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Theme 4: Universities as Interactive partners

Responsible Innovators: an Exploration of Network Conditions in View of Transitions

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Abstract

Responsible innovation is an interactive process in which societal actors and innovators are mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of innovations and their marketable products and services. Being engaged in responsible innovation means a relatively intense participation in the complex networks involved. This paper explores the networks of a specific class of responsible innovators, i.e. university spin-off companies as a channel of market introduction of new technology. A growth model is estimated including openness in networks, and four case studies are analyzed to illustrate different growth paths and different networks from a transition point of view. We observe that spin-offs in responsible innovation are more open than other spin-off companies, that they grow quicker, and that partner diversity matters in growth. In addition, well-performing spin-offs (in terms of growth and progress in transition) tend to employ multi-scalar (local-global) networks dealing with many different functions. Such spin-offs also benefit from their sustained product-market focus and from a favorable national policy.

Keywords: responsible innovation, networks, open innovation, university spin-offs, transitions.

Jel codes: M13, O33

1. Responsible Innovation and Networks

Since the early 1990s, the source of innovation success in companies has gone beyond a linear process of being productive in R&D, improving management practices, and delivery of new quality products and processes to market. Learning in innovation today has become an interactive process in networks with involvement of a wide range of organizations, like suppliers, customers, competitors, community groups, universities, and government agencies (Chesbrough 2003; Laursen and Saulter 2006; Lichtenthaler and Lichtenthaler 2009).

These tendencies have been highlighted in the concept of open innovation defined as the use of purposive inflows and outflows of knowledge to accelerate internal innovation and to expand the markets for external use of innovation respectively (Chesbrough 2003). Three core processes are involved (Enkel et al. 2009), first, the 'outside-in' process meaning that innovation in the company benefits from external inputs (inbound), and second, the 'inside-out process' referring to bringing ideas to market through other organizations, i.e. selling IP. The third process is a 'coupled' process referring to *co-creation* with complementary parties through alliances, joint ventures, etc., in a 'give and take' process. Open innovation in itself is not a new phenomenon. Many companies were already practicing open innovation before the early 2000s, such as in outsourcing and research collaboration with a lead customer, but the urgency to practice open innovation in a conscious and systematic way has increased in the past decade due to a quicker speed of technology development, increasing global competition, and a grown attention for 'responsibility' aspects of innovation (Dahlander and Gann 2011; Huizingh 2011; van den Hoven et al. 2013).

The small literature on responsible innovation indicates that this type of innovation requires high levels of openness in knowledge relations. Important reasons are the close involvement of society and users in order to increase the benefits from innovation and to early detect risks of inventions and new technologies, but also to have inventions quicker introduced to the market. Responsible research and innovation can be described as a transparent and interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products' (von Schomberg 2012). This definition is not only end-result oriented with regard to the type of application of new products, processes, methods, etc., but also clearly process-oriented, putting an emphasis on the interaction between science and society (Owen et al. 2012; van den Hoven et al. 2013).

To gear the innovation process to societal (sustainability) needs or to see sustainability as a driver of innovation is not new, and questions on the desirability of particular new technologies 'among the public' have been raised earlier (Roome and Winn 1993; Hall and Vredenburg 2003; Leydesdorff and Etzkowitz 2003) but the emphasis today is much stronger than in previous times, particularly in many high-level policy and strategy EU documents. We mention the EU Innovation 2020 strategy to create smart growth or the Horizon 2020 program that defines Societal Challenges as one of the main priorities (EC 2011). The emphasis is also stronger on a *long-term view* on sustainability innovation, namely transitions. Transitions are stepwise or radical system changes in infrastructure and institutions facilitating the introduction of a new sustainability technology, together named socio-technical transitions (Geels and Schot 2007, 2008; Markard et al. 2012). The issue of how to promote and govern transitions to sustainability has attracted attention both among policymakers and researchers. This includes among others transition management, strategic niche management, and the multi-level perspective, also ways to deal with the manifold uncertainty at hand (Rotmans et al. 2001; van Geenhuizen and Thissen 2002; Raven and Geels 2010; Smith et al. 2010; van den Bergh et al. 2011; Smith and Raven 2012). Moreover, it is increasingly acknowledged that network structures play an important role in the potential of emerging technologies to spread, particularly in the performance of socio-technical niches, where new technologies emerge and are 'nurtured' outside mainstream pressure from the market or regulatory forces (Lopolito et al. 2011; van der Valk et al. 2011; Hermans et al. 2013).

