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Capability factors in changing patterns of international knowledge relationships of university spin-off firms in Northwest Europe

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Abstract

Industrial competence is increasingly dispersed across the globe, urging technology-based firms in Europe to establish international knowledge relationships, sometimes even at larger distances. This paper examines patterns of international knowledge relationships and the influence of capability factors of university spin-off firms on building such relationships and changes herein, using a sample of 105 of firms in Northwest European countries. In early patterns, 62 per cent of the sampled firms employed knowledge relationships abroad. Remarkably, these relationships often cross continents, witness the spin-offs active outside of Europe outnumbering the ones active within Europe (33.5 versus 28.5 per cent). The main capability factors affecting these early relationships tend to be PhD education in the founding team, participation in training, and the capability to innovate on a practical level that responds to market demand. Subsequent changes have led to a high overall internationalization in knowledge relationships of 82 per cent, but also reveal diverse trends among spin-offs, namely, no change for one third of them versus an increase of spatial reach for another one third. This result points to absence of an overall pattern of evolving steps, except for the trend that later relationships are mainly influenced by previous patterns.

Keywords: university spin-off firms, knowledge relationships, spatial reach, capability factors, entrepreneurial orientation, inertia

1. Introduction

Firms that are embedded in inter-organizational knowledge networks are generally seen as absorbing a wide range of specialized knowledge and, as a result, are performing better compared to firms without such embedding (Malerba and Orsenigo, 2000; Powell et al., 1996; Tether, 2002). Various studies indicate the importance of knowledge collaboration on a *global*

level (Clercq et al., 2012; Kuemmerle, 2002; Bolzani et al. 2015); 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 only a few places in the world (Amin and Cohendet, 2006; Kiederich and Kraus, 2009; Teece, 1992). The OECD (2012) observes an increased role in international research activity for countries like China, Korea, Brazil and India. In R&D investment, the US is still in first position but is followed by China, just ahead of Japan, whereas Korea equals the UK (EC, 2013). This changing landscape of R&D and related innovative businesses may urge young technology-based firms in Europe to increasingly establish international knowledge relationships with a larger spatial reach to acquire competitive knowledge. However, aside from a spread of R&D ‘hotspots’, the world is also facing an economic growth in a selected number of large cities, calling for many new infrastructural and construction solutions. Currently, 54 per cent of the world population is urban, but the United Nations expects two-third of the world population living in cities by 2050. And, while the level of urbanization increases in all continents, it is expected to grow at a quicker rate in Africa and Asia (UN 2014). This development may (have) cause(d) reinforce the trend in building international knowledge relationships, namely on a practical level in collaboration with customers on site in design and implementation of housing, city-planning, waterworks, port development, etc. (Jensen et al., 2007).

Developing capabilities to grow is seen as critically important for young technology firms. A larger set of capabilities enables firms to better identify and understand relevant information about new external situations and translate that into decisions and actions (Cohen and Levinthal, 1989; Escribano et al., 2009; Sapienza et al., 2005; Yu et al., 2011; Muzzi and Albertini, 2015). This particularly holds for searching, selecting and maintaining relationships in international context, and for benefitting from them. There are two contrasting views on capabilities’ impact on perceiving opportunities (threads) and responding among young technology firms, which result in an ongoing debate on the matter. Thus, the question remains whether these firms are facing a high vulnerability by not adequately responding to external changes and suffering from inertia, or – in a more optimistic view – benefit from a relatively large flexibility in decision-making, responsive learning and quick adjustment (Zaheer, 1995; Boccardelli and Magnusson, 2006; Zahra et al., 2006). The last view is adhered in studies on born-global development (e.g., Sapienza et al., 2006; Teixeira and Coimbra, 2014; Crick and Crick, 2014). We take the stance of a slight inertia and some small incremental changes for countries in which risk-taking is not popular in business culture (GEM 2014; Hofstede and Hofstede, 2005).

We define the focal firms, university spin-offs, as relatively young and independent firms established by university staff and/or graduates in order to develop and commercialize knowledge created at universities (Pirnay et al., 2003; Shane, 2004). What makes spin-offs different from many other young technology-based firms is that they originate from a non-commercial environment, in many cases, a technology research environment. Thus, spin-off

entrepreneurs are in need of market knowledge regarding customer requirements, changing demand, pricing, etc. as well as complementary technical knowledge to develop and design a marketable product (Lockett et al., 2005; Styles and Genua, 2008; van Geenhuizen and Soetanto, 2009). Despite policy attention, in most European Union countries, the growth of university spin-off firms has been slow and behind expectations (Colombo and Grilli, 2010; Mustar et al., 2006), one reason - among others - tends to be a limited international knowledge network while actual developments call for internationalization over larger distances (Taheri, 2013; Bolzani et al., 2015). This justifies the need for a better understanding of factors underlying establishment and extending of international knowledge relationships to which this paper responds.

To our knowledge, there has been no research to date revealing internationalization patterns of spin-offs over time, as well as the influence of capability factors on building and changing these patterns. We only find a few specific studies on internationalization of university spin-offs. In one of the studies, spin-offs' lifecycle is taken into account and has a focus on networks (Pettersen and Tobiassen, 2012), while the study by Teixeira and Coimbra (2014) has a focus on the speed of internationalization through exports and foreign direct investment, not as knowledge relationships. And finally, Bjørnåli and Aspelund (2012) and Taheri and van Geenhuizen (2011) do use a capability (competence) approach but measure international knowledge networks at one point in time, excluding changes in the patterns. Given the pressing need among young technology-based firms to internationalize, the aim of this paper is to picture and understand the changing pattern of these firms' international knowledge relationships, specifically, the extent in which differences herein are determined by firm capabilities.

In this study, knowledge relationships are conceived as relatively stable relationships through which important knowledge about R&D and business activity in a broad sense is developed and exchanged. They may include the forming of strategic alliances, learning through customer specification of products/services characteristics, co-development of solutions, and regular meetings on innovation organized by international branch societies, etc. (Lubatkin and Lane, 1998; Almeida et al., 2003). As we study spin-off firms at two points in time, we may observe that relatively weak primary international knowledge relationships aimed for opportunity recognition, change into secondary relationships developed for exploitation of international opportunities (Styles and Genua, 2008), all with changing mechanisms of learning (Almeida et al., 2003; Hite and Hesterley, 2001). As many questions regarding network changes have remained unanswered, the design of a supportive policy in enhancing internationalization seems rather difficult, which is a further justification of our research.

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 networks? 2) To what extent are the differences in early patterns affected by capability factors, and to what extent does that also hold true for later patterns?

Drawing on interview data concerning 105 university spin-off firms in Northwest Europe in 2006 and an update among the same firms in 2011/12, the paper makes the following contribution to the empirical literature: a deeper view on international knowledge relationships, namely, insight into the coverage of continents and changes herein over time, and into the influence of early developed firm capabilities on the patterns involved.

It needs to be mentioned that we exclude the role of internet in our analysis because electronic communication tends to be important mainly in searching and learning about potential partners (it can easily accelerate and increase geographical scale). It tends to be less important in the collaboration and learning activities themselves as these require a great deal of tacit communication, though we realize that this may be changing in the course of time (Loane, 2006; Van Geenhuizen and Nijkamp, 2012).

The paper unfolds as follows. Theoretical and empirical perspectives as well as model development are discussed in Section 2. The methodological steps, including data collection, are explained in Section 3. Next is the analysis of the changing spatial pattern in knowledge relationships in Section 4 and the exploration of the role of capability factors in Section 5. The paper ends with conclusions, policy suggestion and some future research paths.

2. Theory

2.1 Introduction

Firm capabilities, as aggregates of skills and accumulated knowledge allowing firms to deploy assets and coordinate activities, enable the building, maintaining and utilization of relationships with various partners (Lavie, 2006; Raymond et al., 2014). As newly established firms go through different stages of development – including exploration and exploitation – regular adjustments of existing relationships with partners are important coming with new challenges and new needs for capabilities arising at each stage (Ndonzuau et al., 2002; Vohora et al., 2004).

Networks provide firms with multiple resources including essential knowledge on (international) markets, sources of financing, applied technology, etc. which is particularly helpful for university spin-off firms that lack such knowledge at various points in time (Tsai, 2001; Kiederich and Kraus, 2009). Knowledge relationships enter in various situations, for example, when specialized knowledge on innovation is scarce and only available in a few ‘hot spots’ in the world, when spin-offs produce for global niche markets with specialized customer needs on site or when they outsource to specialized suppliers. Thus, uncertainty and learning aspects are not limited to characteristics of geographical markets, but also include knowledge on specialization patterns that can be explored by establishing international relationships even across continents. Accordingly, young firms may connect with specialized partners worldwide in various manners,

immediately at firm establishment or shortly after, in case of ‘born globals’ (Andersson and Wictor, 2003; Knight et al., 2004), or in a stepwise way, thereby increasing experience and avoiding uncertainty (Johansson and Vahlne, 1977, 1990).

It is worth notice that insights into the behavioral changes and adaptation in born-global development (in exports) have increasingly produced more refined and slightly different classifications of born-globals by reconsidering timelines and criteria on scale and scope (Jones and Coviello, 2005; Kuivalainen et al., 2012; Teixeira and Coimbra, 2014). We mention different time lag between the firm founding and beginning of international operations, and speed of subsequent international growth; extent of firm’s internationalization on the basis of share of turnover gained in international operations; and a narrow geographic scope versus a broad geographic scope (many different countries involved). In the current analysis, we respond to these ideas by focusing on changing geographic scope of network relations involved.

It is widely accepted in literature that firms capabilities and absorptive capacity facilitate recognizing and acquiring new knowledge, and in a next step eventually assimilating and exploiting it (Cohen and Levinthal 1989; McAdam et al., 2011; Teece, 2007; West and Noel, 2009; Zahra and George, 2002). And this holds also true for building international knowledge networks. Firms with stronger capabilities are, first, better equipped to identify and gain external knowledge that is useful wherever in the world it is. And secondly, as firms get better to overcome cultural and institutional barriers, developing a larger spatial reach eventually to other continents is also more likely (Escribano et al., 2009; Huber, 1991). In practice-oriented literature on the phenomenon of internationalization, four types of barriers are recognized (BIS, 2010; OECD, 2009): (1) resource barriers, like short in investment capital, management skills and reputation, (2) network barriers, like lack of knowledge on foreign markets and international partners, (3) cultural barriers, like difficulty to adjust to cultural norms in doing business and (4) institutional (legal) barriers, like in dealing with different financial regulations, intellectual ownership issues (Oviatt and McDougall, 1994; Prashantham, 2005). However, the analysis of patterns of international knowledge relationships itself in this paper does not include bridging of cultural or institutional distance and barriers.

2.2 Capability factors

An extended R&D capacity in terms of size of R&D staff and training of connected personnel does increase firm capabilities in identification and acquisition of new knowledge while overcoming particularly (technical) barriers in these attempts. This makes us assume that R&D capacity and training provide spin-off firms with better intellectual possibilities to connect with potential partners internationally, even in other continents (Veugelers, 1997; Nooteboom et al., 2005; Escribano et al., 2009; Murovec and Prodan, 2009; de Jong and Freel, 2010; Bishop et al., 2011; Xia, 2013; Visintin and Pittino, 2014).

Drawing on literature that puts an emphasis on accumulated knowledge within firms' founding teams as an influence on firm capability and absorptive capacity, we assume that size of the founding team is an important factor in building and managing knowledge relationships, while smaller starting teams have limited capacities in searching for the right partners and best matching domain knowledge (Colombo and Grilli, 2010; de Jong and Freel, 2010; Murovec and Prodan, 2009; Styles and Genua, 2008; Xia, 2013). We also assume that accumulated knowledge through working experience and education of founding team members, as skills, expertise and understanding that have been gathered prior to the start, are important factors in spin-off firms' capability and absorptive capacity, and have a positive influence on acquiring new knowledge even internationally (e.g. Colombo and Grilli, 2005, 2010; Jansen et al., 2011; Pettersen and Tobiassen 2012; Visintin and Pittino, 2014; Zhang et al., 2006). For example, Bjørnåli and Aspelund (2012) suggest that university spin-offs benefit from (industrial) experience of their founding teams while establishing international relationships through strategic alliances and sales. Moreover, a PhD education of founders, could provide firms with stronger capacity to overcome barriers like cultural (language) barriers and information barriers concerning relevant international networks (Lane et al., 2001; Liu, 2012; Bolzani et al. 2015). Having a PhD education can also be an indication for already established networks in pre-internationalization phase that speeds up internationalization after firm start (Madsen and Servais, 1997; Styles and Genua, 2008).

