



Understanding novelty creation in exploration networks—Structural and relational embeddedness jointly considered

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Abstract

In exploration networks the key-organisational question is not how to organise a division of labour but instead how to create novelty. The aim of this paper is to develop an understanding of how such novelty in exploration networks is created. Based on an empirical analysis of the multimedia and biotechnology industries in the Netherlands, this paper shows that exploration networks face a trade-off between diversity and selection. Moreover, the findings indicate that depending on the type of exploration task, exploration networks need to make a combination of density and tie strength in such a way that diversity and selection are aligned. The paper concludes, among others, that the views of Burt, Coleman and Granovetter should not be seen as contradictory, but rather as proponents of complementary views.

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1. Introduction

The aim of this paper is to develop an understanding of how novelty is created in exploration networks. The focus of this paper is therefore on interfirm networks that engage in the exploration of novel combinations. We define exploration as a situation that can generally be characterised by breaking with an existing dominant design and a shift away from existing rules, norms, routines or activities, in view of novel combinations. Exploration is an inherent uncertain process that can hardly be planned for (March, 1991). There is growing consensus in the academic literature that in such a setting, strategic alliances can be an extremely effective organisational form as they bring together complementary actors from different technological backgrounds. In the context of learning and innovation, exploration thrives on a diversity of knowledge which yields a potential for Schumpeterian novel combinations to

emerge (Nooteboom, 2000). It is in this heterogeneity that actors are able to combine and integrate complementary knowledge and capabilities (Porter, 1990; Hamel and Prahalad, 1994; Grabher, 1993; Hagedoorn, 1993; Hagedoorn and Schakenraad, 1994; Smith Ring and van de Ven, 1994; Grandori, 1997; Spekman et al., 1995; Uzzi, 1997; Nooteboom, 1999, 2004; Ahuja, 2000; Rowley et al., 2000).

In spite of its noted importance, novelty creation forms an unaddressed topic in the innovation literature. In this literature, a distinction is made, following life-cycle theory, between two stages in the innovation process. The first initial stage is one of volatility, characterised by the creation of Schumpeterian novel combinations. The second stage is a stage of consolidation in which dominant designs emerge (Abernathy, 1978; Abernathy and Utterback, 1978; Abernathy and Clark, 1985) and in which production systems focus on efficiency, economies of scale and experience. The cycle is generally held to imply a shift from product to process innovations, as product forms settle down and competitive pressure shifts to efficient production. In other words, the literature is very clear about the change in focus from exploration to exploitation. However, the origins of exploration itself remain

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a mystery. The question of how exploitation ‘feeds’ future exploration is left unanswered (Nooteboom, 2000). This issue on ‘the origins of novelty’ forms the central question in this paper and will be studied in the context of interfirm networks engaging in exploration, further referred to as ‘exploration networks’.

This focus on exploration networks is related to the literature on innovation systems (Carlsson and Stankiewicz, 1991; Malerba, 2004) and regional economics (e.g. Bathelt et al., 2004). Although in this literature the importance of relations and interaction among heterogeneous firms and actors is clearly acknowledged (Nelson and Winter, 1982; Dosi et al., 1988; Nieto and Santamaria, 2007), an in-depth understanding of the structure and role of interfirm networks is still underdeveloped (Pavitt, 2002; Malerba, 2004). For a deeper understanding of networks we need to turn to the social network literature. Social network theory enables us to describe and measure networks of relationships in great detail, providing us with several well-developed measures and techniques to assess the structure, ties and dynamics of relational networks.

1.1. Social network theory

Networks and relations among actors are the primary object of analysis in social network theory. Before discussing this literature and some of its proponents, we can make three observations on this literature that have relevance here. One observation is that there is a strong universalistic tone on the optimality of the network structure, which abstracts from any kind of context. As we will argue in Section 3, the considerations of three influential scholars in this literature, Granovetter (1973), Coleman (1988) and Burt (1992) lead to different conclusions with respect to the optimal network structure. As we will show in this paper, the question is not who is right, but who is right under which conditions. A second observation is that in this strand of literature, there is a strong focus on the structural properties of networks. Due to this strong focus on structural elements of networks, the identification of relevant environmental conditions and how they influence this structure have generally been ignored by social network theorists (Ahuja, 2000). A third observation is that these structural properties are treated as relatively ‘stand-alone’ properties. An understanding of how these properties interact and how this interaction may affect interfirm learning is underdeveloped. This relates to the distinction between structural embeddedness and relational embeddedness (Granovetter, 1985), which have been treated as independent factors in the literature on interfirm networks thus far (Rowley et al., 2000). The claim that we submit in this paper is that the combination of structural and relational embeddedness may have a profound effect on interfirm learning. Therefore, they should be examined in joint consideration.

In doing so, we attempt to reconcile two views on organisation, namely a competence-view and a govern-

ance-view. Solely relying on a competence-view would negate the notion that firms, when cooperating in networks, also become mutually dependent. This dependency yields a risk of conflict and opportunism and may possibly influence the way firms interact, connecting with a governance perspective. The literature on competence building has neglected the governance of relational risk, and transaction cost theory has neglected issues of learning and innovation. A combination of the two perspectives should yield a more complete understanding of inter-organisational relations (Williamson, 1999; Nooteboom, 2000, 2004; Dosi and Marengo, 2000).

To summarise: two questions have remained unanswered in the literature on interfirm networks so far, namely (1) what are the origins of novelty in exploration networks and (2) how do structural and relational embeddedness combine systematically? This paper tries to fill these voids. In doing so, this paper addresses these issues by studying the following questions:

- What are ‘general’ structural properties of exploration networks?
- How does this combination of structural properties enable and constrain the creation of novelty in such networks under different environmental contexts?

This paper therefore contributes to our basic understanding of interfirm networks in two ways. One is that we treat network structural properties as dependent variables, which is largely unexplored territory in the literature. The dominant approach so far has considered network embeddedness and network structure as independent variables, which condition firms’ (economic) behaviour and its performance outcomes (Madhavan et al., 1998). In this way, firms’ behaviour and its performance are considered as dependent variables and network structural properties as independent variables. As argued above, the key finding of this approach is that networks can increasingly be seen as a viable organisational form. In this paper, we are interested in those factors that enable and constrain networks, i.e. factors that may explain the emergence of certain combinations of network structural properties. A second contribution is to develop an understanding of how these combinations of network structural properties affect the creation of novelty in exploration networks. For that we need to go inside the black box of exploration networks in order to understand some of the mechanisms that explain how novelty is created, a process that is abstracted from in the literature on interfirm networks (Kogut, 2000; Madhavan et al., 1998; Beeby and Booth, 2000; Ahuja, 2000; Rowley et al., 2000; Hagedoorn and Duysters, 2002).

In Section 2 we further discuss social network theory and focus on some key structural properties that have relevance when developing an in-depth understanding of networks from a learning and innovation perspective. Next, in Section 3, we focus on the characteristics of an exploration

context and the implications for the structural properties of networks embedded in such a context. Then we turn to the empirical part of this paper for a qualitative, tentative test of our claims. We do so by analysing the structural properties of exploration networks in the multimedia and pharmaceutical biotechnology industry in the Netherlands, over the period from the late 1980s towards the early years of the new millennium. This will be done in Section 4. Based on this tentative testing and some new insights that these empirical analyses provide, we will analyse how the identified combination of network structural properties (structural and relational embeddedness) affects the creation of novelty in exploration networks. And in how far this is conditioned by the environmental context of both industries. This will be done in Section 5. Finally, in Section 6, we conclude.

2. Social network theory

Networks and relations among actors are the primary object of analysis in social network theory. In this section, we first briefly discuss the work of three influential scholars, namely Granovetter, Burt and Coleman. Each of their considerations leads to different conclusions with respect to the optimal network structure. As we will argue, the question is not who is right, but who is right under which conditions.

2.1. Granovetter

The distinction between strong and weak ties was introduced by Granovetter (1973). Strong ties are formed by relations which are intensive, frequent and possess informational resources which one already has. Granovetter associated these strong ties with a dense network structure. Weak ties are formed by relations with persons one is loosely connected to. As they operate in different networks, weak ties offer the advantage of providing access to heterogeneous sources of knowledge and information. Neither type is preferred as both have different qualities and it depends on the conditions which of the two a firm may favour (Rowley et al., 2000). These considerations refer to the competence side of interfirm relations.

2.2. Burt

Burt (1992) focuses on the efficiency of networks and stresses that there are costs associated with maintaining contacts. Redundant contacts carry the same information. Therefore, firms should aim to have non-redundant contacts that are complementary and do not overlap, so called 'structural holes'. Structural holes are 'disconnections between players in the arena' and provide opportunities for information access, timing, referrals and control. According to Burt an efficient network structure is characterised by non-redundant contacts and brokerage opportunities (Pitt et al., 2006). So, Burt takes a structural

embeddedness perspective whereas his considerations refer to the competence side of interfirm relations.