The focal attention in this paper is on a particular class of small technology-based companies, namely university spin-offs, as a major channel of knowledge transfer (interaction) between universities and the economy and society (Shane 2004). On the one side these companies may work as a trigger in transition processes, on the other they suffer from shortage in resources, particularly knowledge of the market, marketing skills, management capability and investment capital (van Geenhuizen and Soetanto 2009). Accordingly, their position in transitions is not clear. More importantly, if responsible innovation or sustainability is a major *driver* of innovation among them, a higher level of complexity emerges in the learning networks (Hall and Vredenburg 2003; Sweet et al. 2003). These networks are more open as they include a wider variety of partners, like public authorities, pressure groups, and customer groups aside from the conventional ones, calling for additional skills and (managerial) competences, and it may be questioned whether young spin-offs are able to cope with all this, given their short in resources.

To our knowledge there are no studies to date that have addressed responsible innovation among university spin-off companies. Moreover, the perspective of responsible innovation itself is relatively new, reason why the first studies addressing this perspective are just in the process of being published today (Owen et al. 2012). Given the exploratory stage of research, the paper contributes to the literature by connecting responsible innovation with open innovation for a selected category of technology-based start-up companies, university spin-offs, which is entirely new. We draw on a sample of 105 companies and 59 ‘responsible innovators’ among them, as well as four case studies of these companies, in answering the following questions: 1) To what extent are spin-offs as responsible innovators more open in their networks and does a different openness influence their growth? 2) What are other relevant characteristics of the networks with regard to contributing to sustainability transitions?

2. Responsible Innovators in Practice

In our exploratory study, we use a given dataset of spin-off companies from two universities, Delft University of Technology (Delft, the Netherlands) and Norwegian University of Science and Technology (NTNU) (Trondheim, Norway). No differences are assumed in national innovation systems, entrepreneurship culture and size of the small domestic market (GEM 2010, ProInno Europe 2011). However, there is one notable exception important for the current study and that is a more positive and supportive national government's attitude towards wind-energy innovations in Norway compared to the Netherlands. The population of spin-offs was selected in such a way that all companies survived to 2006 with an age not older than 10 years (150). The overall response rate was 70%. In 2006/7, data were collected using a semi-structured questionnaire in face-to-face interviews with the principal manager, focussing on company characteristics, particularly the product/service and the profile of the networks regarding type of partners and degree of openness. In 2011, data were collected, first, among the same companies, namely on their size (jobs and turnover), changes in product/services and status, and secondly, among various case studies with a focus on their networks.

Translating the concept of responsible innovation into measurable indicators of business activity and interactive processes does not go without difficulty. First, the conceptualization of 'ethical acceptability', 'unattended social fields' and 'contested innovations' in a business context, is still rather weak. This means that we have to adopt a pragmatic approach in selecting those companies engaged in product/services that satisfy broad criterions of sustainability, safety, health, etc., while overlooking others, for example, the ones that avoid to be engaged in contested technology and are not involved in sustainability anymore, etc. Secondly, and particularly true for this study, we can only partially grasp the process characteristics, like those serving (early) detection of disadvantages of new technology in consultation with main societal stakeholders. The process characteristics we measure through the social networks, could cover them, but we guess that in the social networks in 2006/7, there were no clear ideas about responsible innovation in a broad sense. However, at the time, there were clear ideas about environmental sustainability, the role of medical technology and safety, etc. These observations make us believe that the current study - while using somewhat older data to explore the networks involved, except for the case studies - deals with a somewhat limited approach to responsible innovation.

In the current study, a distinction is made between a full and a partial involvement of the spin-off companies in responsible innovation. The first means that all activity of the company is focused on a responsible innovation product/service, the last means that only part of the activity can be labeled as such. In addition, we picture the area of application of the product, process, advice, etc. (Table 1). A small majority of the sampled companies (56 per cent) is engaged in responsible innovation in 2010, either full or partially; a good 40 per cent of the companies is not dealing with responsible innovation. A full involvement mostly refers to the medical sector and sustainable energy, both at 19 per cent of all involved companies, the last is also partially involved (at a level of 10 per cent). Sustainable mobility (including vehicle technology) is third in full involvement at 12 per cent of all involved companies. Waste treatment/recycling is fourth regarding full involvement at 10 per cent. In more detail, the medical sector includes design of instruments for minimal invasive surgery, ergonomic furniture, prostheses and practical help in daily care of elderly, as well as new medicines. Sustainable energy as a category includes new types of solar cells, improved batteries for storage, improved windmills (blades), improved turbines, but also energy saving in use of refrigerators and cooling systems. Safety is mainly concerned with conditions on ships and equipment for mining on sea.

In addition, we define relatively narrow subsamples of responsible innovators, namely those involved in the products, processes mentioned only at a relatively high level of innovativeness. Following such narrow definitions, we qualify 27 per cent (N= 28) or, more broadly, 33 per cent (N=35) of all sampled companies as 'responsible innovators'.

Table 1: Application area of responsible products/services (broad definition)

Application area	**Full involvement**		**Partial involvement**	
	Abs.	**%**	**Abs.**	**%**
Medical care and cure	11	18.6	0	-
Sustainable energy	11	18.6	6	10.2
Sustainable mobility, vehicle technology	7	11.9	7	11.9
Efficient industrial processes	1	1.7	5	8.5
Efficient waste treatment (recycling)	6	10.2	0	-
Sustainable buildings and safety	4	6.8	1	1.7
Totals broad definition (N = 59 spin-offs)	40		19	

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In the remaining section, we explore to what extent responsible innovators have adopted open innovation practices in their knowledge networks. Networks are measured as 'ego-networks', including relationships established by ego (the spin-off company). This approach provides a limited view on the full networks, but it allows for a deeper understanding of the company's intentions behind the network relationships. Openness in network relationships is measured by using two dimensions, i.e. openness capacity and openness diversity (Ye et al. 2013). Openness *capacity*, as the 'size' of the external knowledge pool, is a two-dimensional variable composed of breadth and depth (Laursen and Salter 2006). Breadth, number of different types of knowledge acquired, and depth, tie strength between the company and its partners, constitute the knowledge pool that is actually accessed. The mathematical modelling is unique in the sense that it assigns weights to the strength variables using entropy-weight method, this measures the effective amount of information of the data and better reflects reality (Ye et al. 2013). Further, openness *diversity* describes the heterogeneity of partners' social background, including spatial orientation (local versus regional). A distinction is made between partners from large companies and from small ones, government representatives at high level, university professors, lead customers, and friends, etc.

Comparing openness capacity and openness diversity between responsible innovators and other spin-off companies brings to light that the first are more engaged in open relations only as far as capacity is concerned (Table 2).

Table 2: Scores on openness capacity and diversity (a)

	Responsible Innovators (narrowly defined) (N=28)	**Other companies (N=77)**
Openness capacity (pool)		
Average (s.d.)	5.50 (2.73)	4.39 (2.44)
min-max	1.51-11.67	1.08-12.35
t-test	-1.99**	
Openness diversity (partners)		
Average (s.d.)	0.80 (0.16)	0.77 (0.13)
min-max	0-0.90	0-0.89
t-test	-1.09	

*p<0.1; **p<0.05

a) Using a somewhat broader definition of responsible innovators (N=35) gives similar results: averages of 5.22 versus 4.42 and a T test result for *openness capacity* (- 1.52) that is significant (p<0.1).

The results are robust as both the narrow and a broader definition of responsible innovators yields statistically significant results with regard to openness capacity. Apparently, responsible innovators at high levels of innovativeness have to stretch their knowledge into different disciplines and subject matter, therefore a larger knowledge pool is needed.

