The Network Embeddedness of New, Technology-Based Firms: Developing A Systemic Evolution Model

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ABSTRACT. The present paper focuses on the interactive relationship between new, technology-based firms and their network environment. The paper analyzes the mechanisms through which new, technology-based firms become immersed in innovation and manufacturing networks. The concept of embeddedness is developed and used to depict such mechanisms.

A systemic evolution model of new, technology-based firms is proposed. The model depicts the evolution of new, technology-based firms in manufacturing and innovation networks. The model emphasizes the *catalