

Innovation, learning and cluster dynamics

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Abstract

This chapter offers a theory and method for the analysis of the dynamics, i.e. the development, of clusters for innovation. It employs an analysis of three types of embedding: institutional embedding, which is often localized, structural embedding (network structure), and relational embedding (type and strength of ties). The analysis is conducted from a perspective of both competence (learning) and the governance of relational risk, which includes risks of dependence and spillover. It employs results from earlier research in organizational learning and innovation, and in the management of inter-organizational relations. A basic proposition is that innovative clusters face the challenge of combining exploration and exploitation. Hypotheses are specified concerning differences between networks for exploration and exploitation, and concerning combinations and transitions between them. Arguments are presented that in some important respects go against the thesis of the 'strength of weak ties'. Some empirical evidence is presented from recent studies.

key words: innovation, organizational learning, clusters, industrial districts, networks

areas of study: geography, regional science, economics, business, industrial organization, organization

Introduction

This introduction gives some considerations concerning the notion of a cluster, derived from Nooteboom and Klein Woolthuis (2003), and discusses the purpose and approach of this chapter. Cooke and Huggins (2002) defined clusters as follows:

'Geographically proximate firms in vertical and horizontal relationships involving a localized enterprise support infrastructure with shared developmental vision for business growth, based on competition and cooperation in a specific market field'

Apparently, clusters and industrial districts are more or less synonymous. The concept of a network is more general, and does not necessarily entail local embedding, a shared objective, or a specific market. Thus, a cluster is a network but not necessarily vice versa. This chapter focuses on clusters in the context of innovation. Presumably, the notions of 'innovation clusters' and 'regional systems of innovation' are close synonyms.

This chapter focuses on cluster dynamics, i.e. the development of clusters in time. There are three reasons for this. First, dynamics stands high on the scientific research agenda. Often, studies of business systems, networks, inter-firm relations and organizations profess the importance of dynamics but remain stuck in, at best, comparative statics.

A second reason for attention to cluster dynamics derives from the effects of globalization. Recent studies show that the famous Italian industrial districts are becoming locally disembedded, and shift some activities, especially in production, to emerging proximate lower wage countries such as Rumania (Boschma and Lambooy 2002, Zuchella 2003). An escape from local embedding may also be needed for innovation. Oinas and Malecki (2002) proposed that in the study of regional systems of innovation we should recognize the need for linkages outside a region, and it may be better to speak of 'spatial systems of innovation'. 'Embedding' need not always be tied to location, and may also occur in 'communities' that are to some extent virtual, with communication at a distance. This issue of local and other types of embedding is a central theme of the present chapter. It will be argued that processes of innovation and learning have different stages, with different characteristics. In particular, in early development there may be a relatively greater need for local embedding, while later development requires disembedding, as suggested by Asheim and Isaksen (2002). These considerations raise the question whether local embedding and geographical proximity should be retained as defining characteristics of clusters. If they are, we may have to say that in their development clusters are transformed into other types of networks. To avoid this definitional issue, I will speak of innovative networks, rather than clusters, which may or may not be strongly locally embedded.

A third reason for attention to cluster dynamics arises from considerations of public policy. The purpose, structure and performance of clusters are connected with cluster-specific, local conditions, issuing from a history of development. This can yield problems for the transplantation of a successful form from one institutional context to another. A cluster may arise as a compensation for local weaknesses that do not arise elsewhere. The much-lauded development of networks or clusters in Italy can be attributed, at least in part, to a lack of reliable legal institutions, and a climate of corruption. Then there is no opportunity for generalized institutions-based trust, and one has to fall back on personalized trust in specific relations. According to Pagden (1988), in southern Italy this goes back to a systematic breakdown of institutions, in the 18th century, as a deliberate policy of the Spanish Habsburg emperor, ruler of the kingdoms of Naples and Sicily, to prevent coherent opposition and sedition. One should beware of ambitions for a generic blueprint for clusters that can be applied anywhere. Clusters yield solutions to specific problems/opportunities in specific contexts. As a result, public policy, if such policy is viable at all, should probably retreat from the design of cluster structure to the facilitation of processes of cluster development, as a function of local conditions, in 'giving a nudge here and there'¹, to yield triggers or remove obstacles. This requires an understanding of how clusters may develop and adapt to changing internal and external conditions.

¹ This phrase is due to Bo Carlsson, at a seminar at the Erasmus University Rotterdam on 5th December 2003.

Above, reference was made to a few studies that have broached issues of cluster development under globalization and innovation (Asheim and Isaksen 2002, Boschma and Lambooy 2002, Oinas and Malecki 2002, Zuchella 2003). The purpose of the present chapter is to proceed along those lines. The plan for the present chapter has three major elements, as follows.

First, this chapter proposes that clusters, or innovation networks, entail three kinds of embedding: *institutional embedding*, which often but not necessarily entails local embedding, *structural embedding* and *relational embedding*. The first derives from geography. The second derives from the social network literature. Structural features of networks are size (number of participants or ‘nodes’), density (actual number of direct ties between nodes as a ratio of the maximum possible number), centrality (of which there are several forms), and stability of structure (rate of entry and exit). Relational embedding appears in the social network literature in the notion of the ‘strength of ties’, but is developed in more detail in the literature on alliances or inter-organizational relations (IOR’s). As a result, an adequate understanding of clusters requires a combination of geography, social networks and inter-organizational relations.

Second, it is proposed that for an adequate understanding of clusters, we need to combine *competence and governance perspectives*, as advocated by Williamson (1999) and Nooteboom (1999, 2004b). The former focuses on innovation and learning, the latter on the governance of relational risk. Theories of competence are (or should be) based on theory of knowledge, learning and innovation. Theories of governance typically include elements of transaction cost economics (TCE, Williamson 1975, 1985), particularly the notion of relation-specific investments that cause dependence and ‘hold-up risk’, and instruments for governance such as contracts, mutual dependence, hostages, and intermediaries (in ‘trilateral governance’). In the integration with competence perspectives, we go beyond TCE, to include effects of innovation, learning and trust. Some instruments of governance derive from relational embedding (mutual dependence), some from structural embedding (reputation, go-betweens), and some from institutional embedding (contracts). Trust may be based on both institutional embedding (values and norms of behaviour) and relational embedding (personalized trust). Next to hold-up risk, there is spillover risk: the risk that others adopt one’s knowledge for competition. Spillover may be direct, to partners one is directly connected to, or indirect, via partners to competitors. This depends on network structure. Spillover also depends on relational embedding, i.e. the strength of ties (in terms of mutual openness and understanding).