The capability to innovate is seen as another factor influencing internationalization patterns (Love and Roper, 2013; Teixeira and Combra, 2014). We assume that firms with stronger innovation capability who are active in highly innovative products/services with patent protection and concomitant reputation are better able to connect with international partners in acquiring new knowledge (Andersen, 2006; Geenhuizen and Taheri, 2010). However, there is some ambiguity here, as internationalization may not only be driven by knowledge needs as an input for advanced R&D, but also by needs for practical knowledge in international markets if the innovation is relatively close to application and already introduced to the market. The last occurs if spin-offs that are specialized in solutions in civil engineering, transportation and urban design and planning, etc. are engaged in project work overseas requiring collaborative learning on site with customers.

2.3 Knowledge relationships over time

Firm capabilities root back to capabilities built by a firm in the past that develop over time, allowing for extending the networks (Grandi and Grimaldi, 2003; Madsen and Servais, 1997; Pettersen and Tobiassen, 2012). According to the stepwise model of internationalization, firms develop and gain new and different capabilities through experiential learning in direct interaction abroad (Johansson and Vahlne, 1977, 1990). For example, the increased capabilities of a firm after some time enable it to be involved in problem-solving in a particular international industry setting, like in on-site civil engineering of coastal works, logistics in seaport development, and

water management in developing countries, or in an international research setting on new materials or life sciences. Due to these dynamics, it is plausible that capability factors from the past have been adapted in the meantime, making most of them redundant with regard to later patterns of internationalization.

Early networks often (gradually) change from locally embedded social networks of friendship in early stages to more business type of networks with customers, suppliers, etc. at larger distances even internationally at later stages (Almeida et al., 2003; Hite and Hesterley, 2001; Schutjens and Stam, 2003). And focusing on international networks, patterns of knowledge relationships might gradually change based on what has been built in early patterns and impact from newly developed capabilities and needs (Madsen and Servais, 1997). Prior networking may make international knowledge relationships more efficient and better to manage because spin-offs have already learned to integrate internal knowledge with knowledge from external partners (Raisch et al., 2009). However, because the establishment and management of networks dealing with research or business activity is resource intensive, we expect no drastic changes, only minor ones, after five years, thereby referring to a certain amount of inertia derived from resource and/or routine rigidity and overall risk-avoiding behavior in entrepreneurship (Gilbert, 2005; Hofstede and Hofstede, 2005).

2.4 Control factors

With regard to location of spin-offs, to distinguish the influence of the regional economic specialization and small firms being part of a global knowledge hub, we include *location* as a *control variable* (Andersson et al., 2013; Colovic and Lamotte, 2014). Accordingly, we assume that spin-offs in clusters inhibiting networks that are already globally active, namely, clusters with a strong focus on the oil/gas production and related services, as well as a small size of the regional economy, are more likely to employ international knowledge relationships in other continents. Further, resources are essential in enabling to establish international knowledge relationships, like investment capital and understanding of foreign culture and institutional systems, which tend to be poor at young age but may increase with age and size of firms (Sorensen and Stuart, 2000; Sapienza et al., 2006). For these reasons, we include the *age* and *size* of spin-off firms as *control factors*, without being able to make an assumption about the direction of the influence (positive or negative). This is due to lack of insight into the presence of ‘born globals’ and stepwise developing firms (Pettersen and Tobiassen, 2012; Sapienza et al., 2006).

And finally, we include two factors as being connected to entrepreneurial orientation (EO) of firms in our modeling, firstly, the choice of the industry type between science-based and market-based industry (Pavitt, 1984; Tidd et al., 2005) and secondly, the initial vision of the firms on their future markets (Lumpkin and Dess, 1996; Morgan et al., 2009). Science-based firms tend to be globally oriented in learning while they face larger turbulence and needs for risk-taking connected to evolving new technology, venture capital and patenting issues, all require

specialized knowledge probably through international partners. However, in sectors pushed by market demand, adaptive learning is important which tends to benefit more from local face-to-face interactions in solving problems (Asheim et al., 2007; Liao et al., 2003; Nemet, 2009). For these reasons, industry is included in our analysis as a *control variable*. The argument on the selected industry sector connects with the suggestion that the initial vision regarding future (potential) markets influences the places where the firm develops or gains new knowledge. This initial vision on the close future includes the options of becoming a large or small international firm, or remaining small and active in the regional/domestic market.

3. Methodological aspects

3.1 Data collection

We draw on data involving two university cities in Europe, Delft (Netherlands) and Trondheim (Norway). The two countries involved (the Netherlands and Norway) share a similar, somewhat risk-avoiding entrepreneurship culture (GEM, 2010), gain similar scores on the main European Innovation Scoreboard indicators (ProInno Europe, 2011), and both have relatively small domestic markets, urging them to be export-orientated. According to this pattern, we mainly measure differences between the two regions, Delft and Trondheim, and not between countries. We selected the two cities, because of the contrasting positions. Delft is a part of the Randstad metropolitan regions and the major industry in this area is commercial and service industry (Statistics Netherlands, 2013), while the major industry in the Trøndelag area, where Trondheim is located, is mining, agriculture including farmed fish and processed wood, with oil and gas production as the fastest growing sector with a strong international orientation (Statistics Norway, 2013). Furthermore, the size of the regional economy is ten times larger in the Province of South-Holland where Delft is located, compared to Trøndelag (Soetanto, 2011).

