) firm or remain small and mainly domestically oriented (Lumpkin and Dess, 1996; Morgan et al., 2009).

### **3. Data and methods**

#### *3.1 Data collection*

We draw on data concerning two university cities, Delft and Trondheim. The two countries involved, the Netherlands and Norway, share a similar, somewhat risk-avoiding entrepreneurship culture (GEM, 2010), have gained similar scores on the main European Innovation Scoreboard indicators in the relevant years of this study (ProInno Europe, 2011) and face relatively small domestic markets, urging specialized firms to be export-orientated. Data-collection took place in two stages, in 2006 and in 2012. In 2006 we constructed the database by focusing on the population of spin-offs that are all active in commercializing knowledge created at the universities and survived to 2006 with an age not older than 10 years. All the firms in this population (150) were invited for an interview, leading altogether to an overall response rate of 70 per cent (105 firms) (Note 1). Data were collected using a semi-structured questionnaire in personal face-to-face interviews with the principal manager, as member of the founding team. To analyze early patterns of international knowledge relationships, we collected cross-sectional data on knowledge relationships and on several firm characteristics related to capabilities during the start-up phase and first years. We went back to the firms in 2012 with a concise e-mail survey and/or telephone call to determine their internationalization pattern at that time (Note 1).

#### *3.2 Measuring the dependent variable*

The dependent variable in this study, reach in international knowledge relationships, is measured as an ordinal variable in four broad categories (Table 1): (1) no international knowledge relationships, (2) only in Europe, (3) only in North/South America or Asia, and (4) in all relevant continents simultaneously (Europe, North/South America, Asia). We asked the respondents about the “most important organisation from which the firm acquires essential knowledge developed in the context of the firm’s growth”, which could for example be a large customer or research organisation, and we asked the location of this knowledge partner. Because many spin-

offs were reluctant to mention a particular city as information – for sensitivity reasons - the country level was adopted. To avoid fragmented patterns, we aggregated countries to the level of continents.

### *3.3 Measuring conditions of capability formation*

We include participation of founders in market-related training in the model, as a dummy variable. The other variables are measured as follows: founding team size as number of its members; working experience as the average number of working years prior to firm foundation (first three team members); education as number of doctorate degrees in the founding team; and experience with innovation by measuring an advanced level indicated by patents and breakthrough products/services, versus a relatively modest level, indicated by orientation towards practical market demand. Furthermore, domestic social networks are measured through network size as the number of social partner relations (ego-centered network) and through diversity of partners as indicated by their socio-economic background and location. In measuring socio-economic background, we distinguish between eight different categories of partners, among them large businesses, government and financial investors. In measuring location, we distinguish between the city-area, broader region and country (see Note 2 for details). Further, the features of internationalization in 2006 act as independent variables in the model of 2012, and these are measured as the spatial reach in the same categories as for internationalization in 2006 and additionally, as being present abroad taken as using office(s) or representative agents/distributor(s) at that time, or not (Table 1). Selection of presence abroad is motivated as follows: Accessing a foreign country can be done in many modes, but using offices (manufacturing sites) and representative agents/distributors tends to require larger amounts of financial and social capital compared to other modes, eventually preventing quickly changing patterns (BIS, 2010).

With regard to control factors, firm location is measured in two categories as a dummy variable, Trondheim or Delft. Measuring the category of industry as part of EO, we distinguish between science-based as involved in basics of chemistry and physics (e.g. nano-technology, new materials, membranes), versus market-based as involved in specialized input to complex production systems or infrastructures, e.g. testing instruments in sustainable energy, monitoring

and information processing in transport, drilling equipment in mining, new types of waste water treatment plants and recycling. Furthermore, the initial entrepreneurial orientation of the spin-off firm is measured in two strategic intention categories, remaining small with regional/national markets versus large with international markets.

