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Competency rallying for technical innovation—The case of the *Virtuelle Fabrik*

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Abstract

Technology improves at an ever-increasing rate, but the speed at which firms can adapt their strategies and competencies to develop technological innovations and exploit market opportunities remains limited. While networks provide an option to increase agility through collaborative access to relevant external competencies, we know little about systematically managing such networks. This paper identifies a collaborative network process that we label competency rallying. We describe the set of inter-organizational routines involved in competency rallying in a case study of the interactions among the partners of the *Virtuelle Fabrik*, a case of an organized regional network in the manufacturing industry in Switzerland. We describe competency rallying as the (1) identification and development of competencies, (2) identification and facing of market opportunities, (3) marshalling of competencies, and (4) short-term cooperative effort for technological innovation and commercialization. The paper contributes a model that furthers the understanding of the organizational character of networks based on specific, learned network capabilities and which allows prediction of the likelihood of success of practical collaboration projects in networked organizations.

Keywords: Innovation routines; Dynamic capabilities; Cluster; Networks; Regional innovation system; Virtual organizations

1. Introduction

Technology-based firms face environments changing at an increasingly rapid pace. Market opportunities for innovations in particular can arise and disappear again in a short time (Ahmed et al., 1996). But the speed with which organizations can adapt to strategic changes that are associated with innovations remains limited (Suikki et al., 2006). This situation, where the environment changes more rapidly than organizations can adapt, has been labeled a "turbulent environment" (Brown and Eisenhardt, 1997). Under such conditions, time constraints make it impossible for firms to adopt appropriate organizational structures and develop operational routines to ensure performance for each change in the market (Suikki et al., 2006). However, this rapid change does not mean that competencies inside the firm are no longer a source of competitive advantage. In contrast, especially for short-term market opportunities, valuable competencies can be a basis for monopolies, as they take too long for competitors to develop (often a decade or more following; Prahalad and Hamel, 1990). But the unpredictable nature of market opportunities at the same time increases the risk that necessary competencies for a desired market innovation may be missing and that existing internal competencies become irrelevant or outdated. In short, turbulent environments paradoxically make appropriate strategies and competencies simultaneously more important, yet seemingly less attainable for a firm.

Neither the concept of collaboration nor the concept of capability, however, is conceptually confined to firm-level analysis. More for historical than conceptual reasons, firms have often been regarded as islands of collaboration in a sea of competitive market transactions. The quest for more network-level analysis has only more recently been voiced for innovation phenomena (Linton, 2002; Saxenian, 1991). We argue that such an analysis offers an answer to the

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apparent paradox described above. Specifically, we suggest that in turbulent environments, virtual organizations can act as "switchboards" (Mowshowitz, 1997) that can quickly "assemble," from a network of firms, a new combination of competencies to meet innovative project needs. Some researchers have suggested that information systems are sufficient as a basis for such assembly (Miles et al., 2000). For example, when ordering a product online, a specific resource combination is brought together in split second for each individual customer, to produce the product, to insure transport risks and guarantees, effect the payment, ship it and so forth. Market mechanisms, embedded in web-based platforms like eBay, make such rapid reconfiguration possible. In this view, rather than organizing for flexibility within the individual firm, agility is a feature that is provided on the (computer) network level.

Innovation, however, normally requires more collaborative effort of users, producers and product development teams (Hippel, 2005) than can be provided by market transactions for readily available and tradable products and services. Still, providing agility for innovation on an organizational network level, rather than the individual firm level, seems appealing. How then might such more intensive relationships be managed?

The initial thesis of the paper is that networks and their evolution can be described in terms of their systematic collaboration capabilities, which correlate with the likelihood of successful innovation projects. On one side, there is support for the premise that organizational capabilities increase the likelihood that collaborative projects happen (Kale et al., 2002; Lambe et al., 2002; Ritter and Gemünden, 2003). On the other side, it has been observed that successful collaborative projects contribute to the success of alliances (Kale et al., 2002; Anand and Khanna, 2000). On this bi-directional correlation we base our assumption that over time networks evolve through a process of building network capabilities from the experience of successful cooperation projects. Or in the words of Miles et al. (2000), we assume collaboration to be a meta-capability for innovation, not only inside the firm, but for networks as well.

The contribution of this paper is an in-depth description of a set of network capabilities for collaboration that we label "competency rallying." We use the term "rallying," meaning, "to rapidly reunite for concentrated effort" (British Academy, 1971), to describe the organizational process of structuring the project and bringing together for temporary cooperation a network of firms with the competencies needed to satisfy a newly identified innovation opportunity. We describe the process of competency rallying in four phases, with distinct collaboration routines: competency creation, market facing, competency marshalling, and cooperative effort. We base our description of this process on an in-depth case study of the manufacturing network *Virtuelle Fabrik* in Switzerland, in which a recurring pattern of successful design and manufacture of products by the *Virtuelle Fabrik* showed the successful performance of the four sets of organizational activities. While the (desired) effect of networks is little questioned in literature, in this paper we advance implementation knowledge, which remains less understood (Linton, 2002). For researchers, we develop candidate descriptions of the collaboration routines, which we suggest are transferable and which can be empirically studied in future research in other settings. For practitioners, we intend to contribute necessary elements, "best-practice" examples, for the functioning of an innovation network, so that its performance can be measured and actions can be directed to its implementation or improvement.

The remainder of the paper is structured as follows. In the next section we present the research setting and the research methodology, which is followed by an extensive description of the four competency-rallying routines of the *Virtuelle Fabrik* network. We complete the paper with a discussion of the findings, final conclusions, and direction for future research.

2. Literature review

Aspects of the competence-rallying process—from the recognition of a market opportunity to value creation—have been discussed before, of course, and these prior discussions provide some of the building blocks for our theorizing. In this section, we briefly discuss relevant prior work that applies to the process as a whole. (Additional research that relates to specific aspects of the process will be discussed as each phase is introduced.) An example of the competence-rallying process can be seen in the industrial district of Prato in Italy, in which many small textile manufacturing firms specialize in various aspects of textile and apparel production, such as weaving, dying, sewing, etc. These small companies are not readily able to identify worldwide customers, nor do they offer a complete range of desired services. Instead, merchants, called *impannatores*, provide access to the highly volatile fashion market opportunities for the entire industrial district and temporarily bring together numerous small companies to fill the requirements for each particular contract. In this paper we go beyond identifying entrepreneurs as actors to develop a more explicit description of what they do and how they do it.