Data-collection took place in two stages, in 2006/7 and in 2011/12. In 2006/7 we constructed the database. The population of spin-offs satisfied various conditions: 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% (105 firms) (Note 1). The data were collected using a semi-structured questionnaire in personal face-to-face interviews with the principal manager, in all but three cases a member of the founding team. To analyze patterns of international knowledge relationships, we collected cross-sectional data and also asked questions about several characteristics of the firms during the start-up phase and first years, as indicators of capabilities, and initial growth. We went back to the firms five years later with a short e-mail survey and/or telephone call to determine their internationalization pattern and growth up to that year.

3.2 Measuring capability factors and control factors

We use R&D expenditure as measured in 2006 as a percentage of average firm turnover over the

past three years. A small minority of the firms (15 per cent) had no turnover because the firms did not sell their product yet, but received substantial national research subsidies or grants from large firms. In those cases, we take income from these sources, as indicated by the respondent. We also use participation in training aside from fostering R&D. Further, the variables used to indicate amount of accumulated knowledge in the founding team are measured as follows: the number of team members, working experience as the average number of working years of the first three founders and education in terms of the number of doctorate degrees in the founding team. With regard to innovation capability, we measured the level of innovativeness thereby distinguishing between a high level as apparent from patents and new products/services being a breakthrough, etc. versus a relatively low level, with a practical orientation towards market demand.

With regard to control factors, firm location is measured in two categories in 2006 as a dummy variable, Trondheim, and Delft. We measure the firm's age as the number of years since a firm was founded, and firm size as the number of employees, in full time equivalent (fte), at the time of the survey (2006) (Table 1). Using the categorization of industry and associated learning proposed by Tidd et al. (2005), we distinguish between two large segments of industries: 1) science-based, dealing with basics in chemistry, life-sciences, nanotechnology, etc., and 2) market-based, including specialized supplier firms providing input to complex (questions) in production systems or infrastructures systems, e.g. machinery and instruments, information processing, sustainable energy production systems, all reflecting demand-pull learning. Furthermore, market orientation is measured as the firm's envisaged customer market in 2006, using the categories regional/national and international, included as a dummy variable.

The dependent variable in this study, spatial patterns of international knowledge relationships, is measured as an ordinal variable in four broad categories: (1) no international knowledge relationships, (2) only in Europe, (3a) in North America or (3b) Asia, and (4) in various continents simultaneously. We asked the respondents about 'the organisations from which they acquire essential knowledge developed in the context of the firm's growth and the location of the most important one. Because many spin-offs are usually reluctant to mention a particular city as information – for sensitivity reasons - the country level was adopted followed by some aggregation to the level of continents due to small numbers per country.

Table 1 Descriptive statistics of model variables

Variable	
Number of university spin-off firms (2006)	105
Idem (2011)	97(a)
Dependent variable: patterns of international knowledge relationships in 2006 (b)	Not internationalized (38.0%) Within Europe only (28.5%) North America or Asia only (5.8%) Various continents (27.7%)
Idem, in 2011 (c)	Not internationalized (18.1%) Within Europe only (25.7%) North America or South America or Asia only (16.2%) Various continents (32.4%)
Control variables (2006)	
Location (dummy)	Trondheim (41.0%); Delft (59.0%)
Firm age	Average: 5.1; s.d.: 3.03; Min-max: 0-10
Firm size (employees as full-time equivalent)	Average: 7.4; s.d.: 7.06; Min-max: 0.5-51
EO-Industry (dummy)	Science-based: 26.7%; Market-based: 73.3%
EO-Market orientation (dummy)	International: 63.8%; Regional/national: 36.2%
Capability factors	
R&D capacity (%)	Average: 39.8; s.d.: 23.07; Min-max : 0-100
Capability through 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 (number)	Average: 0.6; s.d.: 0.86; Min-max: 0-3
Innovation capability (level of newness)	Low/medium (58%) Advanced level, incl. patent protection (42%)

a. Eight spin-offs failed.

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

3.3 Method of analysis

We use Ordered Logistic Regression, based on the assumption that patterns of international knowledge relationships, distinguishing between continents, have a natural ordering. Ordered logistic regression applies maximum likelihood estimation as an iterative process. In the preparation to the modelling, the common checks and considerations are performed, i.e. checking for multi-collinearity and looking at the endogeneity issue. Accordingly, correlations between the independent variables are examined to check for multi-collinearity (Appendix 1). The strongest single correlation is between firm age and firm size (0.58), and there is also relatively strong correlation between firm age and R&D capacity, however, with a negative sign, namely - 0.47, referring to lower R&D expenditure among older firms, which makes us decide to exclude

firm age from further analysis. This step does not result in omitted variable bias, due to its very weak correlation with the dependent variable (see Appendix 1). The remaining correlations (below 0.50) do not indicate serious concern for multi-collinearity (Hair et al., 1995). With regard to the endogeneity issue, we mention the following. While capability factors are measured mainly at the time of the firm start, namely, size of founding team, working experience and PhD education of members of the founding team, knowledge relationships and their patterns are measured as the situation of firms at time of the survey, 2006 and once more in 2011, thus excluding reverse causality and simultaneity bias. However, we need to test four other independent variables in our model for endogeneity: R&D capacity, market orientation, training and innovation capability. The outcomes ensure no serious concern (see Appendix 2).

4. Changes in patterns of international knowledge relationships

4.1 Spatial patterns

A majority of the spin-off firms in our database (62 per cent) employ international knowledge relationships in 2006, often crossing 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 knowledge relationships in merely Asia or North America are rare, around 6 per cent each, but the share of firms with knowledge networks spanning over different continents at the same time including Asia and North America, is substantial, namely almost 28 per cent, indicating that once being active outside Europe may increase the chance of being active in worldwide networks (Table 2).

The pattern of 62 per cent is clearly different from that found in the Netherlands by de Jong and Freel (2010), in which 78 per cent of the network partners are in the *home country* and the rest abroad. This different pattern, may be caused, firstly, by our focus on university spin-off firms, namely, while the other study looks at a broader category of high-technology SMEs. Secondly, the difference may be attributed to the type of knowledge relationships considered, with a more comprehensive approach adopted in the other study in terms of collaboration intensity. However, using a similar definition for internationalization as in our study, a share of 60 per cent internationalization is found among 120 university spin-offs in Italy five years after start-up (Bolzani et al., 2015), which is comparable with our pattern in early years.