**Table 1 Descriptive statistics of variables**

<b>Variable</b>	
Number of spin-off firms (2006); idem (2012)	105; 97(a)
Dependent variable: reach in international knowledge relationships in 2006 (b)	Not internationalized (38.0%) Within Europe only (28.5%) North/South America or Asia only (5.8%) All above continents simultaneously (27.7%)
Idem, in 2012	Not internationalized, incl. shrunk (25.8%) Within Europe only (25.7%) North/South America or Asia only (16.2%) All above continents simultaneously (32.4%)
<b>Controls</b>	
Location (dummy)	Trondheim (41.0%); Delft (59.0%)
EO-Industry sector (dummy)	Science-based: 26.7%; Market-based: 73.3%
EO-Strategic intention (dummy)	International and large : 63.8%; Regional or national: 36.2%
<b>Capability-formation conditions</b>	
<i>Firm-internal</i>	
Market training (dummy)	Yes (31.4%); No (68.6%)
Size of founding team	Average: 2.3; s.d.: 1.16; Min-max: 1-5
Working experience in founding team (years)	Average: 2.6; s.d.: 4.05; Min-max: 0-21
PhD education in founding team (nr. of degrees)	Average: 0.6; s.d.: 0.86; Min-max: 0-3
Innovation level	Modest level (58%); Advanced level (42%)
<i>Networks</i>	
Domestic network size	Average: 3.5; s.d.: 0.95; Min-max: 2-5
Domestic network diversity	Average: 0.33; s.d.: 0.19; Min-max: 0-0.88
Reach in internationalization (2006)	See row above on dependent variable (2006)
Being present abroad (2006)	No presence abroad (75.5%) Office(s) or distributors/agents abroad (24.5%)

a. Eight spin-offs failed (bankruptcy, or being acquired and integrated) between 2006 and 2012.

b. In the modelling part, aggregation to three was necessary for statistical reasons.

### 3.4 Method of analysis

We used Ordered Logistic Regression based on the assumption that the pattern of reach in knowledge relationships, distinguishing between continents, has a natural ordering. Ordered

logistic regression applies maximum likelihood estimation as an iterative process. In the preparation to the modelling, multi-collinearity between the independent variables has been checked (Appendix 1). It reveals somewhat strong correlation between PhD education and working experience, at 0.42, but this is a level that does not cause serious concern (Hair et al., 1995). Further, we mention that logistic regression is less demanding as concerns the relationship between the dependent and independent variables in that the distribution of the variables need not be normal and variance assumptions need not be homoscedastic (Jobson, 1992). This is the reason why we do not pay attention to testing of such assumptions. Although regression coefficients in logistic regression are not as easy to interpret and understand as in other types of regression, the advantage of our analysis is being able to interpret proportional or inversely proportional relationships between each independent and dependent variable. But first, attention is given to changing patterns of internationalization in a descriptive way.

#### **4. Changes in international knowledge relationships**

##### *4.1 Internationalization and its reach*

A majority of the spin-off firms in our sample (62 per cent) employs international knowledge relationships in 2006. These relationships often tend to cross continents, witness the spin-offs active outside of Europe outnumbering the ones active within Europe (33.5 versus 28.5 per cent) (Table 1). In more detail, in 2006, spin-offs active in merely Asia or North/South America are rare, around 6 per cent, but those spanning over different continents at the same time including Asia and America, are more common, at a share of almost 28 per cent.

The share of 62 per cent is clearly different from that found in the Netherlands by De Jong and Freel (2010) in which 22 per cent of the network partners are abroad, while a majority is in the home country. Reasons for this difference may be first, our focus on university spin-off firms, namely while the other study looks at a broader category of high-technology SMEs that are most probably less-specialized and without experience from PhD networks abroad, and secondly, the type of knowledge relationships considered, with a more comprehensive approach adopted by De Jong and Freel in terms of collaboration intensity. Importantly, using a similar definition for internationalization as in our study, in Italy, a share of 60 per cent internationalization is found



among 120 university spin-offs, five years after start-up (Bolzani et al., 2015), which is close to our pattern in early years. Returning attention to our sample, the same spin-offs six years later show that a good 70 per cent have established international knowledge relationships, with an increase in Asia or North/South America (16 per cent), a change that may be enhanced by increasing innovative activities and economic growth in BRICS countries.

As a next step in our analysis, comparing knowledge relationships in 2006 and 2012 for each spin-off individually (Table 2) reveals the following trends. A large group of spin-offs (49.5 per cent) has not changed spatial patterns, of which 33 per cent could have taken next step in spatial reach, which we may qualify as ‘inertia’. In contrast, 34 per cent experienced some sort of expansion in internationalization patterns, of which 20 per cent have extended existing international knowledge relationships to the America’s or Asia, or to all relevant continents simultaneously. The last firm segment represents internationalization dynamics that Johanson and Martín-Martín (2015) qualify as ‘incremental expansion of born globals’. While these authors suggest such dynamics are common for born globals, our results indicate a somewhat more often occurrence of inertia, following initial internationalization. Finally, we also observe a segment that is persistently not internationalized or has been forced to shrink (eventually could not survive) (31 per cent).