Admittedly, it is quite a conceptual investment to take all this on board, in the analysis of clusters, but the claim here is that this has to be done, because competence and governance have different, sometimes contradictory implications for the three types of embedding. For example, while for learning (competence) ties may need to be extended and locally disembodied, for governance local embedding may be needed for trust, on the basis of local reputation mechanisms and thick social relations. Strong ties may be good for governance but bad for learning (competence), as argued in the hypothesis of the ‘strength of weak ties’ (Granovetter 1973, Burt 1992).

Third, for an analysis of cluster dynamics, this chapter employs insights from the literature on innovation and learning, in particular the distinction between *exploitation* and *exploration* (Holland 1975, March 1991). Exploitation refers to the efficient employment of current assets, including intangible assets such as capabilities, while exploration refers to the development of new capabilities. Innovation typically starts with exploration and then moves on to exploitation.

On the basis of all these elements of theory, this chapter addresses the following three key questions:

1. What different requirements do exploitation and exploration have concerning the three types of embedding, i.e. institutions, network structure, and strength of ties? Here, the chapter builds on, but also modifies and extends, insights from the social network literature, and employs results from Gilsing (2003) and Nooteboom and Gilsing (2003).
2. How does exploration arise from exploitation, and how does exploration lead on to exploitation? Here, use is made of a ‘theory of discovery’ developed by Nooteboom (2000).
3. What implications do transitions between exploitation and exploration have for the three types of embedding, from a perspective of both competence and governance? What shifts occur in the parameters of institutions, network structure and strength of ties?

The chapter proceeds as follows. First, it discusses, in more detail, the notions of competence and governance. Since here competence refers to innovation and learning, its discussion will entail a summary of the underlying theory of knowledge. Second, to answer question 2, a summary is given of Nooteboom's (2000) 'theory of discovery'. Third, a proposal is discussed for the different dimensions of tie strength, adopted from Bogenrieder and Nooteboom (2004) and Nooteboom and Gilsing (2003). This provides the basis for hypotheses to answer question 1, derived from Nooteboom and Gilsing (2003). Finally, and here lies the novelty of this chapter, hypotheses are formulated to answer question 3.

Competence

Diversity is a crucial condition for learning and innovation, to produce Schumpeterian 'novel combinations', as demonstrated, in particular, in evolutionary economics (Nelson and Winter 1982). Diversity is associated with the number of agents (people, firms) who are involved in a process of learning or innovation by interaction. Next to the number of agents involved, a second dimension of diversity is the degree to which their knowledge and skills are different. This entails the notion of *cognitive distance* (Nooteboom 1992, 1999), which is based on a *constructivist* and *situated action* view of cognition. Note that here cognition is seen in a broad sense, including not only rational evaluation but also emotion-laden value judgements, and heuristics of attribution, inference and decision making that we know from social psychology (Kahneman et. al. 1982, Bazerman 1998). Constructivism entails that while knowledge directs action, it is also (re)constructed from action. Hence the terms 'experiential learning' (Kolb 1984) and 'activity theory' (Blackler 1995). This goes back to the work of Vygotsky (1962), and Piaget (1970, 1974). According to Piaget, perception, interpretation, understanding and value judgment entail 'assimilation' (Piaget) into cognitive structures developed from previous experience, but in the process there is an 'accommodation' of those structures. Existing cognitive structures constitute *absorptive capacity*. On the level of organizations, this was recognized by Cohen and Levinthal (1990). Here, absorptive capacity includes organizational capabilities to assimilate information, internally distribute it, and implement knowledge in design, development, production and marketing. It depends, among other things, on R&D. Situated action entails that knowledge and meaning are embedded in specific contexts of action, which yield background knowledge, as part of absorptive capacity, which cannot be fully articulated, and always retains a 'tacit dimension' (Polanyi 1962). Generalized knowledge, in lessons abstracted from situated action, always entails some loss of knowledge and meaning. When such generalized knowledge is applied, it is disambiguated and augmented with features of the specific context of application, and is shifted in the process. As a result general, context-independent, formalized, i.e. fully articulated, 'canonical' rules cannot cover the richness, i.e. complexity and variability, of specific action contexts, as recognized in the literature on *communities of practice* (Brown and Duguid 1996, Lave and Wenger 1991).

The constructivist view of knowledge entails cognitive distance between people: to the extent that they have developed their cognitive structures in different action contexts, they will think (perceive, interpret, explain, evaluate) differently. The task of organizations then is to sufficiently reduce such distance, in an organizational *focus*, including epistemic as well as moral categories, to enable the achievement of joint purpose (Nooteboom 1992, 2000). Note the difference between crossing and reducing cognitive distance. It is the difference between *empathy* and *identification*. Empathy entails the ability to understand, in so far as needed for effective communication, what others say and do, and identification entails commonality of thought, with shared mental categories. Organizational focus is closely related to organizational absorptive capacity. It not only enables but also constrains organizational cognition, yielding organizational myopia, which needs to be compensated by engaging in outside relations with other organizations, with different, complementary foci, at some cognitive distance. This yields a new purpose for inter-organizational alliances, next to the usual considerations, known from the alliance literature (Nooteboom 1999). Firms need to make a trade-off between organizational identity and wide scope of internal competencies. A wide scope, with a wide focus, entails limited identity. A limited scope, with a narrow focus and stronger identity, can be compensated by alliances. It is proposed that this trade-off is more fundamental than transaction costs for determining the boundaries of a firm.

This notion of organization as a *focusing device* connects with the notion of organizational culture as being founded on fundamental ‘basic assumptions’ (Schein 1985), or basic cognitive categories, concerning man, nature, knowledge, and relations between them. Note that such cognitive categories serve for guiding cognition in the narrow, epistemic sense of attention, perception, and interpretation, but also for setting behavioural values, in a moral order, to facilitate collaboration, constrain opportunism, build trust, and limit and resolve conflicts of interest (governance). Such categories tend to be internalized, to a greater or lesser extent, by people, as part of tacit knowledge, assimilated in socialization and habituation.

The notion of organization as a focusing device may have implications for the notion of a cluster. Perhaps a defining characteristic of a cluster is that it, also, entails a shared culture with corresponding cognitive focus, in an epistemic and moral order. This is certainly facilitated by local embedding and geographical proximity, but those may not be necessary. Perhaps there is a viable and fruitful combination of geographical distance complemented by frequent meetings to build and maintain the shared focus.