Further, studying the same spin-offs five years later shows that 82 per cent of them established international knowledge relationships with a substantial increase in relationships in merely Asia or America (16 per cent), a change that might be enhanced by the more recent developments in innovative activities and growth in BRICS countries pushing firms to improve their own capabilities in dealing with international relationships. This much larger internationalization and also the larger distances involved comply with the more optimistic view about young high-tech

ventures' flexibility and adequacy in grasping opportunities. However, the two patterns (2011 versus 2006) are found to be quite dependent without drastic change. Using Pearson chi² test, a value of 40.74 with a p-value of 0.00 indicate that the null hypothesis of independency can be rejected and it can safely be stated that the pattern of international knowledge relationships in 2011 is dependent on the one in 2006.

Furthermore, comparing the international knowledge relationships in 2006 and 2011 for each spin-off individually (Table 2) produces understanding of the extent in which spin-offs have adjusted their networks. We observe two different trends: first, a large group of spin-offs (50 per cent) has not changed spatial patterns among which 33 per cent could have taken next step in spatial reach between 2006 and 2011, and secondly and in contrast, 34 per cent experienced some sort of expansion in internationalization patterns, of which 20 per cent can be qualified as having extended the knowledge relationships to the America's or Asia, or various continents. Remarkably, 16 per cent of the spin-offs in the sample show a shrinking pattern, but these also include failed firms.

Table 2 Change in long distance knowledge relationships on individual level (2006 -2011)

Change in spatial reach	Abs. and %share
Shrinking pattern incl. failed firms	17 (16%)
No change (inertia)	52 (49.5%)
- Remained 'not internationalized'	16 (15.2%)
- Remained 'Europe only'	14 (13.3%)
- Remained 'NA* or Asia'	5 (5%)
- Remained 'various continents'	17 (16.2%)
Increase (one step)	20 (19%)
- From 'not internationalized' to 'Europe only'	9 (8.4%)
- From 'Europe only' to 'NA or Asia or SA*'	4 (4%)
- From 'NA or Asia' to 'various continents'	7 (6.6%)
Increase (two/three steps)	16 (15.5%)
- From 'not internationalized' to 'NA or Asia or SA'	6 (5.5%)
- From 'Europe only' to 'various continents'	5 (5%)
- From 'not internationalized' to 'various continents'	5 (5%)
Total	105 (100%)

*NA: North America; SA: South America

4.2 Partners

The following picture can be observed in 2006. The spin-offs that employed international knowledge relationships are mostly at product/service sales stage employing knowledge relationships with customers and suppliers, e.g. on product specification, while a smaller group was working, on site, in developing countries on a project basis, including civil engineering

consultancy or construction/maintenance in the oil/gas sector, tailoring their activities to meet the needs of customers. Accordingly, in our sample in 2006, market-related organisations, mainly customers and suppliers, are the most important organisations in knowledge relationships (41 per cent), with yearly participation (presentation) to the same annual exhibitions/fairs - as more loose organizational structures - coming in second place (23 per cent). Knowledge relationship with universities and research institutes abroad occurs much less (6 per cent), indicating that specific scientific knowledge tends not to be a pull factor in knowledge relationships for the majority of the spin-offs in the sample.

In 2011, employing a relationship with market-related organizations including customers (52 per cent), suppliers (6 per cent) and market representatives working abroad (27 per cent), is the most important way of networking (in total 85 per cent) while universities are at a share of 10 per cent. This increased activity on the market is accompanied by almost disappearance of the rather loose knowledge relationships through exchange at annual exhibitions/fairs in 2011. This indicates a gradual replacement of weak knowledge relationships aimed for opportunity recognition in the early networks with secondary relationships developed for exploitation of international market opportunities (Styles and Genua, 2008).

The substantial part of spin-off firms active in international knowledge relationships already in 2006 in our sample (62 per cent) may indicate its importance for growth of the firms. As often suggested in the literature on SMEs development, an international orientation, be-it imports, outsourcing, exports, knowledge relationships, etc., is a favorable condition for survival and growth (e.g. BIS, 2010; Puig et al., 2015). We checked this with our data and indeed we found a significant influence of international knowledge relationships – among other factors - on firm employment and turnover growth (Taheri, 2013).

5. Factors influencing patterns of knowledge relationships

In the regression analysis, we use the dependent variable in three classes of reach in 2006 for statistical reasons i.e., no internationalization, internationalization merely in Europe and internationalization in other continents (Table 3). We apply a stepwise procedure meaning that by adding various new variables to the initial model at each step, we can determine the improvement of the models. In Model 1, we include the four control variables and this produces a rather weak result (Pseudo R^2 of 0.10), but all four coefficients, location in Trondheim, firm size and the two EO related variables, are found to be positive and significant. Next we add six variables to the model, representing capability factors mainly in the founding team, which increases the model power by 0.06 in Model 2. Three out of six coefficients are found to be positively and significantly related to spatial coverage of the knowledge networks, namely, capability gained through training, PhD education of one/more members in the founding team,

and innovation capability at the practical level (modest level of newness).

Next, we model the dependent variable of international knowledge relationships in four classes for the same spin-offs in 2011, i.e., no internationalization, internationalization within Europe, internationalization in North America or Asia or South America and internationalization in various continents (Table 4). We use the same stepwise procedure by adding various new variables to the model at each step to determine the improvement of the models. However, we also explore the influence of existing networks in 2006. In the first step, four control variables are included in the model that produces a weak result of Pseudo R^2 of 0.08 (Model 1). By including six capability factors in Model 2, the power increases slightly by 0.01, mainly due to PhD education coefficient being positive and significant. And finally (Model 3), adding the pattern of early international knowledge relationships (in 2006) leads to a coefficient found to be positive and significant and to a strength of the full model of 0.16, which means a substantial improvement by 0.07. The full model displays the significance of only two coefficients, namely concerning the firm's early entrepreneurial intention on international market orientation and the firm's early patterns of international knowledge relationships. This result indicates a strong consistency between early entrepreneurial orientation and later internationalization patterns in reality, and a determinant influence of early patterns on later patterns.