**Table 2 Change in reach of knowledge relationships on individual firm level (2006 -2012)**

Type of change (N=105)	Abs. and Share
Shrinking pattern incl. failed firms	17 (16.2%)
No change (inertia)	52 (49.5%)
- Remained ‘not internationalized’	16 (15.2%)
- Remained ‘Europe only’	14 (13.3%)
- Remained ‘NA* or Asia’	5 (4.8%)
- Remained ‘all relevant continents’**	17 (16.2%)
Increase (one step)	20 (19.1%)
- From ‘not internationalized’ to ‘Europe only’	9 (8.6%)
- From ‘Europe only’ to ‘NA or SA, or Asia’*	4 (3.8%)
- From ‘NA or Asia’ to ‘all relevant continents’**	7 (6.7%)
Increase (two/three steps)	16 (15.2%)
- From ‘not internationalized’ to ‘NA or SA, or Asia’	6 (5.7%)
- From ‘Europe only’ to ‘all relevant continents’	5 (4.8%)
- From ‘not internationalized’ to ‘all relevant continents’	5 (4.8%)

\*NA: North America; SA: South America

\*\* Europe, NA, SA, Asia.

Summarized, aside from a segment experiencing expansion, we also observe a problematic segment, including persistently not internationalized and a shrinking pattern, and an inert segment that could have taken next step in internationalization but did not. The three segments tend to be approximately similar in size, around one third of the sampled firms.

#### 4.2 Partners

Spin-offs employing international knowledge relationships in 2006 are most often connected to customers and suppliers, as main partners, at a share of 41 per cent (Table 3). In part, they are involved in engineering projects in collaboration with on-site customers (utility providers, local authorities). Relationships at important annual exhibition/fairs - as more loose inter-organizational structures – are in second place (23 per cent), followed by market representatives (about 20 per cent). Knowledge relationships with universities abroad occur much less (6 per cent), indicating that scientific knowledge is not a pull factor in knowledge relationships for most spin-offs in early years. In 2012, employing a relationship with customers or suppliers (58 per cent) and employing market representatives/agents (27 per cent) have become stronger. This change was at the expense of participation in annual exhibitions/fairs, indeed, indicating a replacement of weak relationships in opportunity seeking with secondary relationships developed for exploitation of international market opportunities (Hite and Hesterley, 2001; Styles and Genua, 2008).

**Table 3 Partners in international knowledge relationships**

<b>Partner type</b>	<b>2006 (%)</b>	<b>2012 (%)</b>
Customers and suppliers	41	58
Market representatives (agents, distributors, etc.)	+/-20*	27
Conferences/exhibitions	23	2
University (professors)	6	10
Others (e.g. financial investor)	10	3
Total	100	100

\*estimated value, derived from ‘being present abroad’ (Table 1) which is 24.5 per cent. This amount seems slightly over-estimated due to including office(s) abroad.

## 5. Importance of capability-formation conditions

### 5.1 Modelling results

We explore the relationship between capability-related conditions and reach in international knowledge networks. By applying a stepwise procedure through adding various sets of new variables to the initial model, we can determine the improvement of the models at each step (Table 4 and Table 5). In more detail, we also discuss log odds for some individual variables.

For all models (partial and full) the Likelihood Ratio  $\chi^2$  test tells that each model as a whole is statistically significant compared to the null-hypothesis without predictors, Model 2 for 2012 at the lowest level. In Model 1 for internationalization in 2006, we first include the three control variables and this produces a rather weak result (Pseudo  $R^2$  of 0.07) with two EO coefficients found positive and significant. Next, we add five firm-internal variables to the model, representing capability-related conditions, which increases the model power by 0.06 in Model 2. Three out of the five coefficients are found positive and significant, namely, market training, PhD education, and innovation at practical level (modest newness). In Model 3, we add the domestic network variables and observe statistical significance for both coefficients, and a relevant increase of model power (by 0.10). The sign of diversity in domestic networks is positive, as expected. However, the sign of size of the networks is negative. Finally, Model 4 as the full model, has reached a Pseudo  $R^2$  of 0.23. By focusing on individual coefficients, with regard to 2006, capability formation through diversity in the domestic networks tends to be a crucial factor. For one unit increase in diversity in domestic networks, a 6.18 increase in the log odds of being in a higher internationalization category can be expected, given all other variables held constant. For size of domestic networks, the increase is 1.54 in an *inverse* relation, which is a somewhat stronger degree compared to any of the firm-internal conditions.