2.3. Coleman

Coleman (1988) relates the structure of a network to the level of social capital which can emerge between network actors. In this respect Coleman points at the benefits of dense networks for their potential with regard to the build-up of social capital. This social capital is not only built up of information but also facilitates the functioning of norms and sanctions which may form effective ways to coordinate a relationship. In this way, networks and social capital function as a social control mechanism to pre-empt firms from opportunistic behaviour (Grandori, 1997; Rowley et al., 2000). Also Coleman takes a structural embeddedness perspective whereas his considerations are relevant for the governance side of interfirm relations.

2.4. Who is right under which conditions?

Unlike their universalistic tone, the considerations of Granovetter, Burt and Coleman lead to different conclusions with respect to the optimal network structure. So, it seems that there is no such thing as a universally optimal network structure. This is increasingly being acknowledged, among others by Coleman who stated that 'social relationships that constitute social capital for one kind of productive activity may be impediments for another (Coleman, 1994, p. 177). Also Burt (2004) suggests that his view is not necessarily contradictory to Coleman's as networks and social capital are valuable for different populations and purposes. Moreover, due to the strong focus on structural elements of networks such as centrality, density, structural equivalence, structural autonomy, etc. (Knoke and Kuklinski, 1982; Wasserman and Faust, 1994), the identification of relevant environmental conditions and how they influence the structure and functioning of networks has generally been ignored by social network theorists. Recently some studies have tried to shed more light on this and have indicated that the optimality of the network structure is indeed dependent upon the environmental context (Kogut, 2000; Rowley et al., 2000; Ahuja, 2000; Hagedoorn and Duysters, 2002; Nieto and Santamaria, 2007). Following this, we argue that the environmental context has profound implications for how an exploration network is structured and how it functions in view of novelty creation. To further elaborate on that, we first analyse two structural properties of networks more in-depth: density and strength of ties.

2.5. Joint consideration of structural and relational embeddedness: density and strength of ties

Unlike the importance attached to either the strength of ties (Granovetter) or the density of ties (Burt and Coleman), we argue that to understand exploration

networks benefits from a joint consideration of the strength of ties and the density of ties. To substantiate this claim we need to differentiate between *cognitive variety* and *cognitive distance*. Cognitive variety refers to how many different individual cognitive frameworks are present in a network, cognitive distance refers to the difference between any of them (Nooteboom, 2000). The density of ties is relevant as it indicates the potential for *cognitive variety* present in a network. A large number of ties present in a network, as a percentage of the total possible number, provide the possibility to have access to many different types of knowledge held by others. Depending on the cognitive distance between these different frameworks, ties need to vary in strength in order to cross this distance. In the case of a large cognitive distance, firms may need to interact on a frequent basis, over a longer period of time and in relative openness in order to be able to understand the highly new issues. Whereas in the case of a limited cognitive distance, interaction can be less frequent and/or be restricted to a short period of time in limited openness. In other words, the strength of ties is relevant as it indicates the potential to absorb knowledge at varying distances of cognition.

2.6. Strength of ties

To further specify this relation between the strength of ties and the potential to absorb outside knowledge, we need to differentiate between different dimensions of strength. As recognised by Granovetter, the strength of ties entails a linear combination of amount of time, reciprocal services, intimacy (mutual confiding) and the emotional intensity which characterise the tie (Granovetter, 1973, p. 1361). So, next to the amount of time, the combination of reciprocal services, intimacy and emotional intensity provides a good indication of the strength of the relation, especially in personal networks. In this respect, these four dimensions have a general meaning when developing an understanding of the strength of ties. However, in a context of learning and innovation these dimensions of strength are too general and require a more detailed elaboration. So, these four dimensions need to be adapted, which we will do by combining a competence and a governance perspective. We propose as follows. First we propose to keep the amount of time and will refer to this as the *duration* of the relationship. This is relevant from both a governance and competence perspective. The duration of the relation is important to recoup specific investments made in the relationship that are needed to develop a common cognitive framework. Secondly we propose to adapt reciprocal services that deal with the level of ‘give-and-take’ in shared activities. This is a more slippery notion and may lead to misinterpretation. In this respect, we observe that Granovetter’s other three dimensions basically refer to the properties of the ties, whereas this dimension of reciprocal services may also provide an indication of the relational content of ties. Such a more explicit indication of relational content may have relevance from an innovation

point of view. As argued, in the case of systemic knowledge firms need to operate in a more or less orchestrated fashion that may require interaction on many elements. A stand-alone knowledge base allows for more leeway, and interaction on fewer elements may be needed. Hence for the understanding of the strength of ties some indication of the relational content seems to be relevant. We therefore propose to adapt reciprocal services to *scope of content*, by which we mean the extent to which the relation between firms deals with a wide or narrow scope of issues. This is also relevant from a governance perspective as a wider scope generally provides more potential for spill-overs than a more narrow scope. Thirdly we propose to adapt intimacy or mutual confiding to *mutual openness*, i.e. the willingness to share knowledge in view of mutual learning as well as in view of relevant relational risks of spill-over and legitimation. Our fourth step deals with adapting emotional intensity to intensity in terms of *frequency of contacts*. The level of frequency indicates the potential for the transfer of tacit knowledge and thus the chance of spill-overs. A high level of frequency enables an easy transfer of tacit knowledge and thus a high chance of spill-overs, whereas a low level of frequency decreases the potential of the transfer of tacit knowledge and may thus prevent spill-overs. See for a brief summary Table 1.

Following the discussion above, networks can differ in their combinations of density and strength of ties. As indicated, our central argument now is that the optimality of any combination of these two dimensions is dependent on the environmental context in which the network is embedded. This will be the topic of the next section.

3. Structural properties of networks in exploration

In this section we first discuss the general characteristics of a context of exploration. Based on those characteristics we discuss the implications for the optimal combination of structural and relational embeddedness in terms of density and strength of ties.

3.1. Exploration of novel combinations

A radical innovation starts with breaking away from an established way of doing things. Such an event is often initiated by a technological discontinuity which often marks the beginning of a newly emerging knowledge base. This embryonic knowledge base is highly tacit and often

Table 1
Adjusted dimensions of tie strength

Tie strength according to Granovetter	Tie strength in exploration networks
Amount of time	Duration
Reciprocal services	Scope of content
Intimacy	Mutual openness
Emotional intensity	Frequency of contacts

located at a local firm level, bound up in specific assets and people (Nelson and Winter, 1982). The search process is highly empirical as opposed to more rational and driven by technological opportunities rather than demand (Stankiewicz, 2002). Breaking away from the existing dominant design requires from firms that they create ‘variety-in-cognition’, i.e. they need to obtain access new and heterogeneous sources of knowledge as this yields a potential for novel combinations to emerge (Schumpeter, 1939). In this search process firms often need to rely on other firms in order to exchange knowledge and establish connections with complementary knowledge or assets. In this way novelty, in terms of new knowledge, can be created.

Coordination of these search processes is generally light and takes place by means of direct communication and social coordination and control mechanisms that increasingly function as selection mechanisms of who gets access to the newly forming network (Rosenkopf and Tushman, 1994). As described by Dew and Read (2007) there are many overlapping and reinforcing ways of coordination that firms use. In addition to social norms, also some first tentative, shared concepts and technical norms may develop. These reduce cognitive distance, thereby improving mutual understanding among the directly involved firms and hence enabling further learning. In general it is difficult to appropriate as knowledge changes rapidly. By the time a new product has been developed commercially, the knowledge it represents may have become obsolete already, making customers less willing to pay a premium or to make specific investments. It may then be more rational not to go for full appropriation but rather to stay connected with one’s exploration network and to ‘live and let live’ in order to keep up to date with the rapidly changing knowledge base. So, in this phase of exploration, competition is no real issue and demand is hardly present.

3.2. *Implications for the density and strength of ties*

Such an exploration setting poses an important challenge for firms. On the one hand firms need to develop an in-depth understanding of the newly emerging field whereas on the other hand they need to keep a broad focus and maintain access to various possible options. Searching through its existing strong ties enables the firm to develop such a deeper understanding. These ties show high strength in terms of scope of content (to deal with a wide variety of issues given high uncertainty in exploration), frequency of interaction (needed in view of the tacitness of knowledge in exploration, which can only be transferred in close interaction between the involved people) and openness and trust (given the tacitness of knowledge and broad scope of content). Ties should not be strong in terms of duration, for two reasons. A first reason is (too) long duration may inhibit fast architectural innovation, if that is needed, as is often the case in systemic technology (Teece, 1986). A second reason is that, if ties are exclusive, the

network becomes sealed off from the outside world and new knowledge cannot enter the network, killing learning potential.