In processes of learning and innovation, in interaction between firms, cognitive distance, now in terms of difference in organizational focus, yields both an opportunity and a problem. The opportunity lies in diversity: the novelty value of a relation increases with cognitive distance. However, mutual understanding (absorptive capacity) decreases with cognitive distance. If learning performance from interaction is the mathematical product of novelty value and understandability, the result is an inverse-U shaped relation with cognitive distance. Optimal cognitive distance lies at the maximum of the curve. One can increase mutual understanding, but this entails an investment that may be largely or partially specific to a relation, so that by the logic of transaction cost theory the relation would need to last sufficiently long to make that investment worth while. Later, this will yield one of the arguments why especially in exploration, where knowledge is new and understanding cannot be taken for granted, ties require some strength, in the sense of investment in mutual understanding, and that relations must last sufficiently long to recoup that investment. Between firms, mutual identification increases, from whatever point they started, and cognitive distance is reduced, to the extent that they have engaged in continued interaction, especially when that interaction was exclusive. In other words, their foci start to overlap, in a shared epistemological and normative framework. This reduces the novelty value of a partner’s cognition, with a reduction of the performance of learning. This suggests that while familiarity breeds trust (Gulati 1995), it may also reduce learning potential, so that for the purpose of learning ties should not be too strong in terms of duration. In sum, next to optimal cognitive distance there is also something like an optimal duration of ties for learning: long enough to build mutual understanding and trust, but not so long as to run out of steam for learning. Empirical evidence for the hypotheses of optimal cognitive distance and optimal duration is presented in Wuyts et. al. (2003).

The analysis has implications for clusters. Too durable, local embedding, particularly when it is cut off from outside contacts, may reduce cognitive distance too much. It may be good for trust but bad for learning.

Governance

Governance entails the management of relational risk. Here, the focus is on risks of lock-in and spillover. In relational embedding, risk of lock-in includes the ‘hold-up’ risk from TCE. That is relevant here for several reasons, one of which is that it has implications for the intensity of a tie, in terms of its duration and frequency of interaction. Hold-up risk results from dependence as a result of relation-specific investments, defined as investments that have value only (or largely) in a specific relation. This yields switching costs: when the relation breaks, the investments have to be made anew in a new relation. For such investments to be made, the relation should be expected to last sufficiently long, and be sufficiently intensive, in frequent interaction, to recoup specific investments. Lock-in yields a temptation for the partner to expropriate value, in opportunistic behaviour. Lock-in may also arise from structural embedding. Here one is locked into a community by (threat of) constraining coalitions of members of the community, and the need to maintain social legitimacy. There might also be network-specific investments, which can be used within but not outside the network. For specific investments we include the usual types, offered by TCE: location specificity of facilities, physical

asset specificity (installations, tools, instruments), human asset specificity (training), dedicated capacity, brand name specificity, and time specificity. In the current context of learning, we add specific investments in absorptive capacity, for mutual understanding, and in building up relation-specific trust. Investment in mutual understanding is important, in particular, under conditions of exploration, in the emergence of unfamiliar, new, and often highly tacit knowledge. Lock-in may also arise from institutional embedding. Here, one is locked into local obligations of loyalty and conformity, and lack of cognitive distance, in ‘group think’. Cluster-specific investments may arise in finding out ‘who is who’ in the network, getting embedded in local reputation systems and social foundations of trust, and gaining social legitimacy.

Linkages with other actors yield access to variety of knowledge, but, by the same token, also a risk of spillover. This is the risk that knowledge that is part of one’s ‘core competence’, which constitutes competitive advantage, may be used in competition, either by a direct contact (relational embedding), or indirectly, elsewhere in the network, through a sequence of direct contacts (structural embedding). Note that this risk therefore depends on density of the network. Thus, density has both a potential advantage of knowledge access, and a potential disadvantage of spillover. Note that the assessment of spillover risk requires a trade-off between knowledge adopted by others and knowledge gained from them. The risk is potentially serious only when there is a net loss rather than gain. The risk of spillover also depends on how tacit or documented knowledge is, with the latter spilling over more easily than the former. It also depends on the absorptive capacity of potential competitors, i.e. their ability to effectively understand and implement knowledge spillovers. That depends on the ‘cognitive distance’ between actors, i.e. differences in their ability to perceive, understand and evaluate relevant phenomena. Finally, spillover risk depends on the speed with which knowledge changes: if it is obsolete by the time it has spilled over and has been absorbed and imitated by potential competitors, spillover risk drops out (Nooteboom 1999).

Relational risks require governance to limit them and to create trust. Counter to TCE (Williamson, 1993), we hold that trust can go beyond calculative self-interest, in loyalty and *benevolence*, and yet be viable in markets, although we acknowledge that such trust should not be unconditional, and is subject to limits (Nooteboom 2002). In the notion of trust, we need to distinguish between ‘competence trust’, in the ability of people and firms to satisfy expectations, and ‘intentional trust’, in the commitment of people to perform to the best of their abilities, and not to engage in opportunistic behaviour. A survey of instruments for the governance of intentional risk, as ‘sources of collaboration’, is given in Table 1. Here, a distinction is made between macro and micro, and between self-interested and other-directed sources of collaboration.

 Table 1 about here

The distinction between macro and micro sources of collaboration, in Table 1, is also known as the distinction between ‘universalistic’ or ‘generalized’ sources versus ‘particularistic’ sources, made by Deutsch (1973: 55), and between impersonal and personalized sources made by Shapiro (1987). The first arise from institutional embedding, in laws, norms, values, standards, and agencies for their enforcement. This yields ‘institution-based trust’. This kind of trust requires that we trust those institutions to support trustworthiness of people and organizations. They also arise from structural embedding, in opportunities for coalitions and in reputation mechanisms. The ‘micro’ sources arise in specific relations, in relational embedding, and are often personalized.

The table further distinguishes between self-interested and altruistic or ‘other-directed’ sources of co-operation. The self-interested sources are associated with the notions of deterrence and ‘calculus-based trust’ (McAllister 1995, Lewicki and Bunker 1996). In the present reconstruction, this includes *opportunity control* and *incentive control* (Nooteboom 1999). Opportunity control entails that the space of feasible action is constrained. Incentive control affects the choice of opportunities, in the space of feasible actions. This corresponds with notions of power as limiting or enabling a repertoire of possible actions, and as affecting the choice of actions from that repertoire. Within organizations, opportunity control entails control by hierarchy, and in inter-firm relations it entails control by contract. Contracts are only useful to the extent that one is able to adequately specify them and monitor conformance to them.