Such a regional collaboration for innovation resembles project management, but in an inter-organizational setting, innovation activities are systematically organized to achieve concrete assignments to teams with defined budget and time limits. While the internal operation of projects has been well studied in project management literature, we focus here on projects as the home of learning for the organizations—and in our cases the networks—in which they are embedded, much in the sense of the learning organization (Senge, 1990). In this view, projects are not only engines to achieve the concrete assignment but as well contribute to the evolution of the network and its competencies (Watanabe and Hobo, 2004). Projects are interesting study objects to understand network dynamics because they are observable milestones in an evolutionary process: projects make use of competences and at the same time learning in projects has an impact on what Prahalad and Hamel (1990) define as the development of competencies, from their use and reuse in many different markets and contexts. However, as Suikki et al. (2006) conclude for managerial implications, and Cullen (2000) for legal or contractual structures, more research is needed to capture the dynamic and evolutionary character of networks.

One way in understanding and predicting the evolutionary dynamics of networks is through the analysis of the managerial service available to them to manage innovation and change (Penrose, 1968). In contrast to technical competencies, more recently the term dynamic capabilities has been used to describe organizational capabilities that allow reconfiguring of capabilities and other resources (Teece et al., 1997; Eisenhardt and Martin, 2000). Dynamic capabilities are strategically relevant in changing environments and impact business success. Suikki et al. (2006), for example, have observed how organizationally embedded project management competencies on the firm level impacted the success of Nokia in its turbulent environment (the telecommunications industry). Eisenhardt and Martin (2000), in their review article, formulated the strategic benefit of such organizational capability on firm level and argued that they actually are useful research objects that offer potential for generalization across a broad range of specific settings. They called for further empirical research into the nature of such dynamic capabilities and suggested adopting existing knowledge from other disciplines, like the above mentioned project management. We therefore propose that competence rallying is a type of dynamic capability. It is not limited to firm boundaries and can as well be addressed as an inter-organizational routine of coordinated activities in networks.

3. Research setting and methodology

In this section we describe the design and execution of our research study, addressing in turn research site selection, data collection and data analysis.

3.1. Research setting

The research setting for our study is the *Virtuelle Fabrik* network, a virtual organization started in 1996 as a network development project (a cooperation between the network members and university researchers) in two adjacent regions of Lake Constance and the Swiss Midlands. In 2007 these networks are still operating as two separate ongoing collaborative enterprises. This site was chosen as an illuminating case site for our research, for several reasons. First, the network engages in the recurring creation of short-term projects for the development of a new technology product from a relatively stable evolving regional network of firms. The networks routinely create technological innovations by engineering and manufacturing new products. Members of these virtual organizations (ranging from small and medium enterprises to production divisions of large multi-nationals, as shown in Table 1) have cooperatively produced dozens of products, from simple parts of a complex module for a letter-sorting machine to entire products like the litter shark, a city dustbin for which the Swiss Midlands network was awarded the prestigious Swiss innovation award "Idea Swiss" in 2004. Table 2 presents several examples of products worked on by the *Virtuelle Fabrik* and a brief description of the way competencies from the partner firms were rallied for these technological innovations.

Table 1
Examples of members of the Virtuelle Fabrik

Network Northwest Switzerland (www.Virtuelle-Fabrik.ch)
3M (Switzerland) AG
Brüco AG
Qua design Partner AG
Sika (Switzerland) AG
Wyser AG
… total 18 partners
Network Lake Constance (www.vfeb.ch)
Alwo-SMA AG
Bühler AG
Intellion AG
Pantec Engineering AG
SULZER INNOTEC
… total 17 partners

Second, characteristics of the network resemble previously studied situations, providing connections to the literature. Because of its regional orientation in the upper Rhine Valley around Lake Constance or the Swiss Midlands between Zürich and Bern, the setting shows cluster or industrial district characteristics as described in economic research (Piore and Sabel, 1984). Internally the network uses trust and contracts as complementary governance elements, which Blomqvist et al. (2005) identified as essential for technology collaborations. Besides geographical collocation in a Swiss region, the setting shows a technology regime (Guerrieri and Pietrobelli, 2004) because the *Virtuelle Fabrik* has a focus on mechanical engineering and manufacturing and with this develops international links. Apart from the achievement of individual projects, the main motivation for participants to collaborate in this setting is similar to the motivation of increased flexibility for innovation alliances that Kumar and Snavely (2004) identified or the agility motivation (Goldman et al., 1995) for virtual organizations. With the cited project examples, the *Virtuelle Fabrik* is a worthwhile research setting that fulfills a critical success factor of "regional material cycles for operative economy and regional value creation" (Gerstlberger, 2004). Over time, the *Virtuelle Fabrik* network learned and improved not only its technical competencies but as well its organizational capability to identify opportunities for new projects, to create, and

Table 2
Examples of manufacturing projects worked on by the *Virtuelle Fabrik*

Manufacturing project	Description of product	Description of competency rallying
1. Mechanism to electrically retract a car steering wheel	The mechanism targets a market of less than 10,000 items a year and is therefore not interesting to auto suppliers used to lot sizes of hundreds of thousands. It is technically challenging, as it has to meet safety standards of auto industry at competitive manufacturing cost	The network was prepared to face such opportunities, responding within 2 days to the customer request. To marshal the best competencies, ten potential technologies were identified. In a co operative effort with the customer, engineering changes were implemented and prototypes manufactured
2. Large precision base for machine tool	The base was a 20-mm sheet metal, roughly 1 m × 1.5 m in size. More than 300 holes were needed for the assembly of all mechanisms of the machine tool. Placement of the holes defined the machine's precision. The base was too big for most manufacturers' equipment	Alternative technologies such as drilling, laser drilling, and water drilling were identified and compared. Marshalling of a large dimension tool machine, on which the piece could be machined in one fixing. Value created was quality improvement (because of one fixing), and 75% cost reduction
3. Module for a letter-sorting machine	The manufacturing of a module of an industrial postal letter sorting machines that was fully engineered. To meet short delivery deadlines, the manufacturer needed additional manufacturing capacity. The module was structured in mechanical and electrical sub-assemblies, and painted sheet metal as the cover and stand	Competencies from the network, e.g. controller manufacturing for textile machines, and sheet metal manufacturing and painting from furniture industry were marshaled for the customer project. A short-term cooperative effort undertaken with the customer to achieve a frictionless integration of mechanical and electrical sub-systems of the module
4. Air-conditioning unit	The concept of an air-conditioning unit, fitting a demand niche in the upper range of the market was engineered and manufactured as a project lasting about 2 years	During a presentation of the Virtuelle Fabrik an engineer in the audience revealed having a product concept and asked the necessary competencies to be marshaled from the network. On stage, project members analyzed the idea and proposed an initial architecture of contributions from three partners. Business was agreed, in a cooperative effort with the customer the unit was engineered, prototyped, and 50 copies manufactured after 18 months
5. Re-engineering stability of a large sun-umbrella	Finite element simulation competency of an engineering firm in the network was used to improve wind stability of large restaurant umbrellas marketed by a textile manufacturer	The network was prepared to face market opportunities from outside its companies' core businesses. The network's brokers channeled a customer request from textile industry to highly specialized competencies available in a firm from the mechanical industry
6. Litter shark	City litter boxes with specific design quality and features like explosives	Rapid reaction to WTO conform call for tender of an industrial designer and a manufacturer. Conversion of the initial project into a growing international business

complete them. To study the antecedents of this apparent phenomenon of innovation agility, we distinguished distinct stages in the process of creating and entrepreneurial execution of technology projects across a network of cooperating firms (Poole and van de Ven, 1989).