However, searching only through strong ties lowers chances for finding new information as cognitive distance decreases over time. This creates a need to increase cognitive variety, i.e. the importance of different and new sources of knowledge outside this existing network through establishing linkages with weak ties (Granovetter, 1973). These ties generally show low strength in terms of durability, scope of content and trust and openness. On the other hand, frequency of interaction may be generally high in order to be able to absorb the knowledge they hold, a process that should take place in a relatively speedy manner given the high rate of change in exploration. Given the fact that, in view of fast knowledge change in exploration, specific investments in mutual understanding have a short economic life, it is indeed possible to maintain relations that are not too strong in duration.

However, too many weak ties may increase the chance of misunderstanding when cognitive distance among the various ties is (too) large, ultimately leading to chaos (Nooteboom, 2000). Learning among heterogeneous actors can only happen when information and knowledge are transferred efficiently and when this knowledge and information can be retained (McKelvey, 1997). This requires some overlap in cognition that implies (sufficient) strength of ties. So, weak ties should be seen in relation to the existing strong ties that firms have. It is in the *mix* of strong and weak ties, by combining what is already known and what is new, that novelty is created, yielding a dense network structure. In this respect, the existing strong ties facilitate triangulation among their multiple weak ties and thus better enable to assess the value of the obtained information and knowledge (Uzzi, 1996; Rowley et al., 2000; Hagedoorn and Duysters, 2002).

In sum, in a setting of exploration novelty originates through the creation of variety-in-cognition on the one hand while maintaining sufficient absorptive capacity on the other hand. Variety-in-cognition is created through weak ties (weak in all dimensions, except for frequency). The knowledge they hold is subjected to triangulation and evaluation in a dense network core of strong ties (strong in frequency, openness, scope of content whereas limited in durability). This brings us to the following two hypotheses:

Hypothesis 1. In exploration, non-redundant ties (weak scope of content, duration and openness) function as bridges over which novel knowledge crosses boundaries of groups of firms. The absorption and evaluation of such knowledge are mainly done by redundant, strong ties within such groups.

Hypothesis 2. This combination of peripheral non-density and a dense core enables the alignment of diversity and selection mechanisms, which spurs novelty creation in exploration.

Such a combination of high density and strong and weak ties brings important benefits, both from a competence perspective and from a governance perspective. From a competence perspective, it creates a potential of a rapid recombination of ties that enables a rapid exploration of novel combinations. In this way, novelty is created through *novel combinations of ties*. From a governance perspective, it brings the advantage of a rapid transfer of reputation, especially with regard to trust-in-competence rather than trust-in-intention, an important issue given the limited possibilities to use contracts in exploration.

However, there are also risks associated with this network structure. From a competence perspective, rapidly recombining different types of knowledge through different ties may create a risk of misunderstanding when cognitive variety becomes too big. Receiving many of such diverse inputs may invoke an integration problem as non-redundant actors may not (sufficiently) engage in triangulation and absorption processes within the dense core. If a firm receives too many different signals and knowledge inputs, the cognitive limits of those firms to deal with such a degree of diverse information are quickly reached. This leads us to our third hypothesis:

Hypothesis 3. Too much variety created through non-redundant ties may lead to difficulties in terms of efficient selection of the various inputs, which results in a negative effect on novelty creation.

From a governance perspective, this process of recombination of knowledge often requires specific investments in order to make these different types of knowledge fit with one another. This may create a risk of hold-up as in general such investments can only be recouped in relation with the specific partner, which requires some duration of the relation. When the durability of ties becomes too low, possibilities to recoup such investments decrease. This has consequences again from a competence perspective as firms may then show less inclination to invest in exploration and networking activities.

Another risk from a governance perspective is that of knowledge spill-overs. The rapid recombination of ties creates a (large) potential for such spill-overs, leading to acts of freeridership. On the other hand, the rapid transfer of reputation in the network may put limits on the possibility of such acts of freeridership, which is in line with Coleman's closure argument (1988). Table 2 summarises our argument.

4. Case studies: pharmaceutical biotechnology and multimedia

To assess in how far our above developed insights and hypotheses hold, we now discuss the empirical analyses of two different industries in the Netherlands, namely the multimedia industry and the pharmaceutical biotechnology industry. We have chosen these industries because they are similar in terms of knowledge intensity, have an explorative

Table 2

Potential benefits and risks of a dense network in exploration

	Competence perspective	Governance perspective
Potential benefits	Rapid recombination of knowledge	Rapid transfer of reputation
Potential risks	<ul style="list-style-type: none"> ● Risk of misunderstanding/chaos ● Insufficient creation of new knowledge 	<ul style="list-style-type: none"> ● Hold-up ● Potential for spill-overs

nature and are situated in the same country (the Netherlands). At the same time they differ in terms of key characteristics of exploration (as we will describe below). This provides an ideal base for comparison about different exploration networks.

An important reason to choose these two industries is that they were 'hit' by radically new technology whose effects started to come through by the late 1980s. In multimedia this was the emergence of the Internet and in pharmaceuticals this was the advent of biotechnology. These inventions initiated a process of exploration of 'novel combinations'. Here, the sources of expertise that were needed to create such novel combinations were widely dispersed. As a consequence, the locus of innovation was typically found in networks of learning, rather than in individual firms. Furthermore, a comparison between these two industries is particularly attractive because they embody some key differences with direct relevance to our object of study. One is the type of knowledge base underlying both industries (Breschi and Malerba, 1997). The knowledge base in multimedia is a highly systemic one, forming a sort of technology system that is built up of different types of technologies such as hardware and software technology (Smeulders, 1999; Marsili, 2001). In contrast, the knowledge base in pharmaceutical biotechnology is more of a stand-alone nature (Degenars and Janszen, 1996; Orsili, 2001), due to which new technological knowledge would not have highly disruptive consequences for adjacent technologies or other parts of the overall system (Teece, 1986). A key issue in view of internal validity is that we keep the national context constant. Although we acknowledge the influence of the national context on technology development (Mowery and Nelson, 1999; Rycroft and Kash, 2002), keeping it constant enables us to determine how far differences across our two industries are attributable to industry characteristics as discussed above, rather than to national factors.

4.1. Data collection and analysis

Given the sectoral focus of this paper and the broad nature of the transformation process that we study,

we need information that covers a wide range of issues. This information should inform us among others, on relevant industry characteristics, changes in aggregate learning and innovation patterns activities by firms, the role of interfirm networks, and so on. To obtain this information, our primary source of data is formed by industry reports and policy studies. Given their (growing) importance to the Dutch economy both industries have been extensively studied, especially how they were affected by the transformation process over the past 10–15 years. These studies were carried out by individual (scientific) researchers, specialised research institutes and consultancy firms. Clients of these studies ranged from the Dutch Ministry of Economic Affairs, the Dutch Ministry of Transport and Telecommunication, various industry associations, the OECD and EU. Most of these reports cover (some of) the issues that we are interested in and, taken together, these multiple sources enabled us to develop an approximation of our construct ‘exploration’ in both industries, from the 1980s and throughout the 1990s towards the early years of the new millennium. Using a variety of industry reports also enables us to triangulate among them. In addition, we have approached recognised industry experts with our analysis. Their role was to check whether the analyses we made were correct in terms of facts and completeness and to come up with additional information. In this respect, choosing these two industries bring us another important benefit. The innovation dynamics in both industries has taken place in a relatively short period of time, with, as far as the Netherlands is concerned, a major chunk in the 1990s and the early years of the new millennium (Dialogic, 1999; Enzing and Kern, 2002). In this way, choosing these two industries enables us to study (relatively) recent events, enhancing the reliability of our experts’ judgement. In sum, this combination of data collection methods has enabled us to make use of triangulation—which is important for the internal validity and reliability of our methodology—along two steps: first by triangulating among the various reports and studies themselves, and next by triangulating between our analysis, as derived from these reports and studies, and experts’ judgments.

A final issue is that we chose to study two different periods in the multimedia industry because we found that over the 1990s, two types of exploration networks emerged (whereas in pharmaceutical biotechnology only one type exploration network developed). In the multimedia industry, one network developed in the early 1990s, peaked around the mid 1990s, and focused primarily on the search for new *technologies* through the integration of converging technologies. The other network emerged from around 1995, and peaked around the year 2000. In this network, the focus was more on the exploration and fast development of multimedia *products and/or services* (‘business exploration’) for the ever growing mass-market.