Even under the best of institutional conditions, legal ordering cannot be closed, including all relevant future contingencies, to carry their implications to the present ('presentation') and cover them in the contract (Macneil 1980). This is problematic especially in innovation, with its unknowable future contingencies of contract execution. Also, in exploration knowledge is likely to be highly tacit, which would also inhibit the specification of contracts. In incentive control, partner B behaves well towards A because he is dependent on A for one or more of the following reasons: A has a unique, difficult to replace value to B, B faces switching costs as a result of relation-specific investments, partner A holds a hostage from B, or B has to protect his reputation. Large size and density of a network enhance reputation mechanisms. This is especially important when contracts are not feasible, as in innovation. The notion of hostage is also taken from TCE. In business, hostages often take the form of information or knowledge that is sensitive, in the sense that it could cause great damage when leaked to competitors. It can also take the form of cross-participation, or the borrowing of staff, with the threat of poaching them.

Now we turn to the other-directed sources of collaboration, in trust that goes beyond calculative self-interest. On the macro level, they lie in established, socially inculcated norms and values (macro). They include pressures of allegiance to groups one belongs to, and values and norms inculcated by socialization into those groups. Of course, one can never be sure *ex ante* to what extent a stranger without reputation has actually internalized such norms and values. Here, Williamson (1993) was right in saying that under such conditions of behavioural uncertainty one must take the possibility of opportunism into account. However, that does not automatically imply that one should always go for control by deterrence, in opportunity and incentive control, even if they are feasible and effective. On the micro level of specific relationships, trust may be based on empathy. This entails that one knows and understands how partners think and feel. It is connected with mutual openness, and acceptance of control by others, which are crucial for the build-up of trust (Zand 1972). While trust can go beyond calculative self-interest, it has, and should have, limits. Empathy allows one to assess strengths and weaknesses in competence and intentions, to determine limits of trustworthiness under different conditions. Identification-based trust goes further: it entails that people think and feel in the same way, sharing views of the world and norms of behaviour. This may lead to affect- and friendship-based trust. Routine-based trust, proposed by Nooteboom (1999), entails that when a relation has been satisfactory for a while, awareness of opportunities of opportunism, for oneself and for the partner, is relegated to 'subsidiary awareness' (Polanyi, 1962). One takes the relation for granted and does not continuously think about opportunities to gain extra advantage. As Herbert Simon has taught us long ago, routinized behaviour is rational in view of bounded rationality, since it allows us to focus our limited capacity for attention and rational evaluation on matters that are new and have priority. Routines are rational also in the sense that they are based on proven success in past behaviour. On the other hand, their lack of awareness creates the problem that they may no longer be adequate when conditions change. However, when results or perceived events exceed certain tolerance levels, triggered by emotions routines are often summoned back from subsidiary into focal awareness, to be subjected to rational scrutiny.

Exploration and exploitation

Exploitation, i.e. the efficient employment of current assets and capabilities, is needed to survive in the short term. Exploration, i.e. the development of novel capabilities, is needed to survive in the long term. Thus, to survive in the short and long term, firms must combine the two, somehow. That is a paradoxical task. Exploitation often requires the maintenance of a stable organizational structure, in division of labour, with unambiguous terms and clear standards, in a narrow organizational focus, while exploration requires the reverse: loosening of structure for novel reconfigurations, shifting meanings and deviation from existing standards, in a wide focus.

A key problem is how exploration may be based on experience in exploitation, which is particularly important from the perspective of 'activity theory', according to which learning is based on practice, and yet is able to escape from it. Another problem is how to ensure that the outcome of exploration will be exploitable. How do exploitation and exploration build on each other? What path of development can we think of that maintains exploitation while at the same time yielding exploration? For this, Nooteboom (2000) proposed a heuristic 'cycle of discovery', with several stages, in which there is an alternation of variety of content and variety of context. First, variety of content (of a

concept or practice) that emerges from exploration is reduced, in *consolidation* into a *dominant design*, as suggested in the innovation literature. As a result of reduced uncertainty, demand increases, and new producers jump on the bandwagon. Related industries and existing distribution channels go along, and adapt, from fear of missing the new boat. The new technology/product/market combination develops into a dominant design or 'dominant logic' (Bettis and Prahalad 1995) of organization, including network structure and 'industry recipes' (Spender 1989), with pressures to conform, in 'organizational isomorphism' (DiMaggio and Powell 1983). New entrants exert pressure on price, and for the sake of efficient production increase of scale, division of labour and associated specializations emerge.

So far, this is nothing new. The question now is how one gets away from the dominant designs in technology and organization, in a next (radical) innovation. The proposal is that for exploration that yet maintains exploitation, one next needs to open up to a new variety of contexts of application, in *generalization*. These novel contexts of application may be sought voluntarily, in an expansion of activity. Voluntary new applications of established capabilities appears to be based on an instinctive drive that among psychologists is known as a principle of 'overconfidence'. In economics, there is also a pressure to extend the market, as growth in the original market stagnates. With the entry in new markets, one needs to access wider distribution channels, and there is a need to adapt products and organization, which requires knowledge from outside. Clusters may need MNC's as a vehicle for this reach outside existing boundaries. This is in line with Boschma and Lambooy's (2002) analysis of developments in Italian industrial districts, where they identified the role of MNC's as 'bridging enterprises', to carry activities into international markets and to access outside sources of knowledge, and with Asheim and Isaksen's (2002) analysis of how Norwegian clusters had to make a shift from local to global operations. However, new conditions of market, technology and institutions may also be imposed from outside one's familiar niche. An illustration of this, in the development of multi-media, is that publishers finally went along in digitalization and electronic distribution of text, for fear of losing their position (Gilsing 2003). For clusters, this may arise from an invasion of multinationals. A novel context is needed for three reasons. The first is that established capabilities arose and consolidated in a given niche, and therefore perform well there, and are taken for granted, so that new conditions of technology, demand, infrastructure and institutions are needed to gain new *insights in limits* of validity. The second reason is to build *insight in novel goals and motivation* for change, resulting from such misfits, in the novel context. The third reason is to yield *insight into potential novel content* of practice, for which inspiration is found in the novel context.

First, to maintain exploitation as much as possible, there is an attempt to make minor, incremental adjustments to established practice, in what is called *differentiation*. Insight for this may come from previous experience, in novel selections from familiar repertoires, which are retrieved in an attempt to improve fit in the novel context. Next, when this fails, experiments are conducted with novel elements, adopted from the novel context, which seem to be successful where familiar practice fails, in hybrids of old and new elements, in *reciprocation*. This yields an opening up to new variety of content. The function of this is two-fold. First, it still allows for ongoing exploitation, albeit in new forms. Second, it allows for experimentation with new elements, to test their potential, without sacrificing existing basic design principles. When such potential emerges, there is more willingness to make more radical changes in architecture, when that is needed for the novelty to realize its full potential, in *accommodation*. Here, rigidities of established structures, which may have offered an advantage for exploitation, become a liability. Emerging novelties cannot achieve their potential under the systemic limitations imposed by existing structures, practices and ways of thinking. Thus, a cluster may get locked into its previous success. If the cluster or network is unable to cope with this, it may need to be broken up, so that different elements have more scope to adapt, in different ways, to new conditions. Accommodation, then, leads to a new beginning, under radical uncertainty, in search of novel dominant designs, in consolidation.