3.2. Data collection

The evidence guiding our descriptions of and inferences about the process of competency rallying stems from a longitudinal study of the *Virtuelle Fabrik* over a period of 10 years. The researchers conducted over 100 semi-structured interviews with personnel from member companies on a regular basis. Interviewees included company directors, and managers and employees involved in in- and outsourcing at all levels and departments (e.g., production, finance, quality inspections, industrial engineering, and purchasing). Further evidence was collected from attendance at and participation in network meetings, and analysis of network development plans, project observations, and formal reports. By using multiple sources of evidence, findings were triangulated to improve our confidence in their reliability. External concept validity was tested in feedback sessions with *Virtuelle Fabrik* participants. The data from the various modes of data collection are summarized in Table 3.

3.3. Data analysis

Because our goal was developing theory, for data analysis we followed the general approach of grounded theory (Glaser and Strauss, 1967; Eisenhardt, 1989), which has been used successfully in innovation research (Burgelmann, 1991; Leonard-Barton, 1995; Brown and Eisenhardt, 1997), in order to develop a relatively full description of management routines involved in competency rallying in a specific

Table 3
Examples of evidence supporting the proposed process theory of competency rallying in the Virtuelle Fabrik

Process stage	I. Competency identification and development	II. Identification of markets	III. Marshalling of competencies	IV. Cooperative effort
Definition	Partners bring competencies to the network, where experience working with network partners leads to enhancement and co-specialization	Managers look for opportunities to use their competencies outside the primary business of their firm	Managers seek cooperation from companies with competencies needed for a market opportunity	Multiple companies contribute to solving a customer's problem
Type of data				
Semi-structured interviews	Several companies classified their machining resources as A, B, and C. C was complementary functions to be outsourced to the network, indicating increasing focus on competencies	Marketing was expressed to be a general weakness of manufacturing firms in the network during the network development, providing a focus for further developments	Industry cycles in non-related businesses such as mail systems, cereal machines, textile machinery, tool machinery or packaging machines proved anti-cyclic, so sharing competencies was felt to be feasible	Analysis of in- and outsourcing processes revealed duplicate functions, high number of organizational units involved. Partners developed new processes to reduce the overhead
Virtuelle Fabrik development plans	Goal of year 1996 plan was: "bringing together critical mass of competencies" Goal 1 of year 2000 plan was to "develop a methodology to describe competencies as marketable technology services"	Goal 2 of year 2000 plan was: "develop marketing instruments for manufacturing competencies on the level of the partner firm and on the network level"	The Virtuelle Fabrik mission statement is "to develop the competency to cooperate for market opportunities that individual companies cannot (or only to lesser extent) exploit on their own"	Strategy change, from the initial focus on creating market mechanisms as the cooperation mechanism, to designing a web-collaboration platform as of year 1998
Partner observations from meetings and projects	All companies presented their manufacturing capabilities and organized visits to their shop floors before they were accepted into the network	Brokers for the network were assigned to bring an agreed workload to the network Marketing concepts were made for individual companies, sub-networks and the network as a whole	To manufacture an electric retraction mechanism for car steering wheels ten alternative technologies were evaluated to select the most economic one, an example of competency marshalling	A test order bounced back and forth between different departments until it was dropped, indicating an inability to cooperate on a short-term project, and a problem to be addressed by the partners
Results of network developer actions	A partner tested the supply of cog machining from the network. Reliability of supply in the network added to the decision to dis-invest its own, underutilized resources for cog production, an example of focusing on competencies	The foreman of a painting shop from a project member firm learned about the Virtuelle Fabrik and took a job painting windows to fill idle capacity, showing that the project resulted in a shift in mind set	A set of procedural guidelines to marshal competencies were developed in the network including "specification of customer orders," "cost calculation," and the "selection of partners"	Communication and cooperation skills of individuals improved for direct communication between engineers, operations managers, and workers
Observation of manufacturing projects	A comparison of grinding supplied by two expert firms in the network revealed cost differences for the job and led to distinguishing their competencies by part size and manufacturing tolerance	An engineering firm specialized in finite-element simulation of machine parts took over the simulation of wind stability of umbrellas for a textile firm A grain mill manufacturer supplied parts to the auto-industry	Learning in the years 1996–1998 reduced standard response time for identifying the right partners for a customer project reduced to 1 day	Coordination cost among the network partners in the beginning caused about 30% higher prices. Learning reduced coordination cost to competitive levels as of 1999
Informal discussions	Using network competencies was characterized as having a "jogging effect" on the shop floor Reluctance of workers and low motivation from difficulties with "alien" jobs from the Virtuelle Fabrik took about 2 years (until 1999) to overcome. Afterwards, participants acknowledged the training effect	The saying "opportunities are like train rolling through the station. To catch a train you need to practice jumping on trains, not to build new stations"	Ongoing mutual visits of managers to mutually learn about the characteristics of their shop floor were reported Many experiments in cooperative manufacturing are undertaken among the network firms	A regular social event was created, usually a joint dinner in a restaurant. Without a pre-defined program the, "virtual dinner" allowed partners to develop "a take 'n give culture"
Presentation by others	Repeatedly business journal articles on the project were given with the headlines like "Firms concentrate on their core-competencies" Asked why he approached the network with his project, a customer said, "looking at the impressive list of competencies in the flyer, it would be stupid not to inquire about it"	Industrial partners indicate the benefit as: "The Virtuelle Fabrik project opens new markets for firms. We came to an order that we couldn't have imagined before"	Some headlines of business reports: ● "the network builds a customized factory for each customer problem." ● "the factory, which does not exist" ● "temporary unite"	A TV report on the project draws on the football referee metaphor to explain that strong rules are needed for cooperation Business News headline: "partnership in new dimensions"

setting. The primary data analysis approach was content analysis of the texts from interviews and observation to develop insights on the process of development of manufacturing projects among the partner firms. To understand the nature of the dynamics capabilities in the network, we sought to identify recurrent pattern of managerial behavior and decision making, which developed as a process model. Our analysis identifies recurring pattern of behavior that characterize the nature of the process but which are reinterpreted for each occasion. Such patterns are concrete in that they are observable across different specific contexts (Eisenhardt and Martin, 2000), stable over time, and recurring in the configuration, reconfiguration, and deployment of the network's resources for innovation projects. However, such patterns may also evolve over time and therefore require process type of theories that capture the time dimension more easily than variance or factor theories. Processes therefore provide a concrete object of analysis for a phenomenon, which cuts through different levels of traditional analysis, because individuals, teams and firms concurrently collaborate in a network setting (Barnard, 1938; van de Ven and Poole, 2006).