3. Responsible Innovators' Growth

This section explores whether growth trends among responsible innovators differ from that of other spin-offs, and how responsible innovation interacting with open innovation influences growth. It is not clear from the literature whether young responsible innovators or the like grow differently compared to other companies. Derived from the idea that more radical innovations are involved in solving societal problems, one may expect a slower growth due to resistance from traditional solutions and current technologies and institutions (Geels 2002). On the other hand, one may also expect a stronger growth when the solutions are developed in interaction with (future) users and other stakeholders, and are supported with subsidies and niche market conditions. It appears that responsible innovators tend to be less exposed to failure (cease to exist) and tend to better perform regarding strong growth (Table 3). The last is witnessed by a share of 36 per cent among responsible innovators (narrow definition) compared to 18 per cent among other spin-offs.

As a next step, the influence of the networks on growth of the spin-off companies is explored. We limit our analysis to employment growth, for the reason that this growth could be measured accurately, while, for example, turnover was measured using broad categories in order to prevent non-response. In the modeling, growth is taken as average annual growth since establishment of the companies. We estimate a simplified growth model, using the full subsample of spin-offs without concern about innovation level (N=59), this because including the innovation level would yield too small subsamples for our modeling effort.

Table 3 Employment growth in various classes (narrow definition) (a)

Employment	**Responsible innovators (narrowly defined)**		**Other spin-offs**	
Ceased to exist	2	7.1%	11	14.3%
Negative/no growth	12	42.9%	25	32.5%
Low/medium growth	4	14.3%	27	35.1%
Strong growth	10	35.7%	14	18.2%
Total	28	100%	77	100%

Pearson Chi^2=7.24, p=0.07

a)Using the somewhat broader definition of responsible innovators (N=35) does *not produce* significant results.

We assume that young spin-off companies while facing limited resources (van Geenhuizen and Soetanto 2009) need to be reluctant in building relationships with many actors of the same kind and that – given a limited number of partners - a high diversity in partners has a positive influence on growth. Location (city), firm age, growth ambition, and size of the company at start are used as control variables. We also explore one moderating effect, namely of location with network characteristics. Location is included because we assume that in remote cities (Trondheim) spin-off companies are facing a less favorable environment compared to their counterparts in large metropolitan areas, due to weak presence of launching customers, poor test markets, a less rich labor market and smaller knowledge spillovers, in short, a weak development of agglomeration advantages (Saxenian 1994; Audretsch and Feldman 1996; Rosenthal and Strange 2001).

A stepwise approach is used (Table 4). Accordingly, the model power reaches a level of 0.22 (R^2) if only the control variables are included (Model 1), with the coefficients of location and growth ambition as significant ones, indicating a positive influence of being located in Delft, in a large metropolitan area, and a positive influence of the ambition to grow. Including merely the network variables (Model 2) gives a slightly larger model power of 0.26, with coefficients that are significant for openness diversity and for the moderating effect of urban location and openness diversity, but not for openness capacity. The full model (Model 3), including both the control variables and the network variables, reaches a model power of 0.52, with all coefficients significant except for openness capacity (size of the knowledge pool).

Table 4 A simplified model of employment growth

	Model 1 β (s.e.)	Model 2 β (s.e.)	Model 3 β (s.e.)
Control variables			
Location	1.40 (0.56)**		1.68 (0.45)***
Growth ambition	0.82 (0.27)***		0.66 (0.24)***
Firm age	-0.08 (0.36)		-0.64 (0.31)*
Size at start	0.31 (0.26)		0.36 (0.25)**
Network variables			
Openness Capacity (pool)		0.02 (0.27)	-0.08 (0.23)
Openness Diversity (partners)		1.15 (0.30)***	1.07 (0.27)***
Openness Diversity x Location		10.19 (3.29)***	13.73 (2.9)***
N	59	59	59
F	3.90***	6.54***	7.84***
R^2	0.22	0.26	0.52
Root MSE	2.07	2.00	1.68

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

We may conclude so far that networking makes a difference in terms of diversity, as a stronger diversity in network partners tends to enhance growth. This seems especially true if the spin-offs are in Delft, indicating that metropolitan areas not only provide a better location for responsible innovation but also a better place for benefits from networking.

It needs to be mentioned that in another modeling experiment of employment growth, taking the *full* sample (also including not responsible innovators) into account, we find a significant but negative influence of an interaction term 'Responsible innovation X Openness diversity' (Ye and van Geenhuizen 2013). Compared to not responsible innovators this may point to a ceiling of openness diversity with which responsible innovators can deal, given their limited resources and more complex networks.