4.2. The pharmaceutical biotechnology industry

We will start with an exploration of the networks in the pharmaceutical biotechnology industry that have emerged in the Netherlands, throughout the 1990s and the early years of the new millennium.

Over the 1990s a new breed of Dutch Dedicated Biotechnology Firms (DBF’s) emerged that was engaged, mostly through contract research services, in general platform technologies with a potential for applications in the pharmaceutical industry such as e.g. genomics, combinatorial chemistry, high-throughput screening and bio-informatics (Degenaaers and Janszen, 1996; Ernst and Young, 2001).

Research in these platform technologies could be considered as an important ‘engine of knowledge’ (Allansdottir et al., 2002). There were many technological spillovers by means of licences to different parts of biotechnology. Especially platform technologies generate such spillovers by providing platforms also in non-pharma applications such as plant breeding, food-processing (e.g. diagnostic kits), speciality chemicals, bio-informatics and biological catalysis. DBF’s that specialised in platform technologies aimed to provide tools and services to pharma firms that were involved in drug discovery and development. The advantage of this strategy was its potential for relative rapid commercialisation with (hopefully) fast cash-flows (Casper, 1999). So, over the course of the 1990s a knowledge exploration network was emerging in the field of general platform technologies, which is schematically depicted in Fig. 1.

Within this value chain we can discern between two main types of learning regimes, namely:

- Network 1: exploration within a network of DBF’s with academia;
- Network 2: exploitation within a network of one or more DBF’s with a large pharma firm.

As can be understood from DBF’s performed a key role in commercialising scientific knowledge. They connected a ‘basic-scientific environment’ with its emphasis on the importance of new knowledge with a ‘techno-economic environment’ which emphasised economic value (McKelvey, 1997). Given its sole focus on technological exploration, we now further analyse network 1.



Fig. 1. Emerging knowledge exploration value chain and learning regimes in the field of general platform technologies.

4.2.1. Network 1: technological exploration

Network 1 in the basic-scientific selection environment was embedded in a network that was made up of relations between DBF's and (public) research institutes. From the 1980s towards the middle of the 1990s the knowledge base on general purpose, platform technologies had a mainly stand-alone nature due to its strong basis in molecular biology or biology. Due to some high quality research at Dutch universities, there were opportunities for Dutch DBF's, although mainly pertaining to various niches (Degenaaars and Janszen, 1996). The majority of DBF's cooperated with (public) research institutes, indicating that knowledge was highly science-based (Biopartner, 2001), generally resulting in abstract and codified knowledge (through publications). The search process of scientific discovery itself was characterised by a lot of trial-and-error and was highly specific to individual persons and research communities (Enzing, 2000). This process entailed many elements that were difficult to codify such as test set-up, accurate execution, interpretation of test results and so on. It was characterised by serial, incremental improvements, leading to the accumulation of tacit knowledge within stable research groups of academics and DBF's (Enzing and Kern, 2002). In other words, a science-based and fast-changing knowledge base developed, with cumulative characteristics and high specificity to a network of DBF's and academics (Enzing and Kern, 2002). Relations between these people involved were dense and of fairly high durability (4–5 years or more) with frequent interaction in mutual openness on mainly search-related and technological issues.

So, these exploration networks were formed by dense networks of strong ties between universities and DBF's that enabled them to develop an in-depth understanding and critical peer reviews (Enzing and Kern, 2002). Coordination took place through formal and informal mechanisms. The research contract arranged some key economic aspects (such as use of scientific staff and laboratory facilities) and the allocation of intellectual property rights, but beyond that, coordination was mainly social in terms of peer reviews and reputational control in view of academic quality standards.

Towards the end of the 1990s platform technologies increasingly became more multidisciplinary in nature and entailed varying combinations of disciplines. Due to the mainly monodisciplinary orientation of their academic partners in this network, DBF's have also actively started to search and access complementary (scientific) knowledge, wherever it was located. As a result these dense networks of strong ties between universities and DBF's were opening up to complementary, outside sources of knowledge. Such outside sources were formed by universities, research institutes and other networks outside the Netherlands, either at various locations in Europe or in the US. Because this knowledge at universities and research institutes was generally codified, it was easily accessible and transferable by means of publications or Internet (Ernst and Young,

2000). Especially the use of Internet enabled DBF's to share information with anyone around the globe and to access public databases with state-of-the-art (scientific) knowledge. These relations relied much less on geographical proximity and could take place over (very) long distances (van Geenhuizen and van der Knaap, 1997). So, these more virtual linkages with weak ties created a non-dense network that was complementary to these dense, local research networks. The relations in the former were generally of low strength in terms of duration, frequency and entailed a limited set of specific technological issues (Enzing and Kern, 2002). Hence, these peripheral ties compensated for dynamic inefficiencies of the stable core. See also Table 3.

4.3. Exploration networks in the multimedia industry

Here, we analyse how exploration networks in the multimedia industry in the Netherlands have emerged throughout the 1990s and the early years of the new millennium.

Similar to the biotechnology industry, we analyse these networks in terms of density and strength of ties. In this analysis we will take the moment of the adoption of Internet (around 1990), as the worldwide standard for on-line communication, as a starting point.

4.3.1. Network 1: technological exploration

Before the advent of Internet, the existing knowledge base was compartmentalised in separate technologies that co-existed: information-, communication-, audiovisual- and data-transmission technologies. These technologies were mostly stand-alone and most exploration was done by large, R&D-intensive firms that were specialised in hardware or software such as Lucent, Ericsson, Philips, and Sony. The arrival of Internet yielded the insight that for its full utilisation a more fundamental restructuring was required, in technological convergence. Digitalisation provided a technical incentive and opportunity for this integration of technologies. Thus, Internet, together with perspectives for digitalisation, provided powerful incentives to actively search for convergence of these technologies, in new applications (Condrinet, 1998). This led to the entry of new firms that were small in size and formed by people with technological knowledge and a keen interest in exploring the potential for this technological convergence process. In doing so, these new entrants complemented the search activities of the large, R&D-intensive firms. These small firms showed a keen interest in networking because a number of key resources of these firms could only be found outside their firm boundaries (Calia et al., 2007). So, exploration developed between small specialised multimedia firms and specialised suppliers of hardware and software.

The relations making up network 1 were mainly informal and (relatively) symmetric (Dialogic, 1999). Although these relations became more intensive, the growing number of

Table 3
Network properties

	Exploration network in pharmaceutical biotechnology		Exploration network 1 in multimedia	Exploration network 2 in multimedia
	Core	Periphery		
<i>Network structure properties</i>				
Network structure				
Density	High	Low	High	Medium
Centralisation	Medium	Low	Low	High
Stability	Medium-High	Low	Low	High
<i>Tie strength</i>				
Duration	Medium-High	Low	Low	Low-Medium
Frequency	High	Low	High	Medium-High
Mutual openness	High	Low	High	Medium
Scope of content	Medium	Low	Medium-High	Low-Medium
<i>Governance of relational risk</i>				
Relational risk				
Strategic need	High	Medium	High	High
Specific investments	High	Low	Medium	High
<i>Governance</i>				
Governance strategy	Contracts, mutual self-interest, network position, trust-in-intention	Contracts (licenses)	Mutual self-interest, trust-in-intention, transfer-of-reputation	Mutual self-interest, trust-in-competence, contracts
Coordinating mechanisms	Social coordination and control, linking pins, information systems		Social coordination and control, professional norms, 'free-souls mentality'	Direct communication, linking pins, capital ventures, liaison roles
Elements of exploration task	Exploration network in pharmaceutical biotechnology	Exploration network 1 in multimedia	Exploration network 2 in multimedia	
Object of learning	New scientific knowledge	Exploration of technological convergence	User needs and viable business model	
Learning process	Expansive search and exploration	Information-intensive, interactive learning	Searching and learning by doing	
Actors	Scientists and DBFs	Established R&D-intensive firms and new entrants (start-ups, spin-offs)	VCs and start-ups, possibly complemented by large established firms with strong brandname	
Input	Research skills and scientific knowledge	Complementary assets in hardware and software (codified knowledge on various technologies, tacit knowledge on their integration and on directions for further exploration)	Complementary resources and capabilities (capital, possibly brandname in combination with idea and know-how for new business model, marketing capabilities)	
Output	New scientific knowledge	Integration of distinct technologies and converging multimedia devices	Wide variety of portals	
Spill-overs				
Outside-in	High	High (from outside the Netherlands)	High (from outside the Netherlands)	
Within network	High (tacit knowledge on search)	High (tacit knowledge on search)	High (tacit knowledge on creation of business model and supporting organisational processes)	
Inside-out	High	High (to exploitation oriented network, not considered here however)	High (to others networks within Dutch multimedia industry as well as outside the Netherlands)	
Freeridership	Low	Low	Low	
Hold-up	High (low with weak ties)	Low-Medium within network; high by users	High	

entrants led to an overall loosely coupled network structure. Interfirm learning was highly explorative and took place by much trial-and-error, with a great deal of

tacit knowledge on which search directions to explore and how to explore them (Peelen et al., 1998). This resulted in a dense network structure with low centralisation

(Peelen et al., 1998; Jonkheer and Bakker, 1999). Ties were strong in terms of frequency of interaction that was open on various issues, but of fairly short duration. Exact information is not available but a rough estimate based on discussions with multimedia firms in 1998 would indicate an approximate level of duration that varies between 1–2 months and 6–8 months, with 12 months or more being the exception. It was said that the relation had ended when ‘e-mails were not answered anymore’. With regard to frequency a rough estimate would indicate an approximate level between two to three contacts a day and one to two contacts a week, often by email but also by face-to-face discussions.