Next, we discuss international knowledge relationships for the same spin-offs in 2012 (Table 5). In the first step (Model 1), again, three control variables are included in the model and this produces the same weak result of 0.07 (Pseudo  $R^2$ ) compared to 2006. By including the five capability conditions that are mainly related to accumulated knowledge in the founding team, in Model 2, the model power increases only slightly by 0.02, without a significant beta-coefficient of these factors. This lack of significance in 2012 seems to be logically following from changes

in founding teams towards more professional management teams. In contrast, adding early internationalization variables (in Model 3) results in a substantial increase in model power, namely to 0.25, with significance of both coefficients, namely, previous internationalization reach and previous type of presence abroad. And finally, the full model (Model 4) is somewhat stronger than that for 2006: Pseudo  $R^2$  of 0.29, with emerging significance of working experience in the founding team and innovation level, in an inverse relation. By focussing on individual coefficients, the largest increase in log odds in the full model can be found for early presence abroad. Increase of one unit in presence abroad, would expect a 3.17 increase in the log odds of being in a higher internationalization category, given all other variables constant. Regarding early reach, this increase would be 1.25, which is still somewhat large. Increase of odds for innovation level compares, but in an inverse relation. Similar to internationalization in 2006, the results on 2012 point to a relatively strong capability formation through networks compared to firm-internal conditions.

With regard to controls, we may note that the most consistent one for both 2006 and 2012 is ‘entrepreneurial market orientation’, indicating importance of the spin-offs’ early strategic vision on growth and how to achieve it. Also noteworthy is location of the spin-offs which is significant in the full model of internationalization in 2012, with a negative sign. Most probably, the economic downturn within our observation period worked out negatively on Trondheim’s economy and spin-offs’ internationalization, for example, related to exploration/exploitation of oil and gas fields in new areas, like Brazil and northern Russia.

## 5.2 Hypotheses testing

We may summarize the above modelling by turning back to our hypotheses for early patterns and later patterns of reach in internationalization (Table 6). *Hypothesis 1* on positive association of market training is supported for 2006. This conforms to the lack of market knowledge observed in spin-off founding teams in early years (Locket et al., 2005; Van Geenhuizen and Soetanto, 2009) calling for training of capabilities to recognize and exploit opportunities worldwide, in particular to define value propositions and market segments (Escribano et al., 2009; Mohr et al. 2014). However, importance tends to become weaker later on causing lack of support for *Hypothesis 1* in later years. Further, *Hypothesis 2*, on positive association of size of

founding teams, is not supported for early and later patterns of internationalization. This may be understood as caused by existing of an optimum size for teams, not captured in our analysis, above which team members become less productive, for example, in creating consensus about important decisions (Onkelinx et al., 2016; Taheri et al., 2018). The generic nature of founding team size, not referring to specific capability in building international networks, could add to the lack of association. The same generic nature may hold true for pre-start working experience, meaning that *Hypothesis 3*, for early years, cannot be supported. However, a positive association of pre-start working experience is supported by the results on knowledge networks in 2012. Most probably, later types of international knowledge networks are more professionalized in nature and require input from specific business-based experience, as part of a conscious reconfiguration of capabilities (Hite and Hesterley, 2001; Onkelinx et al., 2016).

