

# **Innovation cycles impacting network effects on R&D cooperation project's value creation**

Ariane von Raesfeld  
Business Administration  
School of Management and Governance  
University of Twente  
[a.m.vonraesfeldmeijer@utwente.nl](mailto:a.m.vonraesfeldmeijer@utwente.nl)

Peter Geurts  
Public Administration  
School of Management and Governance  
University of Twente

## **Abstract**

Within the field of innovation in business network several authors raised the need for more research into the forces of innovation and efficiency. These divergent and convergent forces run together (Håkansson and Waluszewski, 2002) and can have often opposing effects on innovation outcomes (Waluszewski, 2011a, Hoholm and Olsen, 2012). Therefore, in this paper we will analyze the divergent and convergent network effects taking place in R&D cooperation projects. We investigated the combined effects of technology development, resource heterogeneity, complementarity, and actor jointness on value creation in cooperative R&D projects. Our study showed in the first place the different and opposing network effects on value creation. Secondly, it showed that the network effects are influenced by cycle of technology development that is controlled by the policy makers selection of projects. Finally, it showed that efficiency and innovation forces are build up from multiple network effects that can not be assigned to one of the ARA layers.

Keywords: Innovation forces, Efficiency forces, Network effects, University-Industry relations, R&D cooperation, Value Creation

## **Business interaction model and network effects**

For some decades research on innovation and technology development emphasized the importance of different kinds of inter-organizational relations for innovation (e.g. Hagendoorn and Duysters 2002; Håkansson, Ford, Gadde, Snehota and Waluszewski 2009). In the 1990's this view is also taken by various national innovation policies that follow the 'National systems of Innovation' approach and organize interaction between science and industry to create new areas of commercialization of research (Edquist, 2005; Lundvall and Borrás 2005). Despite the systemic and network focus of these innovation policies, it seems that policy makers lack proper knowledge about the effect of interdependencies among different players in the innovation networks (Waluszewski 2011a). In this paper we will specify different network effects on innovation performance of industry-university R&D collaboration. A better understanding of these network effects can make policy makers aware of them when stimulating multi-partner industry university interaction.

Within the industrial network approach the first mentions about network effects came from Anderson, Håkansson and Johanson (1994), based on Social Exchange Theory (Emerson 1972; Cook 1982) they stated that if developments build on earlier network elements it will strengthen the existing situation but if the developments are in contradiction to the earlier network elements it will loosen the existing situation. In the same article the authors introduced resource transferability, activity complementarity and actor relation generalizability as network constructs that have an sustaining effect on cooperation in dyadic business relationships. While resource particularity, activity irreconcilability and actor-relation incompatibility have a disrupting effect on the cooperation in a dyadic business relationship. Following this reasoning we assume that resources ties, activity links and actor bonds can have positive and negative effects on relationship development. In this paper we continue on this notion and investigate the positive and negative network effects on innovation performance of university industry cooperation.

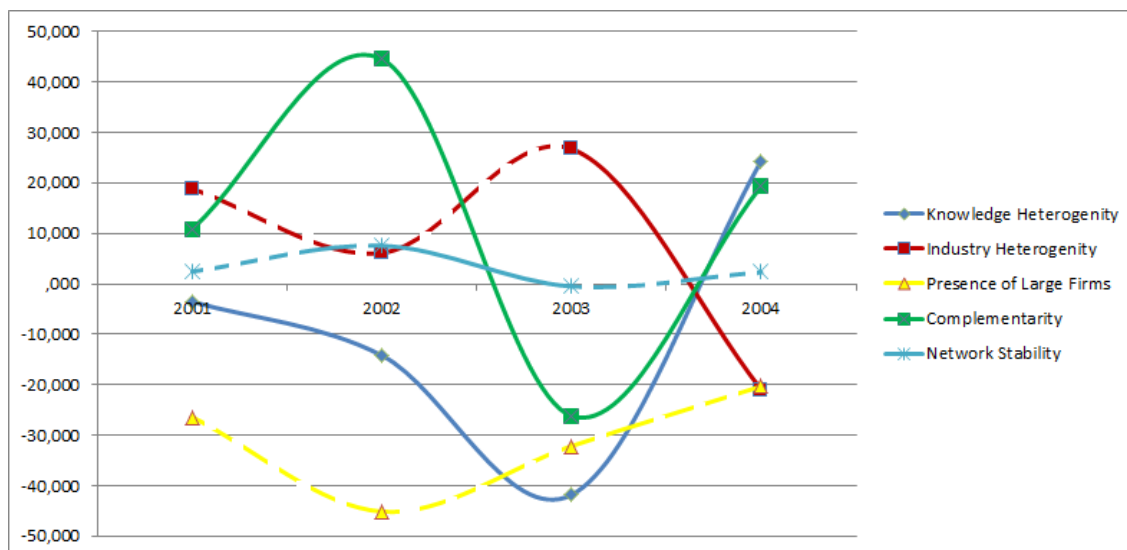
This paper builds on a series of articles we have written about network effects on innovation performance arising in industry-university R&D cooperation in the field of nanotechnology (Raesfeld et al 2012a; 2012b). So far we have distinguished time and space related network effects in line with the model of business interaction (Håkansson et al 2009:41) which specifies three structural or space related aspects (Resource Heterogeneity, Actor Jointness and Activity Interdependency) and in parallel three processes or time related aspects (Paths of Resources, Co-evolution of Actors and Specialization of Activities). Both Time and Space aspects lead in a recursive way to connected relationships that are described as activity patterns, resource constellations and actor webs. We described how network effects develop over time and saw a pattern of nonlinear effects (Raesfeld et al 2013). In this paper we try to explain the non-linear network effects over time on innovation performance in industry university cooperation projects.