This combination of dimensions of tie strength created the possibility for an easy recombination of ties so that the systemic knowledge base could be explored rapidly. The main object of this explorative learning was the exploration of technological integration and later on also some first, new applications. Due to the increasingly systemic nature of knowledge, strong network externalities developed to effectuate technological integration: firms needed to cooperate in hardware and software, in joint development, where no single firm disposed of the necessary knowledge of all technologies (Schaffers et al., 1996). Firms’ capabilities were mainly technology-oriented and centred around the ability to integrate key technologies. Furthermore, governance within the network was based on trust-incompetence and the assumption of intentional trustworthiness with limited opportunism and free riding, without extensive formal safeguards (Dialogic, 1999; Bouwman and Hulsink, 2000). This was further reinforced by firms’ mutual technological dependence and the importance of reputation for the sake of future options for collaboration in unpredictable, emerging networks. The notion of technological convergence was seen as the ultimate challenge for firms engaged in this network and functioned as a sort of shared belief in which direction technological exploration should take place. This shared belief in the promises of technological convergence enabled firms to coordinate their relation in their network by a ‘free-souls mentality’ (Dialogic, 1999; Leisink et al., 1998, 2000; Bouwman and Hulsink, 2000). A clear empirical indication for this observed ‘free-souls mentality’ is for example found in the network of firms that cooperated in the technological exploration of multimedia image processing technology in the period around 1996–1998. When asked what they perceived as the most important benefit of cooperation when exploring this new technology, around 60–65% of the involved firms mentioned access to and exchange of knowledge whereas only 5–10% indicated that they worried about the risk of spill-overs (Oerlemans and Meeus, 2000). See also Table 3.

Over time, towards the second half of the 1990s, these initial exploration efforts started to pay off as multimedia-technology became more widely available by creating the necessary tools (software, user-interfaces, content, distribution) at increasingly lower costs, an important condition

for unlocking a potential mass-market. This induced a new exploration process with a focus on business exploration, at the demand side of the value chain—formed by the value-steps of multimedia packaging, distribution and end-use that started from the mid 1990s onwards.

4.3.2. *Network 2: business exploration*

Network 2 emerged from the exploration of new business models that took place in a variety of ways. Some firms, especially Internet service providers as well as various publishers, opted for related diversification through in-house creation of new business models. Others made use of alliances, either equity or non-equity based, with firms already occupying a certain market position in the growing market for on-line services. Examples are formed by the alliance between VNU, a publisher, and Ilse, a Dutch search engine (Barschot, 2000) or by the integration of successful start-ups by large firms such as the acquisition of Planet Internet, an internet service provider by KPN, the Dutch national telco (Bouwman and Hulsink, 2000). Another type of network was that of a start-up backed by one or more venture capitalist(s) and/or informal investor(s) (Dialogic, 1999).

Towards the end of the 1990s though, the network made up of ‘start-ups and venture capitalists/informal investor’, started to dominate. Its systemic combination of characteristics appeared to be more effective in exploring on-line business opportunities: asymmetric relations among start-ups and highly central venture capitalists/investors, the latter having a strong coordinating role by acting as linking pins and taking seats on the board of these start-ups, which made coordination highly tacit and specific to the network (AT Kearney, 1997; Beam-it, 1999). The main resources provided by these central actors were business knowledge, capital and market access, whereas the start-up often brought in the idea for a new business model. The learning object of this network was to learn about two issues: a quick understanding of user needs and the subsequent development of a viable business model. An important outcome of this first exploration of business opportunities was the growing insight that to make money out of Internet, one needs content which captures the attention of consumers or professional users. This was captured by the notion of ‘content is king’ giving full motivation to and direction for business exploration (Directie EDI, 1996; Schaffers et al., 1996; Booz Allen and Hamilton, 1997). In this search it quickly became clear that one does not necessarily be content-owner per se, but that it was more important to dispose over access to a community of (professional) users who share a common need or interest (Condrijet, 1998).

The exploration of new business opportunities resulted in different business models, which mainly varied in offering intermediary services in the field of either information (infomediaries), on-line marketplaces, or e-commerce. The assessment of these ideas for business models was done by venture capitalists and/or informal

investors, although they were often not really critical (Dialogic, 1999). By allowing for variety and providing abundant capital for exploration, they often accepted half-baked business plans (Steins Bisschop, 2000). Later, this led to a tremendous shake-out of unsuccessful new start-ups, for three reasons. A first reason relates to the easy possibilities for imitation of the various types of business models that lowered entry barriers, eroding initially attractive profit margins (Bughin et al., 2001). A second reason is the unwillingness of website-visitors to click through these web-ads. This made these ‘banner-ads’ very ineffective, which lowered interest of advertisers, resulting in insufficient revenues (Bughin et al., 2001). A third reason is that professional users and consumers suffered from a ‘liability of newness’, with uncertainty and lack of confidence concerning on-line commerce (Booz Allen and Hamilton, 1997; Condrinet, 1998; Dialogic, 1999). This was not only related to the newness of the medium of Internet as such but also to the perception that on-line payment is unreliable. The resulting lack of selection by demand spurred new start-ups, convinced of their ability to develop a brand name for a new portal that would bring ultimate success. The near absence of selection forces in this exploration of business models rapidly led to a situation of ‘chaos’: variety abounded as can be noted from the explosion of portals, while insights into a viable and sustainable business model were still limited (Financiële Telegraaf, 2000). Ultimately, this led to a rapid decrease of confidence in the ‘promises’ of multimedia and made investors decide to withdraw. With capital funds drying up rapidly then, this finally resulted in a tremendous shake-out of multimedia firms in the early years of the new millennium (Steins Bisschop, 2000). See also Table 3.

5. Understanding novelty creation in multimedia and biotechnology

In this section we discuss the insights from our empirical analysis of both industries. We will analyse how the identified combination of density and strength of ties enabled and constrained the creation of novelty in exploration networks.

5.1. Pharmaceutical biotechnology: network 1

As analysed, to deal with the complexity of the scientific search process a dense network emerged, made up of ties that were strong in duration, frequency of interaction and openness. This combination of density and strong ties provided stability and possibilities for triangulation. Due to a growing need for more systemic knowledge towards the end of the 1990s, this existing dense network opened up to complementary sources of knowledge, held at other locations by ties weak in openness, scope of content, duration and frequency of interaction. These ties were coordinated through licences that made it possible to access and use this distant, codified knowledge without the

need for the substantial specific cognitive investments, the build-up of trust and substantial interaction. This was possible due to the fact that this knowledge at distant locations was highly codified through publications and patents. Its potential value could therefore be readily assessed given the generally high absorptive capacity present in the dense, local network. The high rate of change of knowledge meant that such distant sources of knowledge succeeded one another on a regular basis, which required constant monitoring for new potential sources. This relatively high turn-over of such weak ties was possible because the knowledge base was mainly stand-alone in nature, so that substantial technological interdependencies were absent or weak. As a consequence, such weak ties could be replaced without the risk of creating bottlenecks in adjacent technological areas.

In sum, we found a dense network of strong, locally embedded ties that acted as a selection mechanism that was endogenous to the network. This core was then surrounded by a periphery of relations with outside actors with varying levels of entry/exit and durability that were needed in view of the required cognitive variety (i.e. diversity in sources of knowledge). The value of this knowledge that originated from these outside sources was then assessed by the core members of the network. In this way, diversity and selection mechanisms were aligned so that the network proved to be effective in the creation of novelty. This is in line with our first and second hypotheses.