**Table 4 Ordered logistic regression of reach in knowledge relationships (2006)**

<b>Variables</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
<b><i>Controls</i></b>	Ologit coef.(s.e.)	Ologit coef.(s.e.)	Ologit coef.(s.e.)	Ologit coef.(s.e.)
Location (dummy, Trondheim=1)	0.50 (0.38)	0.88 (0.46) *	0.28 (0.40)	0.74 (0.48)
EO-Industry– science-based (yes=1)	0.82 (0.42) *	1.09 (0.46) **	0.70 (0.45)	1.05 (0.49)**
EO-Strategic intentions– int. (yes=1)	1.10 (0.41) ***	1.17 (0.45) **	0.83(0.44)*	1.02 (0.50)**
<b><i>Capability-formation conditions</i></b>				
<b><i>Firm-internal</i></b>				
Market training (yes=1)	-	1.13 (0.46)**	-	0.95 (0.50)*
Size of founding team	-	-0.16 (0.16)	-	-0.24 (0.17)
Working experience	-	-0.01 (0.05)	-	-0.01 (0.05)
PhD education	-	0.81 (0.37) **	-	0.76 (0.39)*
Innovation (modest/pract.) (yes=1)	-	1.01 (0.51)**	-	1.38 (0.55)**
<b><i>Networks</i></b>				
Diversity in domestic network (2006)	-	-	6.03 (1.46) †	6.18 (1.51)***
Size of domestic network (2006)	-	-	-1.44 (0.61) **	-1.54 (0.63) **
LR Chi square	16.70 †	30.79 †	38.23 †	52.49 †
Pseudo R <sup>2</sup>	0.07	0.13	0.17	0.23
Log likelihood	-104.23	-97.18	-93.46	-86.33

\* P<0.1, \*\* P<0.05, \*\*\* P<0.01, †P<0.00

**Table 5 Ordered logistic regression of reach in knowledge relationships (2012)**

Variables	1	2	3	4
<b><i>Controls</i></b>	Ologit coef.(s.e.)	Ologit coef.(s.e.)	Ologit coef.(s.e.)	Ologit coef.(s.e.)
Location	-0.28 (0.38)	-0.52 (0.44)	-0.41 (0.43)	-1.13 (0.51)**
EO-Industry– science-based	0.25 (0.45)	0.14 (0.47)	0.14 (0.51)	-0.08 (0.55)
EO-Strategic intentions– int.	1.48 (0.41) †	1.37 (0.43) †	1.49 (0.47) †	1.45 (0.50) ***
<b><i>Capability-formation conditions</i></b>				
<b><i>Firm-internal</i></b>				
Market training	-	0.51 (0.44)	-	-0.05 (0.51)
Size of founding team	-	0.03 (0.17)	-	0.08 (0.18)
Working experience	-	0.06 (0.05)	-	0.12 (0.06)**
PhD education	-	0.14 (0.36)	-	-0.23 (0.42)
Innovation (modest/practical level)	-	-0.45 (0.50)	-	-1.05 (0.57)*
<b><i>Networks</i></b>				
Internationalization reach (2006)	-	-	1.07 (0.33) †	1.25 (0.37) †
Being present abroad (2006)	-	-	2.77 (0.66) †	3.17 (0.72) †
LR Chi square	15.66 †	19.04 **	54.85 †	62.90 †
Pseudo R <sup>2</sup>	0.07	0.09	0.25	0.285
Log likelihood	-102.33	-100.64	-82.74	-78.71

\* P<0.1, \*\* P<0.05, \*\*\* P<0.01, †P<0.005

In addition, the results support a positive association of PhD education with early international knowledge relationships (*Hypothesis 4*) and this complies with the broader observation about higher education providing capabilities in international partnering (Cavusgil, 1984; Liu, 2012; Xia, 2013), more specifically in overcoming cultural barriers and acting with relatively strong self-confidence in creating trust and in avoiding barriers and conflicts (Freeman et al., 2010; Taheri and Van Geenhuizen, 2011). However, such capabilities tend to fade away in later internationalization, reason why *Hypothesis 4* is not supported for 2012. Considering innovation level, the model outcomes support a positive relationship between a practical level of innovation and internationalization patterns in early years, as phrased in *Hypothesis 5*. The results indeed support that young spin-off firms involved in lower levels of newness in practical application (engineering projects) have already learned to establish market positions and participate in

international consortia on-site, eventually derived from experience gained before graduation from university. In later international knowledge networks, however, *Hypothesis 5* is not supported. Apparently, it is now the turn of spin-offs in more advanced innovations that could take sufficient time in developing capabilities to establish knowledge relationships abroad; this to a larger extent with customers, suppliers, and market representatives compared to internationalization in 2006 (Table 3).