Contrary to expectations, the coefficient of R&D capacity is not significant for patterns of international knowledge relationships in early and later networks, however, the coefficient of training is significant with a positive sign for patterns of early networks in 2006. The importance of training can be easily understood given the lack of market knowledge in most spin-off teams, like on local product specifications and preferences abroad (Locket et al., 2005; van Geenhuizen and Soetanto, 2009). A positive influence of training on a firm's ability to recognize and exploit knowledge opportunities worldwide is confirmed in other studies, for instance, Murovec and Prodan (2009) and Escribano et al. (2009). The non-significant influence of R&D capacity may be attributed to the dominant type of knowledge relationships in this study, namely pulled by the market, as apparent from the strong presence of customers and suppliers as partners (41 per cent in 2006 and 85 per cent in 2011) and weak presence of universities and research institutes (6 per cent in 2006 and 10 per cent in 2011). In addition, on the part of the R&D indicator, different from the study by de Jong and Freel (2010), measuring R&D expenditure seems not sufficient to reflect the firms' internal capacities to build international knowledge relationships. Continuity of R&D expenditure over time may provide a better indication of a firm's engagement in R&D, creating capacity to establish international knowledge networks, as found by Xia and Roper (2008) and Bishop et al. (2011).

Further, contrary to expectations, the coefficient of size of founding team is not significant. Most probably, this lack of a positive influence on international knowledge relationships can be attributed to the generic nature of founding team size, not referring to any specific attribute that should be present to increase success in employing international networks. In contrast, the results

do confirm a positive and significant influence of PhD education on employing international knowledge relationships in early networks, which complies with a broader observation regarding higher education as a characteristic of high-technology entrepreneurs or teams being linked to international partners (Cavusgil, 1984; Lane et al., 2001; Liu, 2012; Xia, 2013). More specifically, it is in line with a positive influence of international networks established during PhD research (Freeman et al., 2010). In contrast, working experience seems to have no significant influence on international knowledge relationships. This might be a result of the generic nature of working experience as measured in the study, not referring to specific experience in employing international relationships.

Furthermore, in terms of innovation capability, the model outcome shows that the coefficient of modest/low level is positive and significant. This result can be explained as follows. Spin-off firms capable of creating lower levels of newness in practical applications are active in existing markets, mostly already in later stages of development and full acceptance of the initially innovative product/service. Accordingly, these firms have already gained established market positions and participate in international knowledge networks through market-based sources in the form of customers, suppliers and sales agents in different countries worldwide.

The results also indicate that none of the capability indicators have influence on international knowledge relationships in the later networks (Table 4), suggesting an overall short term impact of some capability aspects mainly measured in early years after firm foundation that ‘fades away’ while the firm’s capabilities increase or change in focus in the meantime. Furthermore, as expected, early patterns of international knowledge relationships are found to have a positive and significant influence on later patterns, thereby referring to some inertia or resistance to change as apparent for 50 per cent of the sample, to be more precise, 34 per cent of the sample that could have made at least one ‘step’ in increasing reach. This outcome excludes an overall pattern of evolving steps in extending reach in knowledge networks.

With regard to control variables, the location of spin-offs is found to be a significant factor for early patterns of international knowledge relationships: firms in cities with a relatively strong focus on the energy sector, namely, oil and gas, and an overall small regional economy, exemplified by Trondheim, are more likely to bridge larger distances in acquiring knowledge internationally. This pattern is reinforced by developments in oil and gas production activity which is increasingly extended to places at larger distances from Europe, like coastal waters of Brazil and northern Russia, and West Africa. In the Trondheim region, 25 per cent of the spin-offs are active in machinery/equipment in these sectors, compared to 13 per cent among Delft’s spin-offs in the sample. In addition, although we aim to exclude national differences in terms of innovation systems, size of the economy, etc., by comparing Norway and the Netherlands, there is one factor we do not take into account but may contribute to the significant result of location in Trondheim, and that is a different perception of distance in the two countries, leading to a willingness to travel and connect over larger distances in the larger and more remote of the two

countries, Norway. However, location is found to have no influence on internationalization patterns in the later networks.

Furthermore, as assumed with regard to entrepreneurial orientation, science-based spin-offs are found to be more likely to cross larger geographical distances to establish knowledge relationships and that influences firms networks in both early and later stages, which is in line with the spatial dimension connected to the learning concepts posed by Asheim et al. (2007). Also, larger firms in terms of employees are found to be more likely to extend international knowledge relationships early in their network development, probably due to their ability to satisfy the need for stronger human resources and manpower in establishing and benefitting from the relationships involved, and due to larger credibility in attracting financial capital. But this tends to be only true for early networks. The control variable that is consistently positive and significant in all models (early and later networks) is the firm's early intention to developing an international market orientation.

Among all relevant factors, there is a relatively strong dependency on three capability factors in expanding early international knowledge relationships, i.e. PhD education, participation in training and capability to innovate at modest/low levels of newness. The first two may clearly help in preventing or reducing barriers in partner search early in the network development, while the last indicator reflects having gained access to markets which are increasingly at larger distances from Europe with already accepted innovations, like in the oil/gas market and in civil engineering works. Apparently, establishing or extending international knowledge relationships later in the spin-offs' development rests on somewhat different mechanisms compared to earlier networks, mainly influenced by early entrepreneurial orientation and past experience in building knowledge relationships internationally.

Coming back to the two different trends observed in the changes in international knowledge relationships between 2006 and 2011, we can tentatively connect these with drivers and enabling factors as appearing from the modeling. Accordingly, the trend for no change (50 per cent) is most probably influenced by having reached the envisaged markets and partners already in 2006. While the persistent domestic networks (15 per cent) were most probably influenced by missing capabilities such as from PhD education and relevant training, or missing substantial firm size already in 2006. In contrast, extending internationalization since 2006 by parts of the spin-offs (35 per cent) may draw on existing PhD education in the founding team, the early vision on international market-orientation, and already existing international relationships in 2006. Influences of various capability dimensions in 2011 as developed since 2006, which we did not include in our modeling, might play a role in the extension of international patterns in 2011. This would fit the general idea of dynamic nature of capabilities that develop and adapt along the time to maintain competitiveness and fit among young spin-offs (Teece, 2007; Vohora et al., 2013; Oxtorp, 2014). Based on some case study information, we may 'speculate' on positive learning and experience in next steps of internationalization, for example, with venture capitalists,

eventually in consortia of investors that finance international growth, establishment of international branch offices and further collaborations with international parties in the value chain.