## **Network effects in industry university cooperation in the field of nanotechnology**

In our first article on the subject of network effect in industry university cooperation, we investigated two space related network effects, knowledge (technological) heterogeneity and complementarity between partners in R&D cooperation projects and we found a nonlinear U shaped effect of knowledge heterogeneity and a positive linear effect of complementarity of

partners on commercial performance of the projects (Raesfeld et al 2012a). The U shaped effect of knowledge heterogeneity suggests that in the case of the emerging field of nanotechnology processes of learning and complementarity formation are required before diverse knowledge can be integrated. This raised our attentiveness towards time related network effects. Therefore, in a second article we combined the space related effects - knowledge heterogeneity, industry heterogeneity, complementarity, and user interaction - with the time related effect stability of the network, which we defined as the degree of relationship establishment or co-evolution of partners. Although the effect of network stability was not significant, overall the moderation of network stability made the estimation of the models for innovation performance more significant, indicating the importance of long-term relationships for the R&D project performance (Raesfeld et al 2012b). In a third paper (Raesfeld et al 2013) we analyzed the development of different network effects over four years from 2001 to 2004 the period in which nanotechnology started to emerge (Shea 2005). The results of this last study with the explained variable value creation are depicted in figure 1, it presents the change in regression coefficients for different network effects over time, solid lines indicate a significant change in effect over time. Figure 1, shows the different and opposing network effects on value creation, an oscillation effect of complementarity and network stability, a decreasing effect of industry heterogeneity, a linear negative effect of the presence of large firms, and again the U shaped effect of

**Figure 1: Influence of network effects on value creation performance over time (adapted from Raesfeld et al 2013)**



knowledge heterogeneity. These findings describe for knowledge heterogeneity an initial decreasing and negative resource transferability changing over time— into an increasing positive resource transferability. Industry heterogeneity shows a —positive resource transferability up till 2003 after which it decreases and becomes negative. For presence of

large firms the negative effect indicated an incompatibility of established firms in the innovation projects. Over time complementarity of institutional roles in cooperation projects has a positive effect though oscillating in magnitude. And the almost constant positive effect of network stability indicated the importance of having established relationships.

The initial conditions of knowledge heterogeneity, industry heterogeneity, presence of large firms, complementarity and network stability were stable over time, therefore their oscillating effect on value creation could not be explained from differences in initial conditions. Nor could the oscillation be explained -from the steep growth of nanotechnology in these years, from 2000-2004 the worldwide nanotechnology patent activity showed an exponential growth such a pattern we do not find back in the development of the network effect in our empirical setting. So there should be an explaining factor that interacts with the network effects that enable or constrain innovation performance, such as the rules of the policy makers to select particular projects above others. Also, we expected that these findings might be explained by using theory on the learning cycle of innovation (Nooteboom 1999; Van de Ven et al 1999). Therefore in this paper we further elaborate on the impact of learning cycles of innovation in nanotechnology on multiple network effects that influence the innovation performance of R&D projects.

Van de Ven et al. (1999:184) propose that: “the innovation journey is a nonlinear cycle of divergent and convergent activities that may repeat over time and at different organizational levels if resources are obtained to renew the cycle.” A cyclical process model is proposed that consists of a sequence of divergent and convergent phase and explains temporal dynamics in a variety of innovation processes. The respective divergent and convergent phases reflect what March (1991) described as exploration and exploitation. Another learning cycle that continues on March (1991) is provided by Nooteboom (1999) and present an innovation cycle that describes how the sequence between exploration and exploitation proceeds. So while Van de Ven et al (1999) describe a sequence of exploration and exploitation behavior over the innovation journey happening at multiple levels of scale and time, Nooteboom (1999) provides a heuristic to answer the problem of how to maintain continuity, and at the same time prepare for change. In the remainder of the paper we apply the learning cycle heuristic of Nooteboom (1999) to investigate the impact of the development of nanotechnology on network effects.