Note that in the full model (Model 3) the coefficients of age and size at start are also significant, age indicating a negative influence on growth. An explanation may be that responsible innovators are facing a prolonged stage of risk taking and even stronger risks at higher age, frustrating growth. What is also possible is that these spin-offs at older ages and after closing the development stage, make use of suppliers and subcontractors for building pilots, producing small batches and manufacturing components, thereby reducing the number of jobs within the company.

4. A 'Deeper' Insight into Networks

This section serves to illustrate the patterns of growth indicated in the previous section and to explore a set of important network attributes in the light of a potential contribution to sustainability transitions. The focus of attention is on functions of the network and their geographical scale, based on the idea that if the network partners are diverse, e.g. ranging from venture capitalists to governments supporting a pilot (niche), and stretching from the local to the global, the company and its technology solution have substantially increased in credibility and in 'power'.

Case study A represents companies facing a slow growth in Delft and later on in Breda (southern part of the Netherlands) (Table 5). It started in wind energy solutions but - due to diminishing support of the national government - found itself forced to diversify into aerodynamics of vehicles and later on (from 2007) quite broadly into food processing industry, building construction, etc. The current network only encompasses customers (co-developers) and shows a trend of moving from the global to the local. In contrast, case study B represents medium-level growth in Trondheim. The company could maintain focus, due to various national support in wind energy projects. The network is more open in terms of partner diversity as it encompasses venture capitalists, government bodies, launching customers, etc.

Table 5 Selection framework of case studies

Case study (founding year) and technology	**Job growth (fte) per year**	**City**	**Partner diversity 2010**
A (2005) Air flow dynamics	1.3	Delft, moved to Breda	Low
B (2006) Wind turbine technology	3.75	Trondheim and Silkeborg (Denmark)	Medium
C (2001) Medical communication software	0.44 (a)	Trondheim	Low
D (2005) Battery charging technology (EVs)	9.0	Delft and Eindhoven	Large

(a) Integrated in acquiring company in 2007.

In addition, case study C represents the small growth in Trondheim, and also less open networks, mainly including a testing organization for the software. Finally, case study D represents the quickly growing companies in Delft, also employing a site in the southern part of the Netherlands in close proximity to high concentrations of micro-electronics and automotive activity, and it represents both a high level of openness and multi-scalarity in the networks.

We now discuss the case studies in detail, particularly the networks used to access resources that are not available within the company and to access social partners. Company A has benefitted from two main assets in Delft: the wind tunnel facility allowing improvement in modeling airflow dynamics and a strong push towards entrepreneurship at the Faculty of Aerospace of Delft University of Technology (Table 6). The company started in Delft but moved to Breda in a province that provides location subsidy and 'soft' venture capital. Due to a reduction in protective measures for wind energy technology by the Dutch government, the company shifted its focus from shaping wind turbine blades (boundary layer suction), to applications in the vehicle industry (aerodynamics), building construction and food processing industry causing a large network of a similar type of relations, namely with customers, eventually as co-developers. With the current diversification in markets (applications), this company seems not able to contribute to transitions in the wind energy field. The networks include many different customers, but they are not open in the sense of including financial investors, customers, actors dealing with pilot projects, etc. in the core technology concerning rotor blades. As far as social activities are concerned, the company keeps being alert on new technical developments concerning wind turbines and pays attention to potentials of wind energy in the media.

Company B while elaborating a gearless drivetrain (hydraulic) and a solution for better stabilization of the turbine body, has maintained focus over time, supported by government investment and venture capital in various rounds, and two testing customers in Norway. At the same time, it extended presence both in the largest wind turbine cluster in Europe (Greater Aarhus area, Denmark) and in China, the latter country with an eye on relatively cheap suppliers and access to the market. Overall, networks are more open in terms of different functions related to the core technology. As far as social activities are concerned, the company has a strong presence at various meetings and conferences, with both technical and application oriented lectures. Overall, the company already contributes to a transition in wind energy use today. With regard to company C, we observe a limited growth both due to rigidities in the health system towards e-health and lack of co-developers in the Trondheim area. The company was - given its small size and lack of network partners - not able to deal with obstacles in the national health system, blocking the introduction of privacy protection software in e-communication between patients and family doctors. The company was acquired in 2006 by a larger company in Oslo and integrated one year later.