In this scheme, one can recognize the principles of evolutionary thinking: consolidation entails selection among novelty, generalization entails transmission, and differentiation, reciprocation and accommodation generate new variety of forms. The latter process of variety generation has been neglected by evolutionary economics and innovation theory, which have taken the generation of novelty as random (by analogy to evolution in biology) or not amenable to explanation. .

The difficulty of combining exploitation and exploration, in differentiation and reciprocation, depends on three structural features of the exploitation system, which determine its rigidity, and which may apply to both firms and clusters:

- a. The *complexity* of division of labour, defined as the *number* of component activities and the *density* of direct ties of dependence between them. Structure is *simple* when complexity is low.
- b. The *modularity* of the system, on the basis of clear and stable constraints on activities, along such ties of dependence, in the form of *standards*, needed to maintain systemic integrity. The opposite would be ambiguity and variability of constraints, by which activities need to be continually coordinated.
- c. The *tightness* of constraints, i.e. the scope for variety in contributions from component activities. Structure is *loose* when tightness is low.

Exploitation is *systemic* when it has features a and b (complex and tight), and *stand-alone* in the opposite case (simple and loose). An example of the first is an oil refinery, and an example of the latter is a consultancy company. In case of feature b (modularity), component activities can be autonomous, and can be replaced, as long as they satisfy the constraints on interfaces in the position they take in the structure. If exploitation entails a systemic structure, simultaneous exploration is constrained by the many and tight constraints on component activities. Exploration would soon yield a breaking of constraints on interfaces, yielding many unknown repercussions in the dense structure of dependencies, such as change of content of linked activities, which may in turn trigger change elsewhere, possibly resulting in wide ranging architectural change (Henderson and Clark 1990). Management would rightly be wary of accepting that risk and cost, unless there were a clear and proven potential of the novelty that would justify them. Then, to combine exploitation and exploration, particularly when exploitation is systemic, there are two options: separation in place and separation in time.

With separation in place, exploration would take place in a part of the structure (firm or cluster) that is de-coupled from exploitation. This is what we find in many organizations, with, typically, a separation between production (exploitation) and R&D. With such separation in place, an organization needs to combine a narrow focus for exploitation with a wide focus for exploration, which may jeopardize its identity as an organization. Then, exploration often requires organizational disintegration: new elements that do not fit in existing structures (of production, organization, market, distribution channels, institutions) need to shield themselves off in a niche where deviation from established structure and process is feasible. In terms of innovation theory: disintegration is needed to allow for the variety needed for Schumpeterian ‘novel combinations’, in ‘creative destruction’. In terms of evolutionary theory: novel species often arise in seclusion from the niche of their parents, in ‘allopatric speciation’ (Nooteboom 2000). This often requires the emergence of new firms, who are not imprisoned in existing structures and interests, or spin-offs from existing firms, which try to escape from such prisons, or ‘external corporate venturing’, where large companies facilitate spin-offs that may be temporary, with the option of later re-integration into the parent company.

Alternatively, firms may specialize in either exploitation or exploration, and seek the other in relations with other firms with complementary specialization. Here, we find separation in place in networks or clusters. A familiar case is the pharmaceutical industry, where small biotech firms explore novel medically active substances, and when those are found large pharmaceutical firms take over for the lengthy process of clinical testing, and efficient large-scale production and distribution.

Separation in time entails that a firm or cluster oscillates between exploitation and exploration, adjusting its structure as it moves from one to the other. Yet another solution is to try and make exploitation more stand-alone, with fewer and looser ties. Here, a cluster that has not gone the way of systemic integration, but has managed to maintain its less systemic structure, is at an advantage, since it offers more flexibility for re-configuration. Here, it matters what options for reconfiguration are at hand. Here, perhaps, we encounter the notion of ‘Jacobs externalities’ (Boschma & Lambooy 2002). In urban regions with a large variety of different activities, and a rich, varied, complex infrastructure, with a wide scope of spillovers, new ideas, and activities that become complementary in new ways, there is more scope for new exploration.

The analysis yields the following hypothesis for cluster dynamics. Innovation clusters start with exploration, with flexible, loose, informal, locally embedded ties, and then develop towards exploitation, with more durable, tight and locally disembedded ties, and subsequently have to break or loosen up again for novel exploration. However, this hypothesis is rather general and loose, and will now be developed in more detail and with more precision, in terms of network structure and strength of ties.

Features of embedding

What features of embedding are relevant, from the perspective of both competence and governance, for an analysis of differences between networks for exploitation and exploration? First, we turn to network structure, in *structural embedding*. From a perspective of competence, recall that cognitive diversity has two dimensions: the number of cognitive entities and connections in a network (variety), and cognitive distances in the connections. The first is determined by the *size* and *density* of the network. Note that high size and density allow for more access to different sources of information, but by the same token also increase possibilities of spillover. A third feature of network structure is network *stability*, which has implications for how variety develops in time, in entry and exit of new members. High stability may be good for mutual trust and efficiency of exploitation, but bad for exploration. Another well-known feature of structure is *centrality*, of which there are several types. Here, we focus on degree centrality, which is the degree to which some nodes have more direct ties than other nodes do. An extreme case of centrality is a hub-and-spoke structure. Centrality may be needed for the coordination of activities. A central position yields power, but possibly also constraints on behaviour, in view of the many possibly divergent interests it is involved in (Krackhardt 1999), and in its task of centralized coordination it may suffer from information overload. In view of the latter, structure may need to be hierarchical. From a perspective of governance, size and density affect possibilities of lock-in by coalitions, reputation mechanisms, and shared norms of ethical behaviour. Next, we turn to tie strength, in *relational embedding*. Here, building on Bogenrieder and Nooteboom (2004) and Nooteboom and Gilsing (2004), seven dimensions are proposed. The first four arise from considerations of competence and the last three from considerations of governance.

1. *scope*, defined as the range of activities involved in the tie. Does it involve only knowledge on the location and relevance of knowledge, anywhere in the network, or also the actual exchange or joint production of new knowledge (cf. Hansen 1999)? Does it involve knowledge only on a small number of issues, or on a wider range of issues, concerning technology, markets, organization, and reputation of players in the network?
2. *investment in mutual understanding*, needed to build mutual understanding, for crossing cognitive distance. To the extent that this investment takes time and is specific, ties need to entail sufficient
3. *frequency* and/or
4. *duration* of interaction.