The question we try to answer in this paper is:

What is the influence of the technology learning cycle on the relationship between multiple network effects and innovation performance of university – industry cooperation projects?

By empirically investigating this question we hope to contribute to network theory development.

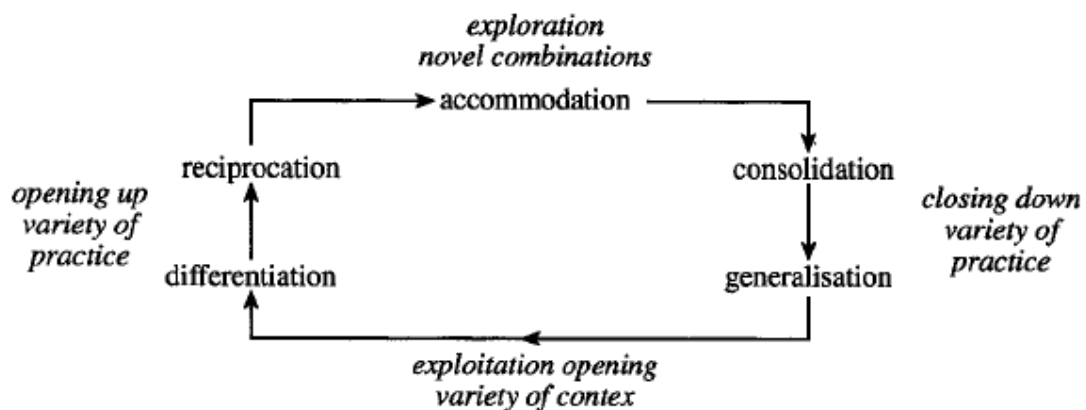
### **Learning cycle**

Since March (1991) developed the exploration-exploitation framework and refined it together with Levinthal, the balancing of exploration and exploitation is a recurring theme in strategic management and innovation literature. Levinthal and March (1993:105) indicated that: “The

basic problem confronting an organization is to engage in sufficient exploitation to ensure its current viability and, at the same time, to devote enough energy to exploration to ensure its future viability, Survival requires a balance ... “ .

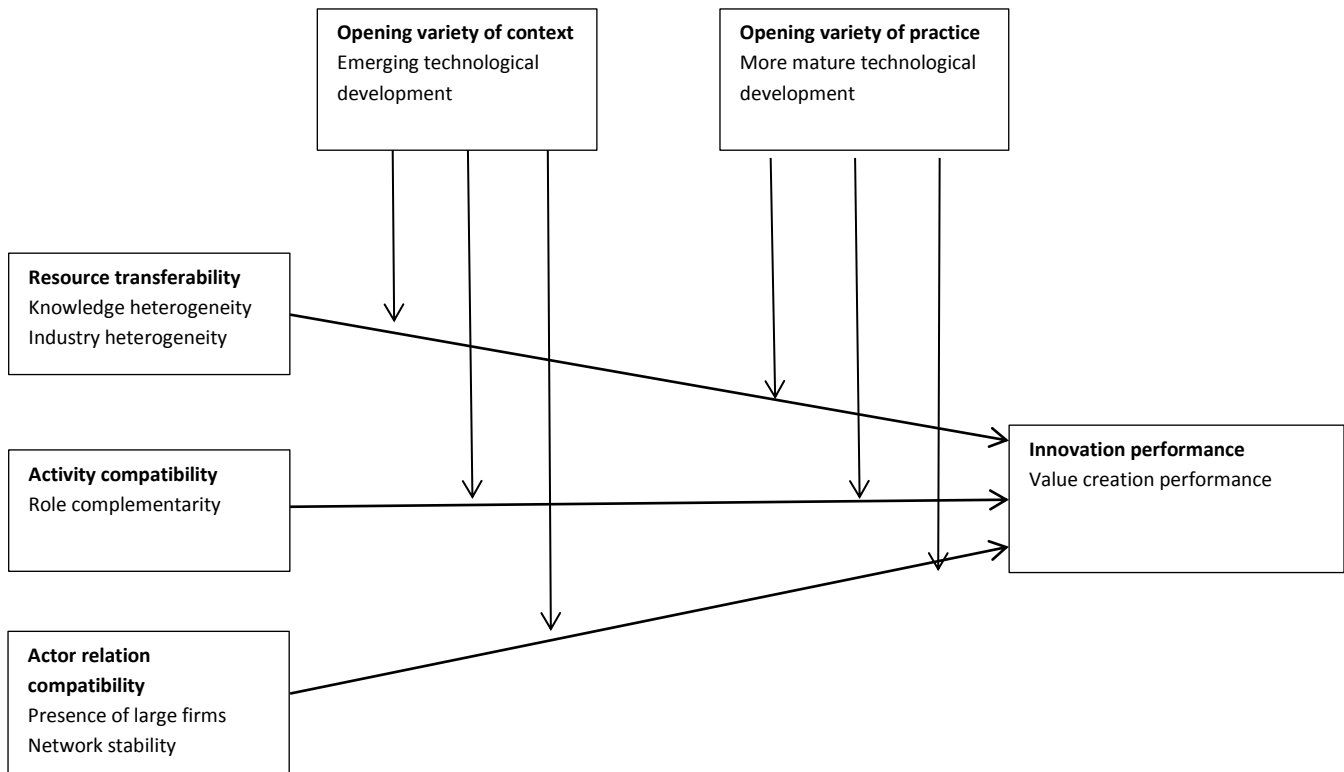
Nooteboom (1999) describes in his cycle of learning how to maintain continuity (exploitation) while organizing for change (exploration) (figure 2) and in that way he explains how the cycle continues. According to Nooteboom (1999) innovation starts when a successful practice is generalized to other contexts. Then when the practice runs into its limitations it has to be adapted towards the new contexts, this is the principle of differentiation and comes with opening variety of practice. For the adaptations exchange of elements from different parallel practices takes place this is the principle of reciprocation and comes with opening variety of practice. Reciprocation puts pressure on integrating elements from different practices in a new one leading to novel combinations. Next the novel combinations have to become a new practice, which requires effort and experimentation, the principle of consolidation in the cycle of learning. After that, one can move in the next cycle.