Such process-oriented research is characterized by multi-level analysis interchanging the unit of analysis from individual technology projects to the network level of the case site (van de Ven and Poole, 2006). By comparing the process of multiple projects, regularities in the occurrence of events could be induced. Al so, the process evolved during the course of the network development, providing further opportunities for comparison between projects undertaken early and late in the development, with more or less developed network processes. This description suggests further research that could be carried out in other settings to develop a more general theory of competence rallying.

4. A process model of competency rallying

In this section, we present two examples of projects in the framework of our model of competency rallying (competency creation, market facing, competency marshalling, and cooperative effort), followed by a more detailed discussion of the individual stages. First, a brief history of the development of a city dustbin, nicknamed the "litter shark," illustrates the stages of innovation in the network. The history of this project begins in 2001, when the industrial designer Mr. Zemp approached Mr. Strebel, CEO of the small firm Brüco (which specialized in 19-in computer racks), to make a dust bin prototype in reply to a call for tender by the City of Zürich. We describe this entrepreneurial activity as an example of *market facing* to exploit a short-term opportunity. To carry out the project, Mr. Zemp second *marshaled competencies* from the network to produce the prototype (by marshalling we mean, "to arrange things in an appropriate order so that they can be used effectively" (British Academy, 1971)). Within a week, they submitted the optimized application. Third, Brüco as a producer engaged in a joint *short-term cooperative effort*, which was necessary to successfully meet the short-term deadlines of this market opportunity. Such rapid cooperation was not spontaneous but, fourth, based on the stable cooperation of the firms in network, which allowed them to continuously develop their individual technical competencies and competitive strategies as well as their capabilities to cooperate for short-term opportunities. The entrepreneurs were selected and further invested in improvements during the tender process, resulting in the award of the Zürich contract, the first of many, making "litter shark" an enduring commercial success.

A second example project was to engineer and build the electric retraction device for a car steering wheel. The manufacturing project started when Ivo Bigger, CEO of Wiftech, one of the network member firms, was approached by a customer and asked if they could provide the part. Wiftech itself did not have the capacity to build the part, but rather than directly declining the request, Ivo Bigger offered instead to take the project to the network, again an example of *facing a market opportunity*. Such market facing required active involvement on the side of the firms and would have been impossible for Wiftech without its participation in the network. Wiftech passed the project on to a project leader from another firm, with whom they were acquainted from various network meetings. A project leader was appointed and 10 different technologies from 10 different firms in the network were evaluated for technological feasibility and for their cost, in an effort to design the part, an example of *marshalling competencies*.

While 10 companies were involved in the search for a technical solution, only three were involved in designing and manufacturing the first prototypes. The joint work of these companies at this stage is an example of a *short-term cooperative effort*. Final production required different partners, as the order quantities involved did not fit the one-of-a-kind manufacturing philosophy of the prototype manufacturers for which the project team was reconfigured from within the network. This project was the first successful complex project in the network after several years of network collaboration and experience from multiple smaller projects, which points to the fact that short-term and project-level success can only be understood by understanding long-term and network-level processes. For the project, the network made use of its multiple mechanical engineering and manufacturing competencies and through the engineering effort and the comparison of the 10 technologies in the project the network members learnt more about the network's competencies. The chosen technology, for example, was semi-fluid aluminum injection molding, a self-developed highly specific technology developed by one of the partners. Through this project, the other partners learned about it and its comparative strength and constraints,

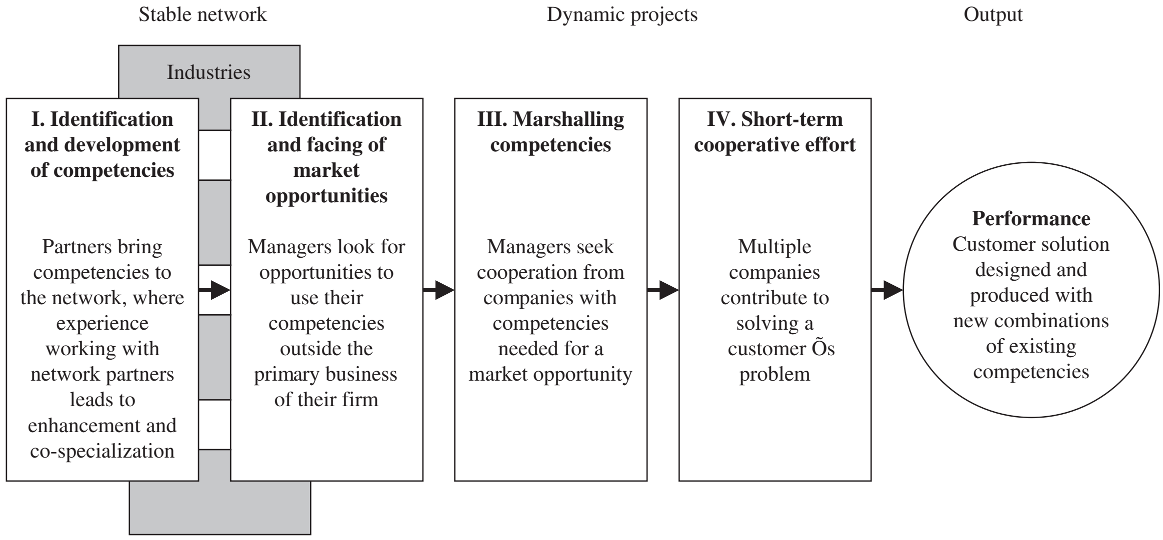

Fig. 1. A process model of competency rallying. The first two stages are carried out in all member firms drawn from multiple industries (represented by gray boxes); the final two stages are carried out for the specific projects identified in Stage II.

illustrating the importance of the *identification and development of competencies*.

In the remainder of this section, we present in more detail the four sets of activities involved in the process and the evidence for each, including the evolution of the understanding of the routines during the course of the network development. We also discuss connections for each set of activities to prior research. For the purposes of this paper, we present these activities as linear and distinct stages of the process of competency rallying, as shown in Fig. 1. We present the process in this way because it fits our data reasonably well and because it provides a simple and analytically useful framework for the explanation of the process. This is not to mean that the process requires a sequential execution of phases because the stages show different time frames and different levels of analysis, which is typical for process theories (van de Ven and Poole, 2006).