With regard to company D, an increased focus on the core technology can be observed. While this company initially had a broad focus on batteries in consumer products, it attracted venture capital (among others international venture capital from the sector) and received national and EU support through research programs on electric vehicles in elaborating its path breaking technology, namely, shortening the charging time of vehicle batteries substantially without damage to the battery. The company opened a second location in Eindhoven at the High-Tech campus, as a ‘place to be’ but also as a place providing access to the automotive and micro-electronics cluster in the region, and to regional financial incentives and ‘soft’ venture capital. Remarkably, already in the early networks various companies in the value chain were present, like battery producers and energy companies. The networks in 2010 are most open as witnessed by the involvement - aside from financers and co-developers/customers – of governments in creating a protective niche.

Table 6 Location and networks

City and scale of networks	**Localized assets and function of networks**
Company A	***No/small contribution to transition concerning wind energy***
Location - Delft, later on Breda (NL)	-TU Delft: **wind tunnel** facility and strong **entrepreneurship building** (Faculty of Aerospace at TU Delft). -Breda is in North-Brabant (Province) providing **location incentives (subsidy) and 'soft' venture capital**
Early Network -Focus: Modena (It), Ingolstadt (Germany) and Utrecht (NL) *Current Network* -Rather closed pattern	-Car industry as **customer/co-developer** and rail industry as **customer/co-developer** -Different industries, e.g. food process industry and construction, due to diversification in markets. Media use for paying attention to potentials of wind energy.
Company B	***Contributes to transition concerning wind energy***
Location - Trondheim with test site in Valsnes -2nd site in Silkeborg (Denmark) -Representation: Hongkong (China)	-NTNU: **wind tunnel** facility**; collaboration** with university of Bath (UK) at start -Silkeborg: access to **wind turbine cluster** in Denmark (Aarhus) -Hongkong: access to Chinese **suppliers and customers**
Network -Trondheim, Stavanger, Oslo -Trondheim and Stavanger	-Venture funds (partly government, oil industry, environmental funds): **financial capital** -Governmental organization and oil company as **(test) customer (pilots)** -Strong presence at meetings and workshops to promote its technology
Company C	***No contribution to transition concerning health care (e- medicine)***
Location -Trondheim	-Source of specialized **knowledge**
Network -Trondheim, Tromsø - Oslo	-Various medical health organizations, performing **pilots** and evaluations of medical e-consult software -Collaboration with large company for **market access** -Joined this company for **market access (acquired)**
Company D	***Strong contribution to transition concerning electric vehicles***
Location -Delft -2nd site in Eindhoven (NL)	- Source of specialized **knowledge** -'**The place to be'**, **access to mechatronics/ automotive cluster;** Province of North-Brabant provides **location incentives (subsidy) and 'soft' venture capital**
Early Network (consumer electronics batteries) *Later Network (since 2010)* -Amsterdam, Vancouver, Taipei, Den Bosch (NL) -Rotterdam, Hoofddorp, Leeuwarden, Den Bosch (NL) -Zurich (multinational)	-**Venture capital**, mainly from the sector, international and regional (multi-scalar) -**Pilot** of public charging stations in various cities, mainly Rotterdam and Leeuwarden **(protective niches),** also supported by energy companies and a **launching customer** -Joined MNC to **access manufacturing of hardware and customer markets 'overseas' (acquired)** -Participation in national study on *smart* networks

The last network is in the Province of Friesland that plays a role in bringing sustainable energy solutions to market, in the city of Leeuwarden, where a pilot was performed in laying out public charging stations across the city. Most recently, the company joined a multinational because it was not able to gain sufficient strength to continue competition and access mass markets abroad (US) on its own. With regard to transitions, this company is already contributing to a transition, namely, the pilots are followed by projects to establish large scale public charging systems for electric vehicles in various places. Looking back, in particular, the venture capital from the sector and from 'overseas' (Vancouver and Taipei) marked a high level of credibility of this company in the global arena. Currently, the company (as part of the MNC) is involved in a study including various stakeholders to create a *smart network*, in which locally generated renewable energy is utilized immediately for use by electric vehicles and storage in batteries (AgentschapNL, 2013).