**Figure 2 Cycle of learning (Nooteboom 1999)**



The question now is: How can the cycle of learning help us to understand the osculating network effects? –We have seen that the network effects were independent from the initial conditions, so while heterogeneity, complementarity and jointness had the same rate over the years their effect on value creation had not. We assume now that these effects were influenced by location of industry-university cooperation projects on the learning cycle. So in the situation that the technology development in the cooperation is directed towards opening up variety of practice the network effects will be different from the situation that the technological development is directed towards opening variety of context. Figure 3 describes the research model from which the hypotheses are derived.

**Figure 3: research model**



Starting with the resource transferability indicated by the effect of knowledge heterogeneity and industry heterogeneity. Overall integration of knowledge is in particular important at the point where opening of variety of practice is at stake and new solutions have to be developed so we would expect in this situation a positive effect of knowledge heterogeneity. However, from previous research (Raesfeld et al 2012a) we found this effect to be U shaped. While in the situation of opening variety of context and new applications for new problems have to be found, knowledge heterogeneity is less important or can even have an unfavorable effect. On the other hand when looking at industry heterogeneity this is particular important in the situation of opening variety of context and less important in the case of opening variety of practice.

Therefore we propose for resource transferability hypothesis 1:

- a) Knowledge heterogeneity in the situation of opening variety of context has negative effect on value creation.
- b) Knowledge heterogeneity in the situation of opening variety of practice has an U shaped effect on value creation.
- c) Industry heterogeneity in the situation of opening up variety of context has a positive effect on value creation.
- d) Industry heterogeneity has a negative effect on value creation in the situation of opening variety of practice

Next, complementarity between partners who are specialized in particular tasks creates efficiencies. Therefore complementarity always will have a positive effect on value creation, however the effect will be greater in the case of opening variety of practice compared to opening variety of context. As in the case of opening variety of context the nature of complementarity is less well developed compared to the case of opening variety of practice.

Therefore we propose for activity complementarity hypothesis 2:

The positive effect of complementarity on value creation is higher in the case of opening variety of practice compared to the case of opening variety of context.

Finally, the effect of actor-relation compatibility depends on who is involved in the cooperation. Usually involving established large firms has a negative effect on innovation performance of R&D cooperation. This is because established firms have vested interests in current technologies and are usually not willing to cannibalize on the technology they currently produce or use. The negative effect of involving large established firms will be stronger in the case of opening variety of context compared to the case of opening variety of practice. As in the last situation the role the established firm can play is much more developed. In addition, cooperating with partners recurrently has shown to have a positive effect on innovation performance. And this effect shall be larger for the case of opening variety of practice compared to opening variety of context again because the nature of the relationships is probably better developed.

Therefore we propose for actor-relation compatibility hypotheses 3:

- a) Involvement of established large firms has a negative effect on value creation that is higher for opening variety of context compared to opening variety of practice .
- b) Involvement of existing partners has a positive effect on value creation that is higher for opening variety of practice compared to opening variety of context.

These hypotheses will be tested in a network where universities and firms cooperate in R&D projects in the field of nanotechnology.