By moving attention to domestic networks concerning 2006 (*Hypothesis 6*), it appears that these networks are important, specifically diversity among partners as indicated by Johanson and Vahlne (2009) and Torkelli et al. (2012). This is in line with varied learning and first capability formation beyond existing intellectual boundaries that are useful in accessing international networks, like presenting the firm in non-familiar circles and searching for network benefits. Unexpectedly, size of domestic networks is negatively associated with internationalization, implicating that *Hypothesis 6* is only partially supported. The negative association with size refers to the - in general - limited management capability of young spin-offs, in particular constraints in developing capabilities for internationalization if large domestic networks need to be managed at the same time (Van Geenhuizen and Soetanto, 2009). For internationalization in 2012, *Hypothesis 7* is fully supported. Later internationalization patterns are positively associated with early internationalization regarding spatial reach as well as presence of the firms abroad. These outcomes illustrate some path-dependency in internationalization activity, in the sense that after the initial step, various years may follow without attempts to increase spatial reach caused by a slow and difficult formation and realignment of capabilities (Aldomar and Rugman, 2014; Onkelinx et al., 2016).

### 5.3 Reflection

The current estimation results suggest a somewhat low level of explanation of variation in internationalization reach; however, it compares with partially similar estimations, like  $R^2$  of 0.20 found by De Jong and Freel (2010) (see Note 3 for more details). We discuss, first, measurement of the dependent variable, and secondly, composition of the framework, thereby referring to alternative explanations.

**Table 6 Summary of hypotheses testing**

	<i>Pattern in 2006 a)</i>	<i>Pattern in 2012 a)</i>
<b><i>Capability-formation conditions a)</i></b>		
<b><i>Firm-internal</i></b>		
<i>H1- Training (+)</i>	Supported (+)	Not supported (not significant)
<i>H2- Size of founding team (+)</i>	Not supported (not significant)	Not supported (not significant)
<i>H3.- Working experience (+)</i>	Not supported (not significant)	Supported (+)
<i>H 4- PhD education (+)</i>	Supported (+)	Not supported (not significant)
<i>H5- Innovation (practical level) (+)</i>	Supported (+)	Not supported (significant (-))
<b><i>Networks</i></b>		
<i>H6.1-Domestic network diversity (+)</i>	Supported (+)	n.a. (b)
<i>H6.2- Domestic network size (+)</i>	Not supported (signific. but -)	n.a.
<i>H7.1-Early internationalization reach (+)</i>	n.a.	Supported (+)
<i>H7.2- Early on-site presence abroad (+)</i>	n.a.	Supported (+)

a) In brackets the assumed sign(s) and the observed signs/significance.

b) n.a. = not applicable.

We have ‘checked’ measurement of the dependent variable, in particular, the role of redundant information by measuring internationalization in two categories, instead of three (Note 4). The results justify a categorization in three which produces more detail in terms of significance. A categorization in four was not possible for statistical reasons. Further, in composing the framework we have limited ourselves to those variables based on dynamic capability theory, *firm-internal and network-related* ones, merely connected to founding teams’ internal conditions. We have not added more of such variables because sufficient differentiation is a key issue in including a variable in ordered logistic regression analysis (avoiding empty cells). For example, we assumed that capabilities derived through founder’s international – ethnic - backgrounds might be associated with firms’ international knowledge relationships. However, we found only a small number of founding teams (15 per cent) with at least one member with a cross-cultural background. This situation exemplifies variables being excluded from further analysis due to the lack of differentiation in the sample.

In addition, in the composition of the framework, exclusively focussing on capability formation in founding teams, we purposely have neglected capability formation through impact of *external*



factors, except for broad traits of the regional economy (as control). External conditions could have provided alternative explanations. We mention relevance of hostility and presence of particular barriers (Torkelli et al., 2012; Zahra et al., 2000). Hostility is related to external risks, for example, in building a relation with an intermediary as a stranger or in investment in a region with emergent political unrest, leading to loss of control. However, there is also a ‘positive version’, namely availability of support in building capabilities, like through technology transfer offices, incubators and accelerators, and public service organizations (Curran et al., 2016; Powers and McDougall, 2005; Rasmussen et al., 2014; Teixeira and Coimbra, 2014).