Table 3 Ordered logistic regression analysis of international knowledge relationships (2006)

Variables	1	2
<i>Control variables</i>	Ologit coef.(s.e.)	Ologit coef.(s.e.)
Location	0.73 (0.40) *	1.05 (0.46) **
Log firm size	0.58 (0.24) **	0.68 (0.27) **
EO-Industry– science-based	1.25 (0.47) ***	1.57 (0.52) †
EO-Market orientation– international	0.85 (0.43) **	0.91 (0.47) *
<i>Capability factors</i>		
R&D capacity	-	-0.03 (0.10)
Capability through training	-	0.83 (0.48)*
Size of founding team	-	-0.28 (0.18)
Working experience in founding team	-	0.00 (0.20)
PhD education in founding team	-	0.88 (0.37) **
Innovation capability (practical level)		0.95 (0.55)**
LR Chi square	22.15 †	35.99 †
Pseudo R ²	0.10	0.16
Log likelihood	-100.53	-93.61

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

Table 4 Ordered logistic regression analysis of international knowledge relationships (2011)

Variables	1	2	3
<i>Control variables</i>	Ologit coef.(s.e.)	Ologit coef.(s.e.)	Ologit coef.(s.e.)
Location	0.15 (0.40)	0.06 (0.45)	-0.43 (0.50)
Log firm size	0.31 (0.24)	0.40 (0.27)	0.21 (0.29)
EO-Industry– science-based	1.06 (0.50) **	0.96 (0.51)*	0.33 (0.55)
EO-Market orientation– international	1.37 (0.43) †	1.23 (0.45) ***	0.98 (0.46) **
<i>Capability factors</i>			
R&D capacity	-	0.00 (0.10)	-0.01 (0.11)
Capability through training	-	0.08 (0.47)	-0.32 (0.49)
Size of founding team	-	-0.12 (0.18)	0.003 (0.18)
Working experience in founding team	-	0.00 (0.20)	0.02 (0.21)
PhD education in founding team	-	0.37 (0.36)	0.06 (0.39)
Innovation capability (practical level)	-	-0.41 (0.53)	-0.72 (0.55)
Early internationalization patterns (inertia) (2006)	-	-	1.33 (0.34) †
LR Chi square	22.17 †	23.89 ***	40.66†
Pseudo R ²	0.08	0.09	0.16
Log likelihood	-118.52	-117.15	-108.77

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

6. Conclusion

Extending knowledge relationships in other continents is increasingly compelling for small technology-based firms in Western Europe, as new countries are emerging as centres of R&D and centres of new economic activity, mostly in mega-cities. The need ‘to go international’ holds specifically true for the spin-off firms in the two countries in our study, facing small domestic markets. However, university spin-off firms are different in capabilities that enable them in searching for new knowledge and benefiting from this knowledge. Results show that a majority of spin-offs (62 per cent) was engaged in international knowledge relationships in early years, including substantial differences in spatial pattern, witness one third outside Europe (33 per cent) and slightly less merely within Europe (29 per cent). Their internationalization patterns five years later, at a share of 82 per cent, indicated two different trends, first that around one third experienced some sort of expansion in spatial reach, and secondly, that another one third remained with no change while steps could have been taken. We explored these patterns on the

basis of a set of capability factors referring to R&D, innovation capability and capabilities related to accumulated knowledge. Drawing on a sample of 105 young spin-off firms in the Netherlands and Norway, an influence of three capability indicators was found for early internationalization, namely, PhD education, participation in training, and capability to innovate at a modest/low level of newness, but this worked apparently only on the short term. A ‘fading away’ of this influence on later international relationships can be understood given the changing nature of capabilities (amounts and types) needed in subsequent growth. Entrepreneurial orientation was relevant for both early and later networks, of which one stressing the importance of the early strategic vision of the firms on international product-markets. Besides, as expected, the pattern of international knowledge relationships in early networks was found to have a significant influence on the later patterns, pointing to a certain inertia.

To date, a small number of studies on innovative SMEs (as a broader category) deals with spatial patterns of knowledge relationships (e.g., Styles and Genua 2008; de Jong and Freel, 2010; Kuivalainen et al., 2012). The current paper is different and attempted to extend the literature in two important ways. *Firstly*, we added to the insights into international networking by investigating the patterns at two points in time using somewhat large samples which is new in the literature. Such insight is important given an increasing need to cross larger distances for spin-offs to connect with new global players, which has only recently been included in research agenda’s. We found two different trends, namely remaining consistently not-internationalized versus maintaining and/or extending the international relationships, of which one third simultaneously in various continents. The last trend was found to be market-driven in the early networks and based on collaborative learning with customers abroad concerning broadly accepted innovations. Only a small minority connected to a high-level of innovation and primarily university-based knowledge relationships. Our results thus ‘challenged’ the influence of the capability to innovate at high levels of newness of product/processes among spin-off firms, and call for a more nuanced view on drivers of international knowledge networks.

Secondly, we explored the influence of capability factors on international knowledge relationships over time. The capability factors that were important in early networks disappeared as important influences in later networks. This development indicates the dynamic character of capabilities, thereby also supporting the findings from other researchers that firm capability and absorptive capacity work differently under diverse circumstances (Ebers and Maurer, 2014; Murovec and Prodan, 2009; Zahra and George, 2002). Besides, our R&D related indicator was found not to be significantly explaining the patterns of international knowledge relationships in early and late networks, but it was consistent with our finding on the market-driven character of major parts of international knowledge relationships. *Thirdly*, we contributed to the debate on potentials of young high-tech firms to respond to global forces of change in innovation and economic growth. A share of 62 per cent of international knowledge networks, followed by a share of 82 per cent five years later is certainly a basis for an *optimistic* view. However, the observation of a partially *inert* pattern, evidenced by no increase in spatial pattern observed at a

level of 50 per cent, casts some doubt on the adequateness in responding of spin-off firms to the changing business environment.