## **Methods**

### Setting and data

Nanotechnology is seen as the next general purpose technology with the potential to significantly impact industrial activity (Shea, 2005, Bozeman et al., 2007, Wood et al., 2003, Nikulainen and Palmberg, 2010). Academics and policy makers expect that utilization and value creation of nanotechnologies will cut across established knowledge, technological, and organizational boundaries and might disrupt traditional industries (Walsh, 2004, Shea, 2005). Therefore, commercial development of nanotechnologies will depend on the ability to integrate development, producing and using settings distributed across professional groups,

companies, and research organizations (Bozeman et al., 2007, Palmberg, 2008, Nikulainen and Palmberg, 2010, Robinson et al., 2007)

Most industrialized countries develop collaborative structures where universities and firms work together in transferring knowledge for commercial or societal purposes. However, there are surprisingly few studies on the interaction between different actors in the process of nanotechnology development, with the exception of Nikulainen and Palmberg (2010) who investigated the relationship between motives of researchers, university industry interactions, and nanotechnology transfer challenges and outcomes when commercializing scientific knowledge. Their findings show that the most important modes of industry university interactions in the field of nanotechnology take place in Public R&D programs and at conferences. This is in line with earlier findings of D'Este and Patel (2007) who showed that technology transfer between universities and firms mainly takes place in— consultancy, contract research, joint research and training and much less via patenting and spin-off activities.

We tested the hypotheses using a dataset on utilization of technology research projects funded by the Dutch Technology Foundation STW. STW funds utilization oriented technology research at Dutch universities and selected institutions. Through the Dutch Organization for Scientific Research (NWO), STW receives its funding from the Dutch Ministry of Economic Affairs and the Dutch Ministry of Education, Culture and Science. The participants in the project consist of the researchers and potential users of the results who are not directly part of the research group. The 'users' provide input, as well as financial or other contributions to the project. All potential users of knowledge – knowledge institutions, large, medium-sized and small businesses, as well as those involved in R&D – are eligible for participation in a R&D project. They are given the opportunity to work alongside the researchers and be the first to learn of the results. The STW dataset describes 798 Public R&D projects over a period from 1992-2009 and covers per project the researchers and research institutes involved, the participants in the project, commitment of the users, and the resulting products and revenues.

An expert in the field of nanotechnology selected the nanotechnology projects based on National Nanotechnology Initiative's definition: 'Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nm, where unique phenomena enable novel application' (see (Bozeman et al., 2007, Balogh, 2010). This resulted in 212 nanotechnology projects, which started in a period from 2000 until 2004. We excluded 5 projects because they had no other participants involved and therefore complementarity and technology variables could not be generated, so we continued with 207 projects.

Secondly, we listed all the participating organizations (476) from the projects and classified them in six types: firms; governmental parties; research institutes; hospitals;

### *Dependent variables*

Table 1 describes the concepts of the research model and the operational variables used, hereafter we further describe these variables. We used measures *value creation* five years after the completion of the projects), because these performances are likely to lag R&D activity. *Value creation* performance is defined as the degree to which the project generated revenues. For value creation performance we used the revenue generation scale from the STW

database, ranging from 1) project failed 2) no revenues 3) occasionally parts of knowledge are sold but no revenues from exploitation 4) continuous stream of revenues from knowledge exploitation. We merged 1 and 2 because at both levels, no revenues were there. Also, we combined levels 3 and 4 because of a small number of observations at level 4.

### *Independent variables*

The heterogeneity measures for technological and industry heterogeneity and the one for complementarity are calculated with the Hirschman-Herfindahl index as used by Baum et al. (2000) and computes heterogeneity as one minus the sum of the squared proportions of different resource types divided by the project's total number of resource types. High index outcomes indicate an equal distribution of the different types.

Resource heterogeneity is defined as the diversity of resources embedded in the R&D projects. We used two operationalizations for resource heterogeneity: Knowledge heterogeneity and Industry heterogeneity.

*Knowledge heterogeneity* is defined as the degree to which there is a complete coverage of the eight main European patent classes. We calculated the diversity in a project based on the four digit EPO patent numbers. The eight main classes are: A) Human necessities, B) Performing Operations/ Transporting; C) Chemistry; Metallurgy; D) Textiles/Paper; E) Fixed constructions; F) Mechanical engineering/Lighting / Heating / Weapons/ Blasting; G) Physics; H) Electricity. Among the 476 participants the highest numbers of patents are in Human necessities in order of number followed by Chemistry/Metallurgy; Electricity and Physics. Correlation analysis of the eight classes showed strong correlation between Human necessities and Chemistry/Metallurgy and between Physics and Electricity, implying that in nanotechnology R&D these fields are combined.

*Industry heterogeneity* is defined as the distribution of the industry classes to which the participants in the research projects belong. For this measure the Dutch version of the sic coding was used, which consist of 21 different industry classes.

*Complementarity* is defined as the diversity roles per project. Assuming that organizations active in the same line of transformational activities have similar roles, we construct a measure of complementarity of a project that captures the diversity of the project's participant types. The participant types that were identified in the sample were: 1) companies, 2) governmental parties, 3) research institutes, 4) (academic) hospitals/medical institutions, 5) universities/schools and 6) special interest groups.