5.2. Multimedia: network 1

As analysed, in this network a complex search process emerged due to the underlying systemic knowledge base. This created a need for high density in combination with ties that were strong in terms of frequency of interaction, openness on various issues but of fairly short duration. This combination of network structural properties created the possibility for an easy recombination of ties that proved useful when exploring such a systemic knowledge base. Moreover, it was more rational not to go for full appropriation but rather to stay connected with the exploration activities going on and to ‘live and let live’ in order to keep up to date with the rapidly changing knowledge base. So, these network structural properties accommodated the highly interactive searching activities and the emergence of a ‘free-souls mentality’.

An important issue here is that a stable core in this network could not be identified, raising the question how this complex and rapidly changing network maintained sufficient stability and did not fall prey to chaos. This is due to the role of three important selection mechanisms at the industry level. A first one was technology-related. As argued, Internet was selected as the world-wide dominant design for on-line communication and in this respect formed a crucial selection mechanism in the search process. Any new technology developed had to fit into this new

Internet paradigm. A second selection mechanism was cognition-related. A central binding element was the shared belief of converging multimedia devices. Any exploration activity was basically aimed at creating such devices or enabling their use such as e.g. speak- and language technology, data-transmission technologies. A third selection mechanism was governance-related. Governance was formed by the free-souls mentality that formed an important institution for selecting appropriate behaviour in this learning regime. Deviating from this was prevented by the rapid transfer of reputation. The combination of these three central selection mechanisms meant that this network did not fall prey to chaos and was also quite effective in creating novelty.

So, in this network novelty was created in a different way than in the biotechnology case. In this network no explicit distinction could be made between a core and a periphery nor between strong and weak ties. In this way, there was no dense central core of strong ties that acted as an endogenous selection mechanism, as in network 1 in pharmaceutical biotechnology. Instead, there were three exogenous industry-level selection mechanisms that prevented this highly volatile network from falling apart into chaos. So, these findings deviate somewhat from our hypotheses but also point to an interesting new insight. If the network structure does not allow for an endogenous selection mechanism, this can still be accomplished by exogenous selection mechanisms at the industry level. We will address this further in Section 6 when we conclude.

5.3. *Multimedia: network 2*

As analysed, the person-bound nature of the needed resources and the fairly diffuse opportunities, the search process was fairly complex and predominantly tacit. Although there were interdependencies between parties in terms of complementary assets in this network, there were no direct interdependencies in terms of knowledge. This could be noted from the fact that start-ups largely explored alone and that they could adapt their strategy and market approach irrespective of the capabilities of their partners. Once these resources were available, uncertainty at the input-side was fairly limited. The diffuse nature of the opportunity conditions created uncertainty at the output-side of the search process, both in terms of complexity and variability. To deal with this complexity, firms needed to make substantial investments, not only in terms of committing resources but also in terms of specific, cognitive investments. This combination of economic and cognitive investments created a clear rationale for more substantial governance, entailing a mix of mechanisms such as direct communication, capital ventures and liaison roles. Such a role was often performed by the VC or informal investors, enabling informal networking and knowledge-sharing among start-ups. The tacitness of this search process explained why contracts had limited value and why the strength of relations was high in terms of frequency of

interaction and mutual openness. To deal with variability, VC's invested in various start-ups simultaneously, creating a network structure in which they occupied a central position. However, they made an uncritical assessment of business models and allowed for a wide variety of ideas, which made them in fact accepting half-baked business plans. The extant structure then reinforced this process. As such, the combination of central VCs with peripheral start-ups created a relatively stable configuration. However, the direct involvement in exploration by this central firm, in combination with its highly uncritical role, made the network vulnerable as it was unable to create an endogenous selection mechanism. In combination with a lack of exogenous selection forces, such as demand or other environmental factors (e.g. legislation), the network increasingly lost stability and slid off to chaos.

These findings are again in line with our first and second hypothesis and also provide an illustration of Hypothesis 3, claiming a detrimental effect on novelty creation when variety abounds and selection is insignificant. See also Table 2.

6. Conclusions

The aim of this paper is to develop an understanding of how novelty is created in exploration networks. Our qualitative and tentative analysis of exploration networks in the multimedia and pharmaceutical biotechnology in the Netherlands indicates evidence that the combination of peripheral non-density through weak ties and a dense core through strong ties enables the alignment of diversity and selection mechanisms, needed for the creation of novelty. Moreover, the business exploration network in multimedia provided an illustration of our third hypothesis that abundant variety created through non-redundant ties may pre-empt selection with a negative effect on novelty creation.

This implies that there is a trade-off between non-redundancy in networks on the one hand, in order to access cognitive variety, and redundancy in networks on the other hand, for triangulation and absorption. In other words, brokerage enables to access sources of potential added value, conform Burt's argument, network closure is however critical to capturing this value, conform Coleman's argument. Rephrased in Granovetter's terminology, weak ties cross social group boundaries, whereas absorption and triangulation are done by strong ties (strong in terms of frequency, openness not necessarily duration) within a group. So, when understanding novelty creation in exploration networks Burt, Coleman and Granovetter need not to be seen as contradictory, but rather as proponents of complementary views. Management should therefore try to build an optimal portfolio of alliances, featuring weak ties for the creation of novel combinations and strong ties that enable those companies to validate and assess the newly acquired knowledge.

In contrast to our expectations were the findings on exploration of a systemic technology, as in multimedia. This required an overall dense, redundant network of ties that are strong in terms of frequency, openness but show low strength in terms of duration. As indicated, in this network no clear distinction could be made between a core and a periphery nor between strong and weak ties. It entailed a type of novelty creation that mirrored the more radical nature of exploring a systemic knowledge base, leading to the destruction of existing and creation of new technological architectures. As already mentioned, this points to a new insight. Apparently, novelty creation in exploration networks can be done in two ways. One is through the ‘classical way’ according to Granovetter’s ‘strength of the weak tie’ argument. This is what we found in the peripheral network in network 1 in biotechnology, with its focus on technological exploration of a stand-alone technology. As analysed, this was done through a stable overall configuration in which novelty originates from *new combinations* of ties and where selection is endogenous to the network through a dense core of strong ties. This is in line with our theory and hypotheses. For management this requires the need to search for distinct partners that have unique capabilities or technological resources. Novelty creation in this respect is facilitated by teaming up with companies that are relatively far away in the network and that are dissimilar from the focal firm. Dissimilarity seems to breed novelty, albeit recent literature has shown that too much dissimilarity is decreasing the absorptive capacity of firms and therefore the ability to create novelty (Hamel, 1991; Lane and Lubatkin, 1998; Mowery et al., 1996; Fleming and Sorenson, 2001).

An interesting new insight, as it emerges from our empirical analysis, is that there is also another way of creating novelty, namely through a dense network in combination with a high volatility (entry/exit) of ties. This may be associated with a more radical level of exploration in which novelty originates from *novel configurations* of ties in combination with exogenous industry-level selection mechanisms. This implies the need for the creation of fast-to-build flexible alliances which are used to create a radar function that continuously monitors new windows of opportunities for the focal company (see Duysters and de Man, 2003). Firms should therefore try to make the most of the inherent flexibility and speed of non-equity alliances with a large number of partners at the same time. This allows companies to make use of the specific know how and competences of various individual partnerships rather than engaging in a few broad ranging partnerships with one specific partner.

Our third case of business exploration in multimedia indicates that if *both* endogenous selection mechanism *and* exogenous selection mechanism are absent, the network falls prey to chaos and becomes ineffective in the creation of novelty (cf. Hypothesis 3). In sum, the conclusion is that a network structure should allow for the alignment of selection and diversity mechanisms in view of novelty

creation. We find that this is the case for network 1 in pharmaceutical biotechnology. Although we do not find this in a similar way for network 1 in multimedia, the underlying logic is basically the same: selection and diversity mechanisms should be aligned. Here, an important new insight is that if the network structure does not allow for an endogenous selection mechanism, this can still be accomplished by exogenous selection mechanisms at the industry level. If no selection mechanisms are present—endogenous nor exogenous—there is no alignment with corresponding diversity and the network fails in its creation of novelty (network 2 in multimedia).

Overall, the way in which novelty is created differs along the level of exploration, with consequences for aligning diversity and selection mechanisms and hence for the optimality of network structural properties. So, how structural and relational embeddedness in exploration networks (density and tie strength) combine in an optimal way, in view of novelty creation, is strongly conditioned by the nature of the knowledge base that is being explored. This is not only a far cry away from the underdeveloped notions on networks by innovation scholars but also from the universalistic tone of social network theorists.