4.1. Stage I: identification and development of competencies

A first necessary condition for agility and flexibility through a process of rallying competencies is an ongoing process of competence evolution within the network. But time-pacing of this process proved very long term in the case of *Virtuelle Fabrik*, where it took more than 5 years to yield sufficient maturity levels for the successful completion of complex projects. In contrast to the individual projects, this process is not event driven but of evolutionary nature.

Through the course of the development of the *Virtuelle Fabrik* network, the conception of competencies gradually evolved and the relevant managerial scope expanded from projects to partner firms and the network. Initially, the view was quite limited on physical resources: the original goal of the network development was to increase machine utilization, so resources were machines. Descriptions of these machines across the industries were based on the generally accepted classification scheme and terminology from the DIN 8580 standard, which defines all machining operations. Defining resources in this way makes direct comparison possible, which initially led to the expectation that an electronic market for machining capacity could be created across business or industry boundaries. But experiences from collaborative projects soon led to a rethinking of the meaning of resources. For example, two member companies considered themselves experts in grinding in their respective industries, but when they compared their performance, they discovered that one was much cheaper, a fact the companies could not have discovered through benchmarking only within their own industry. This discovery led to a revision in thinking about resources. Rather than viewing them as undifferentiated commodities (e.g., tools or machines), the view shifted instead to competencies: something one firm was better at doing than others. The second, more expensive company was forced to reconsider its competencies, and determined that they lay in grinding smaller-sized parts and to more precise tolerances, which made them more expensive in the particular case, but able to do work that the other firm could not.

Participation in collaborative projects proved to be a driver for the identification and development of competencies in the *Virtuelle Fabrik*, which in turn contributed to further development of competencies within the partner firms. This development occurred because workers within the companies faced requirements from a range of different industries and customer projects, which stretched their existing skills. Managers began to refer to this stretch as the "jogging effect," meaning that the small amount of time they spent manufacturing for the network led to an increase in the fitness of the firm. These experiences also revealed that competencies were not solely linked to machine tools but included competencies to design and engineer complete customer solutions and technological innovations. Examples included assembly, quality inspection and testing, project management, and certification for ISO conformity. Unlike simple machining operations, the competencies discovered in this way were to a great extent intangible. As there were no generally accepted definitions (such as DIN 8580) the development of the network correlated with the development of a shared understanding of the nature of competencies offered by partner firms (Rycroft and Kash, 2004).

As well as within individual member companies, competencies were developed at the level of the *Virtuelle Fabrik* network as a whole. These competencies cannot be localized in one of the member firms because they emerged "in between firms." For example, from successful experiences with initial joint manufacturing projects, stable subnetworks of partners emerged that as a group proved to have competencies for applications for the litter shark, for medical technology, or precision machinery. In this way the network contributed to cospecialization of the partners (Ritter and Gemünden, 2003). Indeed, a few firms decided to give up certain technologies for which they found reliable partners in the network and to concentrate on other competencies that proved to be competitive over a wider range of industries.

In summary, agility and flexibility of networks as the *Virtuelle Fabrik* is observable from external factors, that indicate competence identification and development routines, such as the availability of explicitly profiled competencies and the rate of their reuse in collaborative projects. In combination with the degree of achieved cospecialization these factors indicate the maturity of the network. The number of technical development projects and activities to develop shared understanding within the network indicates learning and development routines of the network. Externally observable as well is the rate of reuse in the number of different industries, as represented by the gray boxes in Fig. 1, which can serve as indicators for search routines to exploit the competencies (Meyer et al., 1997).

The *Virtuelle Fabrik* case demonstrates that competence identification and development routines are contingent on the innovation rate and technical uncertainty of the environment in which the network is operating. Initially, manufacturing resources in the network were handled as well definable as commodities that are tradable in electronic markets, which indeed seems more suitable for markets with high demand uncertainty but limited product innovation. In the course of the network evolution, competencies were rather viewed as problem solving capabilities, which seem more geared to the networks markets with high technical uncertainty and product innovation but lead to the evolution of a different network routine configuration.

4.2. *Stage II: identification and facing of market opportunities*

The second phase in our model is facing of market opportunities. Entrepreneurs like Ivo Bigger or Werner Zemp of the *Virtuelle Fabrik* provided member firms with market opportunities beyond their core businesses and industries, again as indicated symbolically by the gray boxes in Fig. 1. But in contrast to the evolutionary character of competence development, this process is sporadic or event driven. Along the lines of Guerrieri and Pietrobelli's (2004) concept of technology regimes, such opportunities are a known success factor for innovation, but as one participant in the *Virtuelle Fabrik* network put it: "*opportunities do not present themselves neatly labeled as such*."

Explicit market-facing activities emerged only after some time in the *Virtuelle Fabrik* network. The initial focus in the network development was on collaboration in manufacturing projects, which in the first 2 years were carried out primarily for partners from inside the network. Some manufacturing projects had served external customers, but these usually occurred by chance or were initiated by the customer. However, experience and early successes with solving tricky engineering issues showed that the *Virtuelle Fabrik* could actually better perform for products that were not fully specified. To take advantage of this capability, the network started to present itself under the name *Virtuelle Fabrik* in trade fairs and later with its own website (www.virtuelleFabrik.ch). During one of the earlier presentations, a product developer challenged the network's claim of engineering competence by presenting the requirements for a medical air-conditioning unit. The network members reacted publicly with a proposal during the conference and the unit was indeed engineered and later manufactured.

The conception of identifying and facing market opportunities evolved in the course of the network development. Initially, the understanding was simply market orientation (Kohli and Jaworski, 1990) and market access, an important element in other networks, such as Prato, where companies are not equally situated in terms of access to profitable opportunities. Later, with cases like the litter shark, it became apparent that innovative market opportunities do not present themselves neatly labeled as such. Instead, such opportunities were created through sustained entrepreneurial effort (Penrose, 1968), both on the level of the partner firms as well as on the level of the network. As a consequence, market facing was increasingly seen as an event-driven process but one with a long-term time horizon.

Such market-facing capabilities were particularly limited for the partners in the *Virtuelle Fabrik*, who were either internally oriented engineering or production departments, or small and medium-sized firms, where highly specialized management resources are particularly scarce, making the development of market facing an important development for the network. Inspired by the success of the air-conditioning unit, the network engaged in marketing their engineering and production competencies. For example, purchasing criteria were identified that could be used to signal the uniqueness and the buyer value of competencies from the *Virtuelle Fabrik*. A number of target segments and sub-networks of firms were created to plan for growth of businesses. Exposure to new business opportunities raised awareness of market facing among the involved managers, and a saying became common among them:

> Market opportunities are like trains that run again and again through the station. To catch the train, you have to practice jumping on trains, not construct new stations.