*User participation* is defined as the proportion of firms participating in the project. Assuming that research institutes, academic hospital/medical institution, and universities are especially involved in the idea development and firms in the using and producing setting users of the innovation, we measured the proportion of firms as the number of firms participating divided by the total number of participants in the project.

*Presence of large firms.* Das and He (2006) indicated the negative effect of established firms on innovative outcomes in cooperation projects. We measure *firm size* by including one dummy variable for large firms, set to one if a participant is a large firm (default is medium sized firm). For this measure the firms in the project were classified in small, medium or large firms on employee size, small firms 1-49 employees, medium firms as 50-499 employees and large firms are those who have over 500 employees.

*Network stability* is defined as the degree of establishment of relationship structures. Its measurement is a count of the number of participants in a project that had been participating before in the STW network. The participants in the year 2000 were used as base year.

Within nanotechnology more mature domains and more emergent domains can be distinguished, in the more mature domains one is aiming to develop devices and materials and thus to *open variety of practice* to find new solutions. In the case of the more emergent domains one is aiming to find new application fields and thus to *open variety of context*. As proxies for opening variety of context and practice dummy variables for emergent and mature nano-technology domains are used. For this measure the projects were classified in nano-emergent when projects were focusing on nano-manufacturing and bionnano-technology and as nano-mature when projects were focusing on nanomaterials and nano-electronics. The classification between nano-mature and nano-emergent is based on the research of Islam and Miyazaki (2010).

#### *Control variables*

*Commitment of participants* in the project is defined as the degree to which participants actively contribute to the project. We control for commitment as Mora-Valentin et al. (2004) found a positive effect of commitment on cooperation success. Thus one could argue that without commitment, resource combination is difficult. For Commitment of participants in the project we applied the scale from the STW database, which goes from, 1) commitment failed no relevant results for user; 2) users participated in user committee; 3) users participate actively and provide some tangible support such as money or materials; 4) Users participate substantially, by providing extensive support and/or by making cooperation contracts.

#### *Analysis*

To estimate the effect of the independent variables on the two categories for value creation performance, we used a binary logistic regression.

### **Results**

Table 1 summarizes the analyses for testing the hypotheses.. The models 1 and 2 for value creation presents the logistic regression results split into the groups nano-mature representing the opening variety of practice in the learning cycle and nano-emergent representing the opening variety of context in the learning cycle. Table 1 shows that the addition of network effects shows an increase in explained variance. The control variables have the expected effects, commitment has a positive significant effect on both outcomes. Table 2 summarizes how the findings relate to the hypotheses with an indication if the direction is as expected and if significant.

**Table 1: Determinants of value creation performance in industry university R&D projects**

		Value creation					
		1			2		
		B	s.e	p	B	s.e.	p
<b>opening variety of practice (nano mature)</b>	Application performance = 1						
	Application performance = 2]						
	Commitment	1,573***	,464	,001	1,748***	,517	,001
	Participation of large firms (dummy)	-1,458**	,830	,079	-1,738**	1,038	,094
	Knowledge heterogeneity				-32,935*	20,654	,111
	Knowledge Heterogeneity squared				128,394*	84,262	,128
	Industry Heterogeneity				-12,271	12,001	,307
	Industry Heterogeneity squared				39,264	52,822	,457
	Participation user				3,339*	2,129	,117
	Complementarity				12,587**	7,176	,079
	Network Stability				,022	,132	,871
	Nagelkerke pseudo R <sup>2</sup>	,226			,302		
<b>opening variety of context (nano emergent)</b>	Application performance = 1						
	Application performance = 2]						
	Commitment	1,318***	,379	,001	1,512***	,436	,001
	Participation of large firms (dummy)	-1,211**	,549	,027	-1,877**	,822	,022
	Knowledge heterogeneity				5,446	15,851	,731
	Knowledge Heterogeneity squared				-53,891	72,386	,457
	Industry Heterogeneity				22,560**	12,923	,081
	Industry Heterogeneity squared				-66,235	55,506	,233
	Participation user				,996	1,551	,521
	Complementarity				8,022*	6,348	,206
	Network Stability				,012	,124	,922
	Nagelkerke pseudo R <sup>2</sup>	,228			,308		

**Table 2: confirmation and disconfirmation of the hypotheses**

Hypothesis	accept	reject	direction as expected	Significant
<b>Resource transferability</b>				
1a Knowledge heterogeneity in the situation of opening variety of context has negative effect on value creation.		X		
1b Knowledge heterogeneity in the situation of opening variety of practice has an U shaped effect on value creation.	X		X	X
1c Industry heterogeneity in the situation of opening up variety of context has a positive effect on value creation	X		X	X
1d Industry heterogeneity has a negative effect on value creation in the situation of opening variety of practice		X	X	
<b>Activity complementarity</b>				
2 The positive effect of complementarity on value creation is higher in the case of opening variety of practice compared to the case of opening variety of context.	X		X	X
<b>Actor-relation compatibility</b>				
3a Involvement of established large firms has a negative effect on value creation that is higher for opening variety of context compared to opening variety of practice.	X		X	X
3b Involvement of existing partners has a positive effect on value creation that is higher for opening variety of practice compared to opening variety of context.		X	X	