Appendix A

Some background on the Dutch pharmaceutical biotechnology industry

According to recent figures, the Netherlands occupies a 12th position in the overall ranking of nations, based on number of biotechnology companies (Ernst and Young, 2001). Three medium-sized multinational firms are clearly involved in pharmaceutical biotechnology, namely AKZO Nobel (Organon, Organon Technika and Intervet), DSM-Gist Brocades (largest global manufacturer of penicillin), Yamenouchi and Solvay Pharmaceuticals. In addition, foreign pharmaceutical firms have clinical research being carried out in the Netherlands and have relations with Dutch Dedicated Biotechnology Firms (DBF’s). Moreover, some of these DBF’s have relations with firms outside the Netherlands. From the early 1990s towards 1998–1999, the number of entrants by DBF’s per annum increased from 4 in 1994 to 10 in 1998, making 50 in total (Biopartner, 2001, 2002). Around 50% of these firms in the pharmaceutical industry in the Netherlands were active in the field of pharmaceutical biotechnology. This indicated that a pharmaceutical biotechnology industry in the Netherlands was emerging in this period. All these young firms saw R&D as their core activity. They were either independently established

(60%) or spin-offs from academia or existing firms (40%) with virtually no DBF's created through diversification from existing pharmaceutical firms (Enzing, 2000, Enzing and Kern, 2002). These DBF's had relations with academia as well as with large pharma firms, both inside and outside the Netherlands. Their main sources of income were formed by royalties from licences or by offering a variety of specialised services such as contract research, contract manufacturing and/or custom synthesis (Enzing and Kern, 2002). Examples of such DBF's are among others Pharming (transgenic animals), Crucell (platform technologies, gene therapy) and Isotis (human tissue engineering).

Appendix B

There are two methods of identifying networks (Knoke and Kuklinski, 1982). A realist approach is based on the subjective perception of the involved actors. The identification of a network is determined by 'the limits that are consciously experienced by all or most of the actors that are members of the entity' (Knoke and Kuklinski, 1982, p. 22). A nominalist approach is based on the viewpoint of the researcher. Identification of a network is based on the application of his analytical framework used. In this respect, we have followed a nominalist approach by only considering those networks and interfirm ties with relevance from an innovation perspective.

Network measures used in the study:

a. Network structure

- Density: the number of ties as a proportion of the total number of possible ties:
 - Low: very limited number of ties present (the network is sparse or 'empty')
 - Medium: approximately half of the total number of possible ties can be identified
 - High: (nearly) all ties that are possible can be identified
- Centralisation: tendency of a single firm to be more central than all others:
 - Low: many firms with relatively similar levels of centrality
 - Medium: two or more firms with relatively similar levels of centrality
 - High: one firm with high centrality
- Stability: the volatility of ties based on the entry-exit level of firms:
 - Low: high entry, high exit
 - Medium: high entry, low exit/low entry, high exit (and intermediate values)
 - High: low entry, low exit

b. Tie strength

- Duration: the length of relationship in time. Depending on the type of network in its specific industry, we consider the number of weeks, months or years. As argued above, we qualify duration as 'limited' versus 'long' based on a comparison between exploration and exploitation within a single industry setting. Different speeds of change between multimedia and biotechnology make that we cannot compare network properties between these two industries in a meaningful way. We do not want to compare network properties between two industries as such, but rather how such properties differ between exploration versus exploitation within an industry.
- Frequency: the number of contacts within a given time period. Depending on the type of network in its specific industry, we consider the number of contacts per day, per week, per month or per year. Following our arguments for duration, we qualify frequency as low versus high based on a comparison between exploration and exploitation within a single industry setting.
- Mutual openness: the extent in which knowledge moves freely between firms:
 - Low: no knowledge flows whatsoever
 - Medium: one-way flow of knowledge
 - High: two-way flow of knowledge
- Scope of content: the range of issues that is covered in the relation between firms:
 - Narrow: on specific technological issue
 - Medium: two or more technological issues
 - High: technological and non-technological issues

References

- Abernathy, W.J., 1978. The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry. Johns Hopkins University Press, Baltimore.
- Abernathy, W.J., Clark, K.B., 1985. Innovation: mapping the winds of creative destruction. *Research Policy* 81, 41–47.
- Abernathy, W.J., Utterback, J.M., 1978. Patterns of industrial innovation. *Technology Review* 81, 41–47.
- Ahuja, G., 2000. Collaboration networks, structural holes and innovation: a longitudinal study. *Administrative Science Quarterly* 45, 425–455.
- Allansdottir, A., Bonaccorsi, A., Gambardella, A., Mariani, M., Pammolli, F., Riccaboni, M., 2002. Innovation and Competitiveness in Biotechnology: A European Perspective, Background Report. DG-Enterprise, European Commission, Brussels.
- ATKearney, 1997. Bedrijfstaktoets Audiovisuele Sector. Ministerie van Economische Zaken, Den Haag (in Dutch).
- Bathelt, H., Malmberg, A., Maskell, P., 2004. Clusters and knowledge: local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography* 28, 31–56.
- Beam-it, 1999. Resultaten On-line Discussie, Technologieradar Multimedia. Ministerie van Economische Zaken, Den Haag (in Dutch).
- Beeby, M., Booth, C., 2000. Networks and inter-organizational learning: a critical review. *The Learning Organization* 7, 75–88.
- Biopartner, 2001. The Netherlands Life Sciences Report 2001, Gaining Momentum. Biopartner, Leiden.