In summary, agility and flexibility through market facing was observable in the *Virtuelle Fabrik* from external indicators, such as the rate of new project leads generated from within and—more importantly—from outside the network. While the rate of recurring business from one domain indicates focus on growth of business, the rate of experimental projects from new industries and application domains indicated agility and ability of renewal of the network. More generally, successful networks can be expected to strike a balance between the two. Other observable factors are the undertaken effort of developing a coherent message for the network, and the actions undertaken to signal to outside world through trade fair participation, websites and so on.

Experience from the *Virtuelle Fabrik* demonstrates that a balance between experimental and recurrent business in the networks can be expected to be contingent on business and general industry cycles. At the end of business life cycles, or when the industry is generally in recession periods, the number of different industries in which the network is active can be expected to grow, which indicates a search for potential value of exploiting the competencies (Meyer et al., 1997). In contrast, focus on a limited number of more promising businesses should be more successful in periods of growth.

4.3. Stage III: marshalling competencies

The third stage of our model is marshalling of competencies to meet an identified opportunity. For its partners and customers, the core idea of the *Virtuelle Fabrik* network is the ability to adapt to turbulent environments with a quick combination and recombination of the most suitable competencies for a particular market opportunity. In order to meet this need, members of the *Virtuelle Fabrik* developed organizational routines for *marshalling competencies*, that is, for determining which competencies from which partner companies were best suited to satisfy a specific customer's need, to launch projects, and to do so in short time. In the evolution of the *Virtuelle Fabrik* network, this process was increasingly structured into linear phases with clear milestones.

In the first years of its development, the network mainly focused on learning this marshalling capability. This effort was clearly successful: after about 3 years, for one project, one company's engineering department (in cooperation with a team from the network) outperformed the company's own marketing department, which they later discovered had produced an independent bid. Initial activities in *Virtuelle Fabrik* were based on literature, suggesting that markets would be an efficient means of allocating resources, avoiding hierarchical overhead or central management. These activities were guided by Miles and Snow (1986) suggestion of market mechanisms, based on information systems that reveal the status of potential trading partner (a so-called full-disclosure system) and predictions of increased use of market mechanisms based on transaction cost economic analyses (Malone et al., 1987). Following these prescriptions, a "Technology Capacity Bourse" was developed in the early days of the network, that is, a database that contained descriptions of the machine tools available in each of the member companies. The goal of the system was to reduce the cost of searching for partners and specifying competencies.

In the end, and in contrast to findings by Pitt et al. (2006) in the Swedish BioTech Industry, the database in the Technology Capacity Bourse was regarded more as a means to establish a first contact (yellow pages), but an attempt to include real-time capacity information to automate competencies marshalling failed. Project members voiced the feeling that they were not prepared to make sourcing decisions for engineering and innovation solely based on information from a database. This was especially true for many of the intangible competencies developed in the network that could not be described as succinctly and unambiguously as the physical resources (e.g., engineering or integration competencies) where trust and shared experience dominated.

The *Virtuelle Fabrik* turned instead toward making organizational routines explicit. In joint sessions, the early experiences of manufacturing projects, and especially problematic situations were discussed, reflected, and turned into explicit complementary roles that the network felt essential for successful projects. They called one first role "broker," who, like Werner Zemp, represents the business idea and interface to the customer, second role as a "competence manager" for engineering judgment on risks, feasibility of the work, and how it can be divided amongst partners so that the contributions can later be integrated. The third role was called an "in-/outsourcing manager" with decision-making entitlement for each potential partner, similar to what Kodama (2007) describes as boundary spanner for the Matsuhita case, and a "virtual project manager" with skills to plan and coordinate the cooperation. Finally an "auditor" role was specified for financial arbitrage and as the sixth role a "coach," for conflict management (Katzy and Schuh, 1998). These roles clearly had inter-organizational character as they are shared and interchangeable: one partner firm might fill different roles (or even multiple roles) for different manufacturing projects, as long as it was clear who was responsible for a role and all were filled. Also there were, frequent informal social contacts, such as the "virtual dinner," a regularly scheduled social event, and mutual site visits to form what some have called a knowledge market (Davenport and Prusak, 1997) or transactive memory (Brandon and Hollingshead, 2004).

In summary, competency marshalling is the most immediate contribution to agility and flexibility. Its performance is observable from the time that it takes, which in the case of *Virtuelle Fabrik* decreased from initially several weeks to only hours and days after some years of experience. The frequency of project starts quantitatively indicates successful marshalling of competences, while variance in cooperation partners between different projects indicates the maturity of involving a broad range of competencies from the network. The ease and frequency with which competencies are marshaled for experimental or innovative projects can serve as an indicator for the ability of the network to develop and engineer new architectures of products or delivery.

Experience from the *Virtuelle Fabrik* demonstrates that competency-marshalling routines are again contingent on the technical uncertainty in the projects. The lower this uncertainty, both on the side of the competencies needed and on the architecture or configuration of the product, the more suitable electronic markets seem to be. The higher the technical uncertainty, the more relevant problem-solving competencies become, which leads to the observed different configuration of competency-marshalling routines in the network.

4.4. Stage IV: short-term cooperative effort

When the focus of the *Virtuelle Fabrik* shifted, from a marketplace for idle machining capacity to entrepreneurial innovation, the need increased to not only organize transactions, but also to cooperate for development and delivery. Rallying competencies requires that multiple partners temporarily unite to combine their forces in a concentrated effort to create a new solution for a customer. The fourth set of organizational activities in the process distinguishes the *Virtuelle Fabrik* from electronic market places and addresses the question of how management can facilitate and elicit "the willingness of individuals to contribute force to the cooperative system" (Barnard, 1938) in a *short-term cooperative effort*. There were several issues that had to be addressed.

First, the network partners engaged in developing "network cooperation processes," in analogy to sales or purchasing process, but specifically tuned to specific situation of network cooperation to allow partners to give and take business at a reasonable cost. Evaluation of initial projects in the *Virtuelle Fabrik* showed that the additional coordination needed among independent firms led to roughly 30% higher cost than would have been the case for a manufacturing project performed within a single firm. Clearly such a cost disadvantage could not be tolerated. Firms therefore engaged in the reengineering of firm-boundary-spanning processes to make cooperation between firms in the network as efficient as within-company processes. Duplicate activities—such as repeated quality inspections each time a part crossed a firm's boundary, filling out a full set of shipping papers and purchase orders, or entering the workload in the next firm's electronic planning systems—were traced and eliminated.