While investment, frequency and duration facilitate learning, they also facilitate spillover. As argued earlier, long duration of a tie may lead to identification, which enhances mutual understanding and trust, but may reduce learning potential, particularly if the tie is exclusive, i.e. in the areas of collaboration (scope) there are no direct ties with others.

From the perspective of governance, ties require instruments for the management of relational risk of lock-in and spillover, specified in Table 1. This yields the following three dimensions of tie strength:

5. *opportunity control*, by contract
6. *incentive control*, by mutual dependence, reputation or hostages.
7. *trust and mutual openness*, beyond control.

All dimensions of governance depend on *institutional embedding*. Contracts depend on the availability of a legal infrastructure of laws and non-corrupt judiciary and police. Reputation depends not only on the structure of the network, but also on other social groups that facilitate gossip. As indicated in Table

1, trust may be relation-specific, on the basis of empathy, identification, affect and routinization, but also taps into shared values and norms, in a given community. Both reputation and trust depend on forms of social capital such as professional and industry associations, clubs, and the like. Such institutions as well as personal acquaintances may fulfil roles of go-betweens. As noted before, local embedding may be needed more for governance than for competence. Trustworthiness of (potential) partners may be attributed not only from experience in transactions, but also from chance meetings and observations in a rich variety of social settings that are most readily available in local embedding.

Networks for exploration and exploitation

Differences between networks for exploration and networks for exploitation may now be specified in terms of these features of embedding. First we turn to network structure, and subsequently to the strength of ties.

In networks for exploration, there is uncertainty concerning future dominant designs, in both technology and organization, which yields structural uncertainty concerning the configuration of future networks for exploitation. One needs access to actors who might offer complementary knowledge, but one does not know what elements of knowledge will turn out to be relevant when a dominant design develops. Also, one does not know what actors will survive by that time. Therefore, the network has to be *dense*. Later, it will be argued that dense structure is also needed for a reputation mechanism. Here, we start to diverge from the thesis of the ‘strength of weak ties’ proposed by Granovetter (1973) and Burt (1992), according to which structure should not be dense, and ties should be weak. They assumed, implicitly, that one knows:

1. What knowledge will be relevant
2. Who has what knowledge
3. Who will survive to provide direct or indirect knowledge

And that:

4. One is able to absorb that knowledge

In exploration, however, one does not yet have such knowledge and absorptive capacity, and therefore one has to hedge relational bets. One does not yet know what ties will turn out to be redundant, since one does not know who will develop what knowledge and what the configuration of relevant elements of knowledge will be. One has to maintain direct linkages even if they may later turn out to be redundant, to keep options of access open, covering for the risk that some ties will drop out and thereby eliminate indirect access to other sources. Even if a tie is already known to be redundant for access to a known source of knowledge, it may be needed to assess, understand and absorb that knowledge. More precisely, if A remains linked to both B and C, even if there is also a link between B and C, this may help A to understand C by comparing what A understands from C with what B understands from C. In other words, a dense structure enables firms to ‘triangulate’ among their multiple sources and thus better assess their value, and to better absorb knowledge from them. Nooteboom (1999) identified several further roles for third parties or ‘go-betweens’ that will not be discussed here.

The argument against redundant relations, from Granovetter and Burt, was that their set-up and maintenance yield excess costs. However, relevant costs are only those of relation-specific investments in mutual understanding, since other, more generic investment would be useful also in other ties. In exploration, in contrast with exploitation, specific investments other than in mutual understanding are often limited in size, in activities such as prototyping rather than large outlays for efficient production, marketing, distribution, and servicing. Furthermore, in exploration costs are less of an issue, since competition focuses on form, in connecting complementary competencies in the fast development of prototypes, rather than on the price of a ready product, as in exploitation. In sum, we need a careful trade-off between costs and benefits of redundancy. In exploration:

- the relation-specific costs of setting up and maintaining ties may not be high, or at least not as high as in exploitation,
- such costs may not have priority,
- and redundancy may be needed to hedge structural bets,

- bets on knowledge content,
- for triangulating knowledge content and reliability, and
- for aiding the absorption of knowledge.

To maintain the variety of cognition needed for exploration, network *stability* is expected to be generally low, allowing for entry and exit. Exploration is facilitated by volatility of interaction, allowing for chance meetings, to discover interesting potential partners. Here, local embedding may be needed for reasons of competence. Under conditions of radical innovation, with uncertainty concerning what elements will emerge and survive in what configuration, *centrality* is likely to be low, especially in stand-alone technology. Centrality might yield an obstacle, from attempts to maintain the power invested in an established centralized position.

Now we turn to the strength of ties. In exploration, uncertainty is diffuse and wide ranging, so that interaction entails many issues, including technology, organization and perhaps also future market demand, the availability of competent suppliers and so on, and as a result ties tend to be strong in the dimension of *scope*. It was already noted above that building mutual understanding might require a *relation-specific investment*, which requires sufficient *frequency of interaction* and/or *duration*, to make such investment worthwhile. However, since knowledge changes fast, in exploration, the economic life of the investment is short, so that it should be recouped in a short time, in frequent contacts, and duration, though it should be sufficient, *need* not be long. How long duration should be depends, among other things, on the size of specific investment for mutual understanding, which depends on the depth and level of specialization of knowledge, and the degree to which it is tacit. Duration *should* not be too long, for two reasons. The first reason is that it would prevent novel architectures of configurations. This is particularly relevant under systemic conditions, where innovation often takes the form of frequent and rapid architectural change. Here, one might think of the car industry, for example. The second reason is that too durable relations may yield identification that goes so far, in an excess of familiarity, as to reduce innovative potential. However, this depends on how exclusive the relation is. If A and B have a tie, on a certain subject, and both A and B also have other ties, on the same subject, to different nodes, apparently unafraid of spill-over risks, then their mutual value as sources of knowledge may be replenished from those outside contacts, so that a long duration does not necessarily kill learning potential.