## **6. Conclusion**

Internationalization of young high-tech firms is not only important given an increasingly global spread of knowledge hubs, but also and increasingly given the need for *upscaling* of technology solutions, in a frame of sustainability problems. We made the following three contributions to the literature. First, providing a deeper picture of international knowledge relationships in terms of reach, particularly changes on the individual firm level. A small majority (62 per cent) of the firms was engaged in international knowledge relationships in early years (2006) with a substantial global reach. Five years later, we found a somewhat stronger internationalization, witness an overall share of 74 per cent. On the firm level, around one third has extended spatial reach, aside from another one third that could have increased reach abroad but did not, and one third that persistently remained focused on domestic markets or was forced to shrink networks abroad or could not survive. The last two segments indicate important ‘inertia’, different from ideas on ‘incremental expansion of born-globals’, as observed by e.g. Johanson and Martín-Martín (2015). Our second contribution is more theoretical. We provided evidence for association between conditions in which spin-off firms learn and build capabilities, mainly network-related ones, and internationalization reach. For early years, we found a strong role of pre-existing domestic networks, in terms of diversity in the social circles involved. This confirms theoretical ideas on learning, namely, a favorable influence of information diversity on sensing of opportunities and larger variety in strategy formulation and adaptation (Teece, 2007; Clercq et al. 2012; Onkelinx et al., 2016). In addition, important capability building tended to shift over time, namely, in later internationalization mainly derived from early patterns of internationalization. This result also confirms learning theory, namely, on the nature of new

capability formation which tends to be slow due to needs for resources (including time) and for adaption of firm strategy and organization to maintain competitiveness and fit (Teece, 2007; Oxtorp, 2014; Vohora et al., 2004). And third, the study contributes to debates on the liability of young high-tech firms. Our results suggested *coexistence* of three segments, thereby addressing differentiation in internationalization, in compliance with e.g. Kuivalainen et al. (2012) and Knight and Liesch (2016): (highly) dynamic firms undertaking an early internationalization and also further steps, firms that have internationalized in early years but hesitate to take such steps, and persistent absence of internationalization networks and shrinking networks. Only the last segment indicates ‘liability of newness’, leaving us overall with a positive conclusion on the ‘power’ of young spin-off firms, knowing that there is also substantial differentiation between them. However, while we have dealt with university spin-off firms operating at high levels of technology specialization in small countries and endowed with capabilities partly gained through PhD experience, the broader category of young high-tech firms (SMEs) seems to include a larger segment that is faced with short in capabilities in internationalization (De Jong and Freel, 2010). An increased attention is needed for the last segment, because absent or failed internationalization, e.g. through export relations or outsourcing, may constrain upscaling of young firms and their technology solution.

The study has also some limitations which can be addressed in future research. The explanatory power of the models could have been somewhat higher, by including capability building related to external circumstances, like political risks in particular countries but also external support. In addition, given our results so-far, another type of modelling would be meaningful in future research, namely, structural equation modelling (SEM). This modelling type addresses complexity, by including both latent factors and observed variables, and paths among them (e.g. Felício et al., 2016). Further, with regard to generalization of the results, the following can be stated. Both countries involved, the Netherlands and Norway, share a somewhat risk-avoiding entrepreneurial culture in a small and open national economy, specialized in seashore activities and coastal infrastructure works. This situation indicates implications only for technical universities in countries, such as Denmark, Sweden and northern parts of the United Kingdom, where technical universities are involved in similar specializations. Extending the research to other (general) universities in non-coastal regions could be another line in future research.

The findings have important practical implications and can be extended to high-tech SMEs. To enhance an early building of international knowledge relationships, we recommend the following, mainly addressed to the management of incubators and/or universities. First, founding teams preferably develop capabilities through acting in small domestic networks that are diverse, outside academic circles (Hayter, 2015). Similarly, having a founder with PhD experience may be supportive. Such situations cause implications for the composition of founding teams and later mutations in these teams, but could also call for inviting experienced external advisors to work with the firms that are lacking capabilities in their internationalization efforts. Secondly, for large segments of spin-offs, internationalization does not ‘happen overnight’. Instead, the required capabilities need time to develop and mature, and to match with the firms’ strategy and organization (Vohora et al., 2004; Oxtorp, 2014), but acceleration is worth trying, which may impact on training content and process. This connects with our observation of three different segments of spin-offs in internationalization, including diverse levels of newness in innovation, which urges managers or policymakers to tailor training/coaching and design programs that better match with different firm needs. And finally, incubator and accelerator organizations, eventually together with public actors, could establish collaboration with foreign firms or foreign trade organizations in the ‘home’ region, with the aim to exchange information and arrange matchmaking with knowledge partners abroad (Van Geenhuizen et al., 2015). In a strong local cluster (value chain composition), connecting with international cluster partners turns out to be (very) helpful, however, such activity comes with new challenges, like its management and selection of the best models (e.g. BSR Stars, 2017).