## Conclusions

In this paper we investigated the combined influence of the technology learning cycle and network effects on value creation in cooperative R&D projects. Our study showed in the first place the different and opposing network effects on value creation. Secondly, it showed that the network effects are influenced by the position of cooperation projects on the technology learning cycle.

The analysis shows that for resource transferability in the case of emergent technology, industry heterogeneity is important but knowledge heterogeneity is not. It is reversed in the case of mature technology where knowledge heterogeneity is important and industry heterogeneity is not. This suggests that in emerging technology, participants in R&D projects are searching for application domains and are not yet able to integrate new knowledge. The

different effects of industry and knowledge heterogeneity seem to match the argument of Håkansson and Waluszewski (2011:185): "The existence of variety as well as the capacity to take advantage of it in a specific resource is directly related to the total set of resources it belongs to ...". Participating firms with different industry backgrounds provide different resource constellations in which applications can be developed and value can be created (Harrison and Waluszewski, 2008).

For activity complementarity the analysis indicates that complementarity of participants in the projects in terms of institutional roles has a positive effect in both emergent and mature technology, but its effect is stronger in the case of mature technology.

For actor-relation compatibility it clearly shows that the negative effect of presence of established firms is larger for emergent technology. The effect for network stability is as expected but not significant, in further research we need to develop a more fine grained measure and see if the effect is similar. Overall as the ratio between nano-mature and nano-emergent projects differs over the years 2001-2004 these finding can explain the fluctuations in the network effect over time.

### **Further research**

Waluszewski (2011) classified network effects into innovation and efficiency forces in networks and indicated how the two can be balanced by development of actor bonds. Waluszewski (2011:140) states that innovation forces can be understood by the way resources are developed and combined, whereas efficiency forces can be understood from the activities performed and linked within and across organizations. Balancing of efficiency and innovation happens according to Waluszewski (2011) through the development of actors bonds. Assuming that positive effects on innovation performance can be considered as innovation forces and negative effects on innovation performance as efficiency forces, our research shows that these forces cannot be assigned to just one of the ARA layers as suggested by Waluszewski (2011). Interacting network effects originating from different ARA layers build up into a force. Therefore we suggest to further investigate how network forces are build up from multiple network effects..

The description of the three settings of innovation development of Håkansson et al. (2009) seem to describe phenomena related to the Cycle of learning of Nooteboom (1999).. Håkansson et al. (2009) distinguish three settings of innovation development: 1) idea development, 2) production infrastructure development, and 3) user environment development. Each setting is involved in the embedding of different types of resources and activities. The first setting relates to the development of new ideas and solutions by combining resources to develop functionality and seem to resemble the principle of accommodation in the learning cycle. The second setting relates to embedding the new idea or solution in an efficient production infrastructure and enhance compatibility and seem to resemble the principle of consolidation in the learning cycle. The third setting is about the development of the use of the new solution and seems to resemble the principle of generalization in the learning cycle. Our research was more focused on differentiation and reciprocation and less on principles related to the settings of innovation development of Håkansson et al. (2009). Therefore we suggest for further research to analyze the whole cycle of learning.