Remarkably, both the worst and the best performing companies were acquired by larger companies for the same reason, namely, a too small size to access markets. However, there is a clear difference in background, company C was not able to fight obstacles in the health care institutional system in Norway, while company D was not able to access markets 'overseas' with a technology already accepted in Europe.

We may conclude, so far, that the best opportunities for reaching higher levels of sustainability are found among companies like company D in Delft which developed open and multi-scalar networks, proofing a strong credibility, and company C in Trondheim which overcame constraints of its location by being present in the Danish wind energy cluster, while developing open networks. The chance of market introduction and steps towards transition is largest if the companies maintain a tight product-market focus, adapt their location to be present in major clusters, and connect with partners - locally and globally - covering different essential functions. Particularly, in keeping focus on the core technology, protective measures by the national government may be crucial.

5. Concluding Remarks

We made use of a sample of 'responsible innovators' among university spin-off companies and of four case studies of them in answering the following questions: 1) To what extent are spin-offs as responsible innovators more open in their networks and does a different openness influence their growth? 2) What are other relevant characteristics of the networks with regard to contributing to sustainability transitions? The study demonstrated that almost 60 per cent of the sampled companies are engaged in responsible innovation, with medical care/cure, sustainable energy, sustainable mobility, and waste treatment/recycling as the largest sectors. Dependent on a high level of innovativeness, the category of responsible innovators is clearly smaller, namely, around 30 per cent. The results revealed that responsible innovators are more open in their networks than other spin-off companies with regard to the knowledge pool (subject matter), that they grow quicker, and that partner diversity matters in growth. In addition, case study analysis indicated that functional diversity and multi-scalarity in the networks provide the best potentials for contributing to growth and transitions. Location matters, but we could also observe a clear trend for relocation or multi-site development in order to take advantage of particular localized assets not available in the city of location. Also, maintaining a tight product-market focus seems an important condition.

Despite the interesting results this study suffers from some limitations. As previously indicated, the first lies in the *limited* approach to responsible innovation following from the currently still limited conceptualization of responsible innovation and from the nature of the database used, providing data on social networks in 2006/7, years in which responsible innovation was not a common concept and practice. However, our case study analysis made use of data from 2010 and we could picture some recent societal activities of the companies concerned. A major challenge is, nevertheless, to elaborate responsible innovation conceptually and, in empirical research, to picture and characterize recent processes and interaction with societal actors along the way to market introduction/societal use, as a more comprehensive empirical approach. A broader approach would also enable to connect company development to strategic niche development and transitional/evolutionary perspectives which are involved in bringing about societal and technical change (Schot and Geels 2007, 2008; Smith and Raven, 2012), especially by adopting a more comprehensive network view and using standard network analysis tools in measuring the properties of the networks (Lopolito et al. 2011; Hermans et al. 2013). The period of observation of the technology was from the establishment of the company up to 2011. This period needs to be extended to years before establishment of the company and after 2011. It is especially important to understand what happens with the technology after companies are acquired by larger companies. The second limitation originates from the countries where the sample of university spin-off companies was drawn, i.e. the Netherlands and Norway. The results tend to be generalizable given a similar context under the EU framework and similarity with regional economies based on knowledge in the maritime cluster and energy clusters (sustainable energy, energy efficiency, safety), like in Sweden, Denmark and parts of the northern UK (e.g. Scotland). However, this is a small part of the EU, and the interpretation of responsible innovation may be culturally defined, calling for a study of context-dependency across the EU countries.

More importantly, ways need to be found to increase involvement of university spin-offs in responsible innovation. This category of high-tech start-ups is important as a channel for bringing university knowledge to market/society, yet their short in resources puts limits on the number of network partners with which they interact. A major step in future research is thus to identify best practices among university spin-offs in the recent past in being *selective* in choosing those few open innovation partners, e.g. large customers (co-creation), international venture capitalists, governmental or non-governmental organizations, which provide on their turn access to a complex and diversified network (platform) necessary for bringing responsible innovations to market and for contributing to transitions.

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