From a governance perspective, in exploration the use of *opportunity control* by contracts tends to be problematic. In exploration much knowledge is tacit, which complicates the specification of contracts. Uncertainty about contingencies, even in the very near future, may also preclude their detailed specification. Since change is rapid, the content of contracts would have to change frequently, which makes them less cost-effective. In view of new and not yet dispersed knowledge, it would be difficult to monitor and assess conformance to contracts. In exploration, governance is likely to be based on *incentive control*, with a balance of mutual dependence, hostages in the form of sensitive information, a reputation mechanism, and/or on *trust and mutual openness*. A reputation mechanism is especially strong here, in view of the uncertainty about possible future configurations of relations. Since it is impossible to assess who may and who may not in the future yield an important connection, one has to be careful in *all* relations. The point now is that a reputation mechanism requires *density* of relations, and is facilitated by *institutional embedding*. The institutional basis for trust typically lies in professional values, norms, and standards, guarded by professional associations, which also play an important role in reputation mechanisms. Typically, in exploration trust initially is competence trust, in professional knowledge and skill, and this establishes a basis for intentional trust to develop, on the basis of pre-existing professional empathy. Here we find a second argument for *frequency* of interaction, as needed for the build-up of trust, in empathy, identification and routinization (Table 1). Such relation-specific, personalized trust entails, and requires a great deal of *mutual openness* (Zand 1972). It is known from the trust literature that trust is stimulated by mutual dependence. When one cannot do without each other, one simply has to develop trust in collaboration. As indicated, in exploration such mutual need is high, to search for complementary knowledge, in the race for a viable prototype.

In sum, the hypothesis is that in exploration ties tend to be strong in terms of scope, frequency and trust/mutual openness, of some strength in terms of relation-specific investments, depending on the complexity and tacitness of knowledge, and some duration, depending on how systemic the

technology is. They are generally not strong in control, and duration should be limited, particularly when relations are exclusive.

A potential problem now is that density of the network, investment in mutual understanding, frequency of interaction, and trust and openness may yield a high risk of spillover. However, at this stage, in exploration, with large uncertainty on what dominant design will emerge, and to what products it will lead, in what markets, knowledge often is 'pre-competitive', so that spillover risk may be limited. Also, it may be difficult to assess who will in future turn out to be a potential competitor. Restricting relations for fear of spillover would soon entail no relations at all. Finally, knowledge may change so fast as to eliminate serious spillover risk. Another potential danger is that the network becomes too tight and stable, with too durable relations between members of an in-crowd, in a tight 'clan' (Ouchi 1980), which reduces diversity in terms of both people involved and cognitive distance, and yields stagnation. To counter this, as discussed above, ties should not last too long, especially when technology is systemic and innovation is frequent and architectural, and network stability should not be large, offering a certain volatility of network membership, for the sake of novel combinations. This is where the thesis of the strength of weak ties comes into its own.

At several points, the analysis has implications for local embedding. In particular, while reputation mechanisms, instability and volatility of network structure, wide scope of communication, frequency of interaction, and trust could all occur at a geographical distance, they are greatly facilitated by proximity and local embedding.

By hypothesis, in a network for exploitation, conditions are more or less the reverse of those that apply to a network for exploration. First we turn to network structure. Dominant designs have emerged, and technological and market uncertainty have decreased. Knowledge becomes more codified and stable, absorptive capacity increases, and knowledge gets widely diffused. With new entry into the emerging market, competition shifts to competition on price, so that considerations of efficiency become crucial. These pressures on cost yield a need to:

- utilise economies of scale, and this can be achieved because due to decreased uncertainty on the part of customers the market has enlarged. As a result, there is increase of scale, a shakeout of producers, and resulting concentration.
- search more widely for the cheapest sources of supply, which is enabled by reduction of uncertainty and emerging standards. Thus there are both needs and opportunities to loosen activities from their local embedding and to extend the network beyond old boundaries.
- Eliminate redundant ties, which is now possible due to increased certainty about network structure, the location and relevance of knowledge, and the ability to absorb it.

Thus there is a requirement for a less *dense* structure, which is enabled by the fact that now one can identify what competencies are and will remain relevant, who has those competencies, and who is likely to survive in the industry, and there is less need for redundant ties to triangulate knowledge and help in its absorption. Due to the extension of the network, reduction of cognitive distance, codification of knowledge, and slow-down of knowledge change, spillover risk increases. Due to diffusion of knowledge and stabilization of the network, routinization of established practice, and the emergence of standards, interaction becomes less intensive and shifts from developmental to transactional. The increased codification of knowledge furthers diffusion without the need for relation-specific investments in mutual understanding. Investments shift to large-scale production, distribution systems, and brand name, which are all long-term, and increase in size and economic life. In view of such large and often sunk investments, with a long economic life, and to maintain efficient division of labour, network structure is likely to be *stable*. Under systemic conditions, exploitation may require considerable *centrality*.

Concerning the strength of ties, implications of these investments for the *duration* of ties depend on the extent to which they are *relation-specific investments*, which depends on the flexibility of technology: more generic or flexible technology entails that investments are less relation-specific. In increased division of labour for the sake of efficiency, there is an increase in specialization, so that ties entail more specific knowledge, on a narrower *scope* of issues. There is less need for relation-specific trust, and a basis arises for institution-based trust. Reduced uncertainty and codified, diffused knowledge on a more narrow range of issues enable the specification of contracts and the monitoring of compliance, entailing a shift from *trust* and *incentive control* to *opportunity control*. Increased specialization, reduced scope and reduced need for trust reduce *frequency* of interaction, i.e.

interaction in the exchange or joint production of new knowledge (purely in terms of transactions, there may be very frequent ‘just-in-time’ deliveries from suppliers).

In exploitation, the extended reach of the network, into new markets of outputs and inputs, more formality of control, and lesser dependence on reputation mechanisms and trust, entail both opportunities and pressures for local disembedding.

The hypotheses for different conditions for networks for exploration and exploitation are summarized in Table 2.

Table 2 about here

Within these categories of exploration and exploitation, there is still considerable variability of parameters, particularly in exploitation, as a function of contingencies of technology, market, and institutions: systemic/stand-alone, tacitness of knowledge, speed of knowledge change, flexibility of technology, economic life of investments, economies of scale, entry barriers, legal institutions, institutions for trust, etc. These vary with both industry and location. This explains some of the variability and limited universality of cluster structure and performance mentioned in the introduction to this chapter.