Of course, elimination of these activities also removed an important set of safeguards against mistakes and opportunism by partners. Such management of expectations on work performance therefore moved from control at the transaction level to explicit controls as a second set of organizational routines at the level of the network. Companies had to agree to follow the procedural guidelines that the project leaders derived from experiences with earlier projects. Small teams of managers developed what the partners called the "rules of the game." Each rule was presented to all *Virtuelle Fabrik* partners and a formal vote taken on adding it to the set of guidelines for collaboration. These guidelines eventually covered the entire life cycle of a cooperative project and concerned for example how partners are selected, how prices are calculated cooperatively, a checklist of how to specify customer products, and a standard contract.

Third, communication patters among partners altered when stronger networking led to more direct communication between a wider set of employees across member firms in the *Virtuelle Fabrik*, avoiding the delays and inefficiencies of chain-of-command communication. For example, all partner companies formally created dedicated network liaison positions, with the entitlement to by-pass otherwise standard operating procedures for cooperation within the network. For example many allowed direct contacting of engineers and machine operators by peers from other network partners. Consequently, expectations of what individual employees would do changed. For example, for many machine operators, work for the *Virtuelle Fabrik* included external contact for the first time, forcing them to build skills in communication or conflict resolution. Of course, empowering technical staff to accept work for the firm has the potential for conflict between their decisions and the traditional hierarchical control of the company and work processes and the partner companies developed ways to resolve them.

This especially led to a gradual shift toward, fourth, substantial arrangements, arrangements on the productive outcome of collaborative projects from the *Virtuelle Fabrik* network. The established guidelines, for example, covered the context of cooperation at large, e.g., the criteria of acceptance of new partners by the network, quality criteria for the specification of customer products, and the calculation of cost, reward systems, and communication processes in the network. On the other hand, direct procedural arrangements (e.g., a proposal on how to control transactions) were declined by the partner firms. Similarly, after the discussion of several proposals, it was decided that a guideline for the process of allocation of resources within partner firms was not required. Instead, the managers agreed that work could be delegated, but not the responsibility for its quality, timeliness, and cost. In other words, rather than having a rule for how to allocate resources, it was the explicit agreement of the managers to leave open how commitments were met, as long as they were.

This focus on substantial, rather than procedural, cooperation resembles the cooperation routines of the craft industrial mode. As Piore and Sabel (1984) developed with the example of the construction industry, the contingencies are that innovation projects are too short lived, projects too unstable, and firms and employment are too ephemeral for time-consuming processes of grievance arbitration. Moreover, individual customer-defined projects vary too much to justify the establishment of arbitration systems that are unlikely to have any bearing on the facts of future conflict. Unlike mass production, this mode of working requires collaboration between workers and managers. Since such work is always based on a unique design, problem solving becomes a trial and error process based on the partners' experience. It is therefore not surprising that project teams were small and personal leadership was encouraged and structurally supported. The maturity of a network for short-term collaboration is externally visible from indicators such as the number of partner firms involved in collaborative projects, because coordinating larger collaborative projects is more difficult than smaller teams, as well as the autonomy that collaborative projects enjoy in the network, or the variance of changing partners between different collaborative projects, which can serve as a proxy on how well collaboration routines are established on network level, or how much they are limited to bilateral relationships. The stronger these organizational indicators are, the higher we expect on the one side the percentage of directly measurable operatively successful projects with on-time, on-budget, good quality delivery to be. On the other side, we expect from the organizational indicators over time an increase of the chance that the network incubates innovation projects that high value creation with sustainable high growth rates, such as the litter shark.

5. Discussion

In this paper we have developed a process theory (in the sense of van de Ven and Poole, 1990, p. 313) to "… explain the temporal order and sequence of steps that unfold as an innovative idea is transformed and implemented into a concrete reality." Rather than providing a simple description of a case, "… a process theory may produce some "fundamental laws" of innovating (… and) also identify certain path more likely to be effective …." The multiple sources of data collected in our case study suggest that one effective path of innovating in networks is a competency-rallying process, which broadly unfolds in four steps, specifically: (1) identification and development of distinctive competencies, (2) identification and facing of short-term market opportunities, (3) marshalling competencies from network partners to meet the demands of a particular market opportunity, and (4) a short-term cooperative effort.

It is a characteristic of a process theory that there is a logical (rather than a temporal) order of the stages, meaning that their output is necessary but not sufficient to increase the likelihood of success of the project (Mohr, 1982). Put the other way around, missing the contribution of one stage of the competency-rallying process poses a clear risk for project performance. For example, if no market opportunity is identified, there might be excellent network collaboration but little chance for delivery because there is no recipient. On the other hand, even a strong market opportunity will not lead to a successful project in the absence of the contributions of the other stages. Each step addresses specific risks of innovation projects, thus increasing the chance of project success. The identification and development of distinctive competencies addresses the risk of technical problem solving; facing market opportunities, market risks; marshalling competencies, the risk of product architectures; and the short-term cooperative effort, implementation risks.

The steps presented here therefore should not be understood as simple sequential activities of a business process, but rather as pattern of events with different time scales and time pacing. The identification of competencies is an ongoing evolutionary and long-term process. The identification of market opportunities, in contrast, is event driven and occurs only when new opportunities are identified. Marshalling competencies in comparison is short term and in the cases described here takes only days or weeks. This process is time-based and can be structured into phases of milestones to be achieved. The short-term collaboration lasts days or weeks to years, depending on the project needs. Still, there is a logical order in the sequencing of the steps, as it would make little sense to reverse their order.

We further observe in the study that the likelihood that the events of each of the identified stages in the process model occur can be associated with the availability of organizational capabilities on the level of the network of the *Virtuelle Fabrik*. Our local explanation of competency rallying contributes empirical evidence "that dynamic capabilities are not tautological, vague, and endlessly recursive" (Eisenhardt and Martin, 2000). It is our hypothesis that competency rallying includes a structured set of generalizable and specific dynamic capabilities that can be named, as we did in the description of the steps above, and observed in other settings, through events for which observable indicators exist, as presented in Fig. 2. In doing so we build on research on entrepreneurial behavior of individuals (McGrath and Macmillan, 2000)