**Note 1**

Regarding bias of survived firms, a previous study found that around 80 per cent of the spin-offs in Delft managed to survive the first ten years. Using simulation studies, it appeared that firms that have failed in this period do not differ significantly from the ones that survived, which is the reason why major selection bias in the results from not-surviving in the 2006 sample can be excluded. With regard to the same sample in 2012, we mention that 8 spin-offs did not survive (7.6 per cent).

**Note 2**

Diversity of partners in the domestic network is the product of diversity in socio-economic background ( $Hs$ ) and spatial pattern of the partners (local, regional or national) ( $EI$ ):

$$Div = Hs \left(1 + \frac{EI}{2}\right) \quad (1)$$

and 
$$Hs = 1 - \sum_{k=1}^8 \left(\frac{a_k}{N}\right)^2 \quad (2)$$

where  $a_k$  is the number of partners with a different socio-economic background, and where  $k = 1$  (large business), 2 (university), 3 (small business), 4 (government), 5 (family and friends), 6 (financial investors), 7 (lead customer), 8 (others). Note that a partner could be assigned to only one main partner type (identity) while  $N$  is the total number of partners with whom a university spin-off interacts. In addition, diversity in the spatial pattern of domestic partners is calculated as:

$$EI = \frac{E_p - I_p}{E_p + I_p} \quad (3)$$

where  $E_p$  is the number of external, non-local, partners, at more than 60 minutes by car, and  $I_p$  is the number of local partners ( $E_p + I_p = N$ ).

**Note 3**

Escribano et al. (2009), using a logit model to explain managing knowledge flow and innovative outcomes, reach a  $R^2$  of 0.19 and De Jong and Freel (2010) using a multilevel regression model of spatial patterns in knowledge relations do not reach a Pseudo  $R^2$  higher than 0.20. Later studies suggest stronger models, like Bjørnåli and Aspelund (2012), on international alliances and sales among spin-offs from Norwegian universities, reaching a  $R^2$  of 0.42, and Teixeira and Coimbra (2014), using OLS estimations on internationalization speed in export among Portuguese university spin-offs, reaching a  $R^2$  of 0.43.

**Note 4**

We measured the dependent variable in two categories (internationalization, yes/no) in 2006. The results indicate lack of significance of market training, PhD education, innovation at practical level, and size of domestic networks, justifying a more refined measurement of internationalization using three categories.

## Appendix 1- Correlation matrix (n=105) a)

a) Spearman correlation coefficients.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Reach in international knowledge relationships in 2012	1												
2 Reach in international knowledge relationships in 2006	0.46 ***	1											
3 EO-Industry (science-based)	0.17 *	0.27 **	1										
4 EO-Strategic intentions (international)	0.34 ***	0.30 **	0.22	1									
5 Location	-0.00	-0.15	-0.08	-0.17	1								
6 Market training	0.00	0.10	-0.13	-0.10	-0.20 **	1							
7 Size of founding team	0.02	-0.09	-0.08	-0.04	-0.06	0.10	1						
8 Working experience in founding team	0.18 *	0.19	0.17	0.21	-0.33 **	-0.29 **	-0.27 **	1					
9 PhD education in founding team	0.21 **	0.29 **	0.22 *	0.31 **	-0.17	-0.21 *	-0.14	0.42 **	1				
10 Innovation- practical level	0.18 *	0.03	0.28 **	0.35 **	- 0.23 *	-0.12	0.04	-0.19	-0.25 **	1			
11 Domestic network diversity	0.32 **	0.43 **	0.02	0.32 **	-0.22 *	0.15	0.02	0.08	0.11	-0.21 *	1		
12 Domestic network size	0.08	-0.07	-0.17	0.09	0.04	0.21 *	0.06	-0.06	-0.11	0.03	0.33 **	1	
13 Offices/distributors abroad in 2006	0.42 **	0.16	-0.05	0.01	0.01	-0.08	0.13	0.12	-0.17	-0.03	0.05	0.22 *	0.18

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