The study has also some drawbacks. The explanatory power of the presented models remained relatively weak, however, not substantially weaker compared to similar studies (see Note 2). In future research, to reach a stronger model several variables could be studied in greater detail, e.g. working experience in the founding team, which was not found significant in our model and measurement, the same holds for R&D capacity. In future research, making use of a larger sample, the influence of capability factors could be more thoroughly studied by taking existing networks into account (Ebers and Maurer, 2014). Future research could also include mental processes of founding teams, namely, opportunity perception and motivations which were found to be important in a study by Bolzani et al. (2015).

With regard to generalization of the current 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, that specializes in new technology in seashore activities, mainly oil/gas production and ship construction (Norway), and coastal engineering works (ports, water defense) and (sea) transport (Netherlands). This indicates that the results may have implications for technical universities in only a limited number of similar countries, such as Denmark, Sweden and northern parts of the United Kingdom, where universities are connected to seashore activity. Extending the research to other (general) universities in non-coastal regions could be another line in future research.

The findings may also have some practical implications. To enhance the early building of international knowledge relationships we recommend the following, mainly addressed at the management of incubators and/or universities. Founding teams preferably include members with a PhD education, or benefit from similar level of education/experience from colleagues or external specialists, e.g. by establishing an (external) advisory board (Oxtorp, 2014). This is because such experience supports firms to avoid barriers and to use pre-existing networks in identifying the right partner, and also supports in negotiating in different languages/cultures and institutional systems. Advisory boards are more common in Norway compared to The Netherlands. Moreover, the data set revealed a diverse level of innovativeness among spin-off firms, namely, ones with modest/low innovativeness and established market positions versus ones with higher innovativeness that are still in the development stage. This diversity urges managers of incubation centres to tailor training/coaching and support programs for such different types of spin-offs in the efforts to stretch knowledge networks internationally. In this context, it is also practical to take early entrepreneurial orientation, in terms of industry type and market orientation into account, since they tend to drive shaping the patterns of international knowledge relationships.

Note 1

A previous study found that around 80% 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 can be excluded.

Note 2

De Jong and Freel (2010), using a multilevel regression model do not reach a Pseudo R^2 higher than 0.20. Escribano et al. (2009), using a logit model to explain managing knowledge flow and innovative outcomes, reach a R^2 of 0.19 in their best model, and Murovec and Prodan (2009), using structural equations to measure innovation output, do not reach a R^2 higher than 0.25.

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

	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Patterns of international knowledge relationships in 2011	1												
2 Patterns of international knowledge relationships in 2006	0.46 ***	1											
3 Firm age	0.11	0.08	1										
4 Firm size	0.22 **	0.16	0.58 **	1									
5 EO-Industry (science-based)	0.17 *	0.27 **	-0.32 **	-0.30 **	1								
6 EO-Market orientation (international)	0.34 ***	0.30 **	-0.06	0.12	0.22	1							
7 Location	-0.00	-0.15	0.24	0.14	-0.08	-0.17	1						
8 R&D capacity	0.16	0.07	-0.47 **	-0.23 **	0.31 **	0.28 **	-0.16	1					
9 Capabilities through training	0.00	0.10	0.10	0.33 **	-0.13	-0.10	-0.20 **	-0.16	1				
10 Size of founding team	0.02	-0.09	-0.15	0.26 **	-0.08	-0.04	-0.06	0.02	0.10	1			
11 Working experience in founding team	0.18 *	0.19	0.03	-0.13	0.17	0.21	-0.33 **	0.19 *	-0.29 **	-0.27 **	1		
12 PhD education in founding team	0.21 **	0.29 **	-0.10	-0.14	0.22 *	0.31 **	-0.17	0.17	-0.21 *	-0.14	0.42 **	1	
13 Innovation capability-modest/low level	-0.18 *	-0.03	0.32 **	0.13	-0.28 **	-0.35 **	0.23 *	-0.43 **	-0.12	0.04	-0.19	-0.25 **	1

*P<0.05, **P<0.01

a) Spearman correlation coefficient.

Appendix 2

For example, long distances in knowledge relationships might have enhanced the innovation capability or caused a firm to increase investment in training. We tested the endogeneity of international knowledge relationships taking four explanatory variables in the model. These variables were R&D capacity, market orientation, training and innovation capability. First, using two stage conditional maximum likelihood (2SCML) suggested by Alvarez and Glasgow (1999) to deal with endogenous dichotomous variable X (international knowledge relationships) and continuous explanatory variable (R&D capacity), R&D capacity was found not to be endogeneous. Second, we used probit model for endogenous regressors to test for endogeneity while both endogenous variable and explanatory variables were dichotomous. Using IV Wald test of exogeneity, first we assumed that variable X (international knowledge relationships) was endogenous, and we accounted for it using variable Z (market orientation) (Rivers and Vuong, 1988; Wooldridge, 2002). Next, we assumed that variable X (international knowledge relationships) was endogenous, and we accounted for it by using variable Z (innovation capability). Using Wald Test it was checked whether X was endogenous or not, on the basis of whether the error terms in the structural equation and the reduced-form equation for the endogenous variable were correlated. The outcome of the first test $\chi^2(1) = 5.99$ (Prob > $\chi^2 = 0.014$) and second test $\chi^2(1) = 3.30$ (Prob > $\chi^2 = 0.069$) confirmed that market orientation and innovation capability were exogenous. In the same way, endogeneity of variable X (international knowledge relationships) was checked, instrumenting for variable Z (training). The outcome of the first test $\chi^2(1) = 3.07$ (Prob > $\chi^2 = 0.079$) confirmed that training was exogenous. The previous tests were performed for a binary variable international knowledge relationships. Due to a high correlation between this variable and spatial reach in knowledge relationships (0.90), we expect that the negative results of the endogeneity test for international knowledge relationships also hold true for spatial reach in the relationships involved, thereby confirming that R&D capacity, market orientation, training and innovation capability were not endogenous.

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