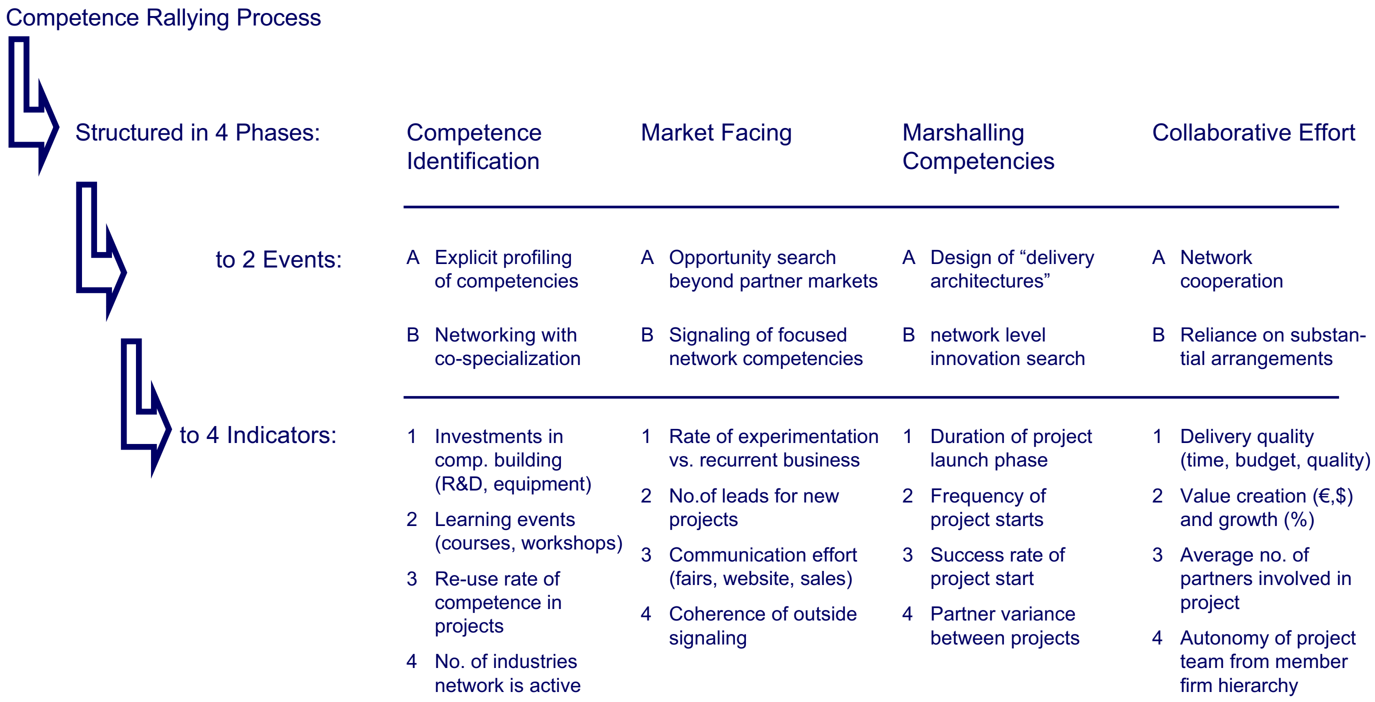

Fig. 2. Operationalization of the process model of competency rallying.

but shift the level of analysis to the inter-organizational level.

In comparison with other studies that are reported in literature, the *Virtuelle Fabrik* exhibits particular innovation circumstances that point to relevant contingencies for competence rallying process. First, the *Virtuelle Fabrik* network partners realized that its competency-rallying process performed best when products were "80% stable," meaning that the product concepts were explicitly spelled out but that there still was flexibility, requiring intensive engineering, for which intensive interaction between customer and designers and among designers is necessary. In short, the process summarized in Fig. 1 worked best for cases of technological innovation where marshalling of distinctive competencies and short-term cooperation mattered.

Second, in comparison with the individual firm, the network provides access to a larger range of competencies (Chesbrough and Teece, 1996). In line with this literature, innovation is found in this case to be one specific dimension of uncertainty distinct from demand uncertainty, task complexity, human asset specificity, and frequency that were found to impact the need for network governance (Jones et al., 1997). Describing Silicon Valley, Saxenian (1991) showed how production networks among computer systems companies spread the risks of developing new technologies. Similarly, in the Hollywood film industry, agents provide access for actors to new films (Goranson, 1999). Innovation networks are contingent (Galbraith, 1973) and distinct from networks that focus on other dimensions of uncertainty by the specific set of organizational routines that they develop in response to it. As the capabilities of the *Virtuelle Fabrik* network emerged over time, and through a series of innovation projects with different degrees of success, its capabilities indeed were associated with a degree of idiosyncrasy, and therefore resulted in distinct paths-dependent network characteristics even between the two Swiss networks.

Contrariwise, for standard, off-the-shelf products, the degree of customized effort represented in this process is probably inappropriate. When the network faces demand uncertainty for fungible goods, simpler electronic markets mechanisms like the technology capacity bourse of the early *Virtuelle Fabrik* development seem appropriate and can be based on products and services provided. A possible future research question then is how companies can develop procurement processes and criteria to decide when to purchase from an electronic market and when to seek the specialized services of a virtual organization such as the *Virtuelle Fabrik*.

6. Conclusion

The aim of this study is to better understand collaboration routines in innovation projects on a network level. The evaluative framework of this paper is to better understand how such cooperation routines contribute to flexibility or agility in response to emerging opportunities. The conclusion is that such agility requires much more than just short-term cooperation or computer supported market mechanisms. The failure of other networks may be attributable in part to an absence of these factors, which leads to the development of suspicion and mistrust among the partners, disinterest, and eventual disintegration of the network

(Human and Provan, 1997). From our study we conclude that agility is the result of entrepreneurial activities, which however are not of one or a few individuals' behavior but which are supported by organizational routines, patterns of recurring behavior that is shared by network partners at large.

As a conclusion the paper contributes a way to understand in more detail processes like competency rallying in the *Virtuelle Fabrik*, through which this network adapts to changes in what they perceive as turbulent environments. In this regard we follow the approach of a ''variance style of organizing processes'' as characterized by van de Ven and Poole (2006) because the fundamental epistemological stance of the study is to understand innovation as a result of processes of inter-organizational change on network level of the *Virtuelle Fabrik*. The identified observable indicators that characterize the events suggest the need for future research to generalize findings presented here beyond case studies. For example, Crowston and Scozzi (2002) successfully used the stages of the process to analyze cooperation in Free/Libre Open Source Software development projects. Empirical studies with larger data sets will allow more mathematical, especially stochastic, modeling of time delay, and the nature of the relationship between organizational routines and performance. Competency rallying is but one network level innovation process. Another obvious future research direction certainly is to identify more relevant processes.

Clusters, regional and national innovation systems, and other types of networks are generally said to further innovation. But current econometric methods and methods of business studies fail short to fully explain the mechanisms through which networks impact innovation performance. The approach presented in this paper thus complements other studies in explaining a hitherto less understood mechanism of how innovation is made to happen.

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