## References

- ANDERSON, J.C., HÅKANSSON, H. & JOHANSON 1994. Dyadic Business Relationships Within a Business Network Context. *Journal of Marketing* 58, 1-15.
- BALOGH, L. P. 2010. Why do we have so many definitions for nanoscience and nanotechnology? *Nanomedicine: Nanotechnology, Biology and Medicine*, 6, 397-398.
- BAUM, J. A. C., CALABRESE, T. & SILVERMAN, B. S. 2000. Don't Go It Alone: Alliance Network Composition and Startups' Performance in Canadian Biotechnology. *Strategic management journal*, 21, 267-294.
- BOZEMAN, B., LAREDO, P. & MANGEMATIN, V. 2007. Understanding the emergence and deployment of "nano" S&T. *Research policy*, 36, 807-812.
- COOK, K.S. 1982. Network Structures from an Exchange Perspective, *Social Structure and Network Analysis*, P.V. Marsden & N. Lin (eds) Beverly Hills: Sage Publications.
- DAS, T. K. & HE, I. Y. 2006. Entrepreneurial firms in search of established partners: Review and recommendations. *International Journal of Entrepreneurial Behaviour and RESEARCH*, 12, 114-143.
- D'ESTE, P., & PATEL, P. 2007. University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry? *Research Policy*, 36(9): 1295-1313.
- EDQUIST, C. 2005. Systems of Innovation Perspectives and Challenges. In Fagerberg, J. Mowery, D.C. and Nelson R.R. (eds). *The Oxford Handbook of Innovation*. Oxford University Press: New York
- EMERSON, R.M. 1972, Exchange Theory, Part I, Exchange Relations and Network Structures. *Sociological Theories in progress*. 2 M. Zelditch and B. Anderson (eds) Boston. Houghton Mill
- HAGENDOORN, J. & DUYSTERS, G. 2002. External Sources of Innovative Capabilities: The Preferences for Strategic Alliance, Mergers and Acquisitions. *Journal of Management Studies* 39(2), 167-88
- HÅKANSSON, H., FORD, D., GADDE, L. E., SNEHOTA, I. & WALUSZEWSKI, A. 2009. *Business in Networks*, Chichester, John Wiley & Sons Ltd.
- HÅKANSSON, H. & LUNDGREN, A. 1995. Industrial Networks and Technological Innovation In: MÖLLER, K. & WILSON, D. (eds.) *Business Marketing: An Interaction and Network Perspective*. Boston: Kluwer Academic Publishers.
- HÅKANSSON, H. & WALUSZEWSKI, A. 2002. Path dependence: restricting or facilitating technical development? *Journal of Business Research*, 55, 561-570.

- HÅKANSSON, H. & WALUSZEWSKI, A. 2007. *Knowledge and innovation in business and industry the importance of using others*. London: Routledge.
- HÅKANSSON, H. & WALUSZEWSKI, A. 2011. co-evolution in technological development the role of friction. *Sinergie Journal*, 58.
- HARRISON, D. & WALUSZEWSKI, A. 2008. The development of a user network as a way to re-launch an unwanted product. *Research Policy*, 37, 115-130.
- HOHOLM, T. & OLSEN, P. I. 2012. The contrary forces of innovation A conceptual model for studying networked innovation processes. *Industrial Marketing Management*, 41, 344-356.
- ISLAM, N., & MIYAZAKI, K. 2010. An empirical analysis of nanotechnology research domains. *Technovation*, 30(4): 229-237.
- LEVINTHAL, D. A. & MARCH, J. G. 1993. The Myopia of learning. *Strategic management journal*, 14, 95-112.
- LUNDEVALL, B-Å & BORRAS, S. 2005. Science, Technology and Innovation Policy. In Fagerberg, J. Mowery, D.C. and Nelson R.R. (eds). *The Oxford Handbook of Innovation*. Oxford University Press: New York
- MARCH, J. G. 1991. Exploration and exploitation in organizational learning. *Organization Science*, 2, 71-87.
- MORA-VALENTIN, E. M., MONTORO-SANCHEZ, A., & GUERRAS-MARTIN, L. A. 2004. Determining factors in the success of R&D cooperative agreements between firms and research organizations. *Research Policy*, 33(1): 17-40
- NIKULAINEN, T. & PALMBERG, C. 2010. Transferring science-based technologies to industry--Does nanotechnology make a difference? *Technovation*, 30, 3.
- NOOTEBOOM B. 1999. Innovation, Learning and industrial organisation. *Cambridge Journal of economics* 23, 127-150.
- PALMBERG, C. 2008. The transfer and commercialisation of nanotechnology: a comparative analysis of university and company researchers. *The Journal of Technology Transfer*, 33, 631-652.
- RAESFELD, A., GEURTS, P., JANSEN, M., BOSUIZEN, J. & LUTTGE, R. 2012a. Influence of partner diversity on collaborative public R&D project outcomes: A study of application and commercialization of nanotechnologies in the Netherlands. *Technovation*, 32, 227-233.
- RAESFELD, A. V., GEURTS, P. & JANSEN, M. 2012b. When is a network a nexus for innovation? A study of public nanotechnology R&D projects in the Netherlands. *Industrial Marketing Management*, 41, 752-758.

- RAESFELD, A. V., GEURTS, P. & JANSEN, M. 2013. Network forces influencing outcomes of innovation journeys: R&D cooperation in nanotechnology in the Netherlands. *IMP conference 2013 Atlanta*.
- SHEA, C. M. 2005. Future management research directions in nanotechnology: A case study. *Journal of Engineering and Technology Management*, 22, 185-200.
- VAN DE VEN, A. H. POLLEY, D.E.& GARUD R. 1999. *The innovation journey*, Oxford University Press, USA.
- WALUSZEWSKI, A. 2011a. The policy practitioners dilemma - The national policy and the transnational networks. *VINNOVA*, 2011:07.
- WALUSZEWSKI, A. 2011b. Rethinking innovation policy. *IMP Journal*, 5, 140-156