Conclusions for cluster dynamics

The analysis already indicated transitions from exploration to exploitation. Here, cluster dynamics is analysed in more detail. According to the ‘cycle of discovery’, discussed above, exploitation emerges from exploration, on the basis of consolidation, and exploration arises from exploitation, in generalization, differentiation, reciprocation and accommodation. As noted before, there are two structural forms for combining exploration and exploitation: separation in time and separation in place. In separation in place, there is an ongoing transfer of activities from exploration networks to exploitation networks. An example is the pharmaceutical industry, where Gilsing (2003) found the following structure. Biotech firms take up an intermediary position, straddling exploration networks with universities and networks with pharmaceutical companies for the transfer from exploration to exploitation. On the whole, their ties with universities conformed to the characteristics of exploration networks, and their ties with pharma companies conformed to the characteristics of exploitation networks. For a summary, see Nooteboom and Gilsing (2004). In the exploration network of universities-biotech, Gilsing found high network density, high frequency of interaction, and high specific investment in mutual understanding. However, counter to expectations, he found that ties were fairly strong in control, quite strong in duration, and weak in scope. This deviated from expectations, but could be explained on the basis of the underlying logic, as follows. While knowledge in the *process* of conducting scientific research is highly tacit, the knowledge *output* that was exchanged between players was highly codified, which opened opportunities for contracting. In contrast with the development and commercial use of technology, scientific research is much less concerned with issues of organization, production, commercialization and distribution, so that scope could be low. Long duration of ties was understandable from the fact that mutual understanding required high specific investment, but still appeared to yield a problem of insufficient flexibility and variability, for the sake of novel combinations. However, it turned out that a core network of durable relations in the Netherlands was complemented with a periphery of more variable ties to universities abroad. Note that in the theoretical analysis durable ties were seen to be problematic for exploration only if they are also exclusive. Durable ties need not limit the diversity needed for learning if the nodes involved tap into non-overlapping outside sources, in shorter and more variable ties. In other words, here we find a hybrid network, with a core and a periphery that have compensating strengths and weaknesses.

Perhaps this finding can be generalized, as follows. If a core network of stable relations is needed, for exploitation, or to recoup large specific investments, or to build and maintain trust, the potentially negative effects for exploration may be eliminated by tacking on a peripheral network that feeds the

core network with diversity. There may be a lesson here for clusters, to maintain local embedding while tapping into outside sources of diversity.

Now we turn to separation in time, with transformations from exploration to exploitation networks, and back again. In his study of the emergence of multi-media, in the Netherlands, Gilsing (2003) found a fairly clear case of the transformation from an exploration network to an exploitation network. However, in the transition there was an intermediate stage, which did indeed show decreased density, increased stability, ties beyond the original local setting, increased centrality, decreased scope, and some increase of contractual control, as hypothesized, but still found considerable trust and frequency of interaction. This could be explained by the fact that the provision of new web-based information services still needed considerable fine-tuning of mutual fit, in a systemic coherence of elements of the overall system (hard-ware, software and content).

The transformation between exploration and exploitation is not always so easy. How difficult it may be depends on the extent to which old systems of exploitation have to be maintained, and how systemic they are. Let us analyze in more detail how transitions along the cycle of discovery might take place. In the stage of consolidation, we expect a transition from exploration to exploitation networks, summed up as follows. In network structure a reduction of density, in the elimination of redundant ties, emergence of centrality for the sake of coordinating specialized production activities, and increasing stability, to maintain systemic structures of production. Concerning strength of ties, scope would decrease, in division of labour and specialization, duration would increase, to ensure stability and the recouping of increased and more durable specific investments, frequency of knowledge exchange would decrease, as a result of standardization, contractual control would increase, due to reduced uncertainty, and trust would decrease, due to more arms-length contacts and extension of the network beyond local boundaries, in search of a widened market and cheapest sources of inputs. Next, in the stage of generalization and attendant differentiation, in new contexts of application, the expectation is that the core exploitation network in the home niche is complemented with a peripheral network that taps into novel contexts. This entails a reduction of centrality, reduced stability, and increased size of the total network. We would expect emerging features of exploration in the peripheral network, and increased frequency of interaction throughout the network, to cope with increasing problems of coordination between centre and periphery.

Next, in the stage of reciprocation, we expect that the overall network begins to loosen up in loosely coupled parts, and may break up altogether. A crucial contingency here is the extent to which the old exploitation system needs to be maintained along with exploration, and the extent to which it is systemic. In the multi-media case studied by Gilsing (2003), technology was systemic, but development occurred outside the old exploitation system. At the periphery, structure becomes dense, and new investments are required for local understanding, in new niches. Local commitment, at the periphery, may exceed loyalty to the centre. Stability decreases further, ties become weaker in control, and need to become stronger in trust, locally and between centre and periphery. If that is not feasible, in the maintenance of the old exploitation structure, the network is likely to break up, in a separation between core and periphery, to allow for allopatric speciation.

Finally, in accommodation, novel opportunities begin to prove their worth, new networks are formed, and move towards consolidation. Existing networks, in the old centre, come under pressure, and may have to break up, to go along with emerging novel dominant designs.

Note that in both separation in place and separation in time we may meet hybrid networks, with a relatively stable and tight core and a looser peripheral network. In fact, as described, the process of transformation from exploitation networks to exploration networks may entail a break-up and separation in place. It is very difficult, though not inconceivable, to accomplish separation in time while maintaining the overall network, due to contradictions in the combination of a narrow focus with a wide focus and the corresponding mix of incongruent organizational cultures, stability and instability, formal control with informal trust, short and durable ties, in local embedding and outside linkages.

The implications for public cluster policy are problematic. Overall, the perspective for such policy seems dubious. Policies appropriate for one stage of cluster development may be opposite to those for another stage. For example, in an early stage of exploration one may need to help 'allopatric speciation', by facilitating spin-offs, shielding embryonic novel ventures from the competitive power of established dominant designs, and allowing for and indeed stimulating locally embedded support.

After consolidation one may need to shift policy towards the stimulation and facilitation of local disembedding and outside reach. When new radical innovation arises from outside, one may need to encourage the break-up of localized clusters, and to eliminate entry barriers, to allow for novel architectures of old and new components. If this is the case, then timing of policy is of the essence, and policies may turn out to be counterproductive by the time they reach execution.

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Table 1 Sources of collaboration

	macro; universalistic	micro; particularistic, relation-specific
self-interest		
opportunity control	contracts, legal enforcement	hierarchy, managerial 'fiat',
incentive control	reputation	dependence: unique partner value, switching costs, hostages
altruism		
benevolence	values, social norms of proper conduct,, moral obligation, sense of duty, bonds of kinship	empathy, routinisation, identification, affect, friendship

source: adapted from Nooteboom (2002)

Table 2 Networks for exploration and exploitation

network features	exploration	exploitation
network structure:		
density	high	low
stability	low	high
centrality	low	often high
strength of ties:		
scope	wide	narrow
investment in mutual understanding	high	low
duration	limited*	often long
frequency of interaction	high	low
opportunity control	low	high
incentive control	medium to high	low to medium
trust/openness	high	generally low

* especially when technology is systemic

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