- Biopartner, 2002. The Netherlands Life Sciences Report 2002, Maintaining Momentum. Biopartner, Leiden.
- Booz Allen and Hamilton, 1997. On-line Services Market Benchmarking. Ministerie van Economische Zaken, Den Haag.
- Bouwman, H., Hulsink, W., 2000. Silicon Valley in de Polder, ICT-Clusters in de Lage Landen. Lemma, Utrecht (in Dutch).
- Breschi, S., Malerba, F., 1997. Sectoral innovation systems: technological regimes, Schumpeterian dynamics and spatial boundaries. In: Edquist, C. (Ed.), *Systems of Innovation, Technologies, Institutions and Organizations*. London, Pinter.
- Bughin, J.R., Hasker, S.J., Segel, E.S.H., Zeisser, M.P., 2001. What went wrong for on-line media. *The McKinsey Quarterly* 4 (web exclusive).
- Burt, R.S., 1992. *Structural Holes, the Social Structure of Competition*. Harvard University Press, Cambridge, MA.
- Burt, R.S., 2004. Structural holes and good ideas. *American Journal of Sociology* 110 (2), 349–399.
- Calia, R., Guerrini, F., Moura, G., 2007. Innovation networks: from technological development to business model reconfiguration. *Technovation* 27 (8), 426–432.
- Carlsson, B., Stankiewicz, R., 1991. On the nature, function and composition of technological systems. *Journal of Evolutionary Economics* 1, 93–118.
- Casper, S., 1999. Institutional adaptiveness, technology policy, and the diffusion of new business models: the case of German Biotechnology. *Organization Studies* 21 (5), 887–914.
- Coleman, J.S., 1988. Social capital in the creation of human capital. *American Journal of Economic Sociology* 94 (Supplement), 95–119.
- Coleman, J.S., 1994. A rational choice perspective on economic sociology. In: Smelser, N., Swedberg, R. (Eds.), *The Handbook of Economic Sociology*. Princeton University Press, Princeton, pp. 166–180.
- Condrinet, 1998. Content and Commerce Driven Strategies in Global Networks, Report for the European Commission. DG-Enterprise, European Commission, Luxemburg.
- Degenars, G.H., Janszen, F.H.A., 1996. *Biotechnology on the Way to the Year 2000, a Future Perspective for Dutch Industry*. Erasmus University, Rotterdam (in Dutch).
- Dew, N., Read, S., 2007. The more we get together: coordinating network externality product introduction in the RFID industry. *Technovation* 27 (10), 569–581.
- Dialogic, 1999. Clustermonitor Multimedia. Ministerie van Economische Zaken, Den Haag (in Dutch).
- Directie EDI, 1996. Thema-Document Multimedia. Ministerie van Economische Zaken, Den Haag (in Dutch).
- Dosi, G., Marengo, L., 2000. On the tangled intercourses between transaction cost economics and competence-based views of the firm: a comment. In: Foss, N., Mahnke, V. (Eds.), *Competence, Governance and Entrepreneurship*. Oxford University Press, Oxford.
- Dosi, G., Freeman, C., Nelson, R.R., Silverberg, G., Soete, L. (Eds.), 1988. *Technical Change and Economic Theory*. Pinter Publishers, London.
- Duysters, G., de Man, A.-P., 2003. Transitory alliances: an instrument for surviving turbulent industries? *R&D Management* 33 (1), 49–58.
- Enzing, C.M., 2000. Bijlage bij de Integrale nota Biotechnologie. TNO-STB, Delft (in Dutch).
- Enzing, C.M., Kern, S., 2002. Eindrapport Life Sciences Impact, Rapportage Voor het Ministerie van Economische Zaken. TNO-STB, Delft (in Dutch).
- Ernst and Young, 2000. *Evolution, European Life Sciences Report 2000*. Ernst and Young Ltd., London.
- Ernst and Young, 2001. *Focus on Fundamentals, the Biotechnology Report*. Ernst and Young Ltd., London.
- Financiële Telegraaf, 2000. *Multimediasector Kan Eigen Groei Nauwelijks Bijbenen*. De Telegraaf, Amsterdam, (26-06-2000, in Dutch).
- Fleming, L., Sorenson, O., 2001. Technology as a complex adaptive system: evidence from patent data. *Research Policy* 30, 1019–1039.
- Grabher, G. (Ed.), 1993. *The Embedded Firm, on the Socio-Economics of Industrial Networks*. Routledge, London.
- Grandori, A., 1997. An organizational assessment of interfirm coordination modes. *Organization Studies* 18 (6), 897–925.
- Granovetter, M., 1973. The strength of weak ties. *American Journal of Sociology* 78, 1360–1389.
- Granovetter, M., 1985. Economic action and social structure, the problem of embeddedness. *American Journal of Sociology* 91 (3), 481–510.
- Hagedoorn, J., 1993. Understanding the rationale of strategic technology partnering: interorganizational modes of cooperation and sectoral differences. *Strategic Management Journal* 14 (5), 371–386.
- Hagedoorn, J., Duysters, G.M., 2002. Learning in dynamic inter-firm networks, the efficacy of quasi-redundant contacts. *Organization Studies* 23, 525–548.
- Hagedoorn, J., Schakenraad, J., 1994. The effect of strategic technology alliances on company performance. *Strategic Management Journal* 15 (4), 291–310.
- Hamel, G., 1991. Competition for competence and inter-partner learning within international strategic alliance. *Strategic Management Journal* 12 (Special issue), 83–103.
- Hamel, G., Prahalad, C.K., 1994. Strategy as field of study: why search for a new paradigm. *Strategic Management Journal* 15 (Summer Special Issue), 5–16.
- Jonkheer, K., Bakker, K., 1999. *Multimedia Bedrijven in Nederland*. EIM, Zoetermeer.
- Knoke, D., Kuklinski, J.H., 1982. *Network Analysis*. Sage Publications, Beverly Hills.
- Kogut, B., 2000. The network as knowledge: generative rules and the emergence of structure. *Strategic Management Journal* 21, 405–425.
- Lane, P.J., Lubatkin, M., 1998. Relative absorptive capacity and interorganizational learning. *Strategic Management Journal* 19, 461–477.
- Leisink, P., Boumans, J., Teunen, J., 1998. *De Multimedia Sector in Beeld, een Verkennend Onderzoek Naar Bedrijven en Werknemers in de Nieuwe Media Productiesector*. GOC, Veenendaal (in Dutch).
- Leisink, P., Teunen, J., Boumans, J., 2000. *Multimedia: De Pioniersfase Voorbij*. GOC, Veenendaal (in Dutch).
- Madhavan, R., Koka, B.R., Prescott, J.E., 1998. Networks in transition: how industry events (re)shape interfirm relationships. *Strategic Management Journal* 19, 439–459.
- Malerba, F., 2004. *Sectoral Systems of Innovation*. Cambridge University Press, Cambridge.
- March, J., 1991. Exploration and exploitation in organisational learning. *Organisation Science* 2, 71–87.
- Marsili, O., 2001. The anatomy and evolution of industries, technological change and industrial dynamics. Edward Elgar, Cheltenham.
- McKelvey, M., 1997. Using evolutionary theory to define systems of innovation. In: Edquist, C. (Ed.), *Systems of Innovation, Technologies, Institutions and Organizations*. Pinter, London.
- Mowery, D.C., Nelson, R.R. (Eds.), 1999. *Sources of Industrial Leadership, Studies of Seven Industries*. Cambridge University Press, New York.
- Mowery, D.C., Oxley, J.E., Silverman, B.S., 1996. Strategic alliances and interfirm knowledge transfer. *Strategic Management Journal* 17 (Winter Special Issue), 77–91.
- Nelson, R.R., Winter, S.G., 1982. *An Evolutionary Theory of Economic Change*. Harvard University Press, New York.
- Nieto, M.J., Santamaria, L., 2007. The importance of diverse collaborative networks for the novelty of product innovation. *Technovation* 27 (6/7), 367–377.
- Nooteboom, B., 1999. *Inter-Firm Alliances: Analysis and Design*. Routledge, London.
- Nooteboom, B., 2000. *Learning and Innovation in Organizations and Economies*. Oxford University Press, Oxford.
- Nooteboom, B., 2004. Governance and competence: how can they be combined? *Cambridge Journal of Economics* 28 (4), 505–526.
- Oerlemans, L.A.G., Meeus, M.T.H., 2000. *Clusters en IOP's, ESB-dossier Clusters in Beeld*. ESB, Rotterdam.

- Pavitt, K., 2002. Knowledge about knowledge since Nelson & Winter: a mixed record, SPRU. <<http://www.sussex.ac.uk/spru/publications>>.
- Peelen, E., Jansen, R.M., Kerbkamp, S.H.A., van Velzen, J.W.N., 1998. The Amsterdam Multi-Media Sector and Suggestions for its Growth Policy. University of Amsterdam, Amsterdam (in Dutch).
- Pitt, L., van der Merwe, R., Berthon, P., Salehi-Sangari, E., Barnes, B., 2006. Swedish BioTech SMEs: the veiled values in online networks. *Technovation* 26 (5/6), 553–560.
- Porter, M.E., 1990. *The Competitive Advantage of Nations*. Macmillan Press, London.
- Rosenkopf, L., Tushman, M.L., 1994. The co-evolution of technology and organization. In: Baum, J.A.C., Singh, J.V. (Eds.), *Evolutionary Dynamics of Organizations*. Oxford University Press, New York.
- Rowley, T., Behrens, D., Krackhardt, D., 2000. Redundant governance structures: an analysis of structural and relational embeddedness in the steel and semiconductor industries. *Strategic Management Journal* 21, 369–386.
- Rycroft, R.W., Kash, D.E., 2002. Path dependence in the innovation of complex technologies. *Technology Analysis and Strategic Management* 14, 21–35.
- Schaffers, H., Maltha, S., Rutten, P., van Stralen, A., 1996. Een Innovatieperspectief voor de Content-Keten. TNO-STB, Apeldoorn (in Dutch).
- Schumpeter, J.A., 1939. *Business cycles: a theoretical, historical and statistical analysis of the capitalist process*. Mc Graw Hill, New York and London.
- Smeulders, A.W.M., 1999. *Multimedia is Beweging*. Universiteit van Amsterdam, Rapportage voor het Ministerie van Economische Zaken, Den Haag.
- Smith Ring, P., van de Ven, A., 1994. Developmental processes of cooperative interorganisational relationships. *Academy of Management Review* 19 (1), 90–118.
- Spekman, R.E., Forbes III, Th.M., Isabella, L.A., Macavoy, T.C., 1995. Alliance management: a view from the past and a look to the future. *Journal of Management Studies* 35 (6), 747–772.
- Stankiewicz, R., 2002. The Cognitive Dynamics of Biotechnology and the Evolution of its Technological Systems, in: Carlsson, B. (ed.), 2002, *Technological Systems in the Bio Industries, An International Study*, Boston and Dordrecht, Kluwer Academic Publishers.
- Steins Bisschop, J.S., 2000. Na Chaos Moet er nu Orde Komen op Internet. *Financieel Dagblad*, Amsterdam, (06-11-2000, in Dutch).
- Teece, D., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. *Research Policy* 15, 285–305.
- Uzzi, B., 1996. The sources and consequences of embeddedness for the economic performance of organizations: the network effects. *American Sociological Review* 61, 674–698.
- Uzzi, B., 1997. Social structure and competition in interfirm networks: the paradox of embeddedness. *Administrative Science Quarterly* 42, 35–67.
- Van Barschot, J., 2000. VNU Wordt Met Ilse Grootste Internetuitgever. *NRC Handelsblad*, Rotterdam, (06-07-2000).
- van Geenhuizen, M., van der Knaap, B., 1997. R&D and regional networks dynamics in Dutch pharmaceutical industry. *Journal of Economic and Social Geography* 88, 307–320.
- Wasserman, S., Faust, K., 1994. *Social Network Analysis: Methods and Applications*. Cambridge University Press, Cambridge, UK.
- Williamson, O.E., 1999. Strategy research: governance and competence perspectives. *Strategic Management Journal* 20, 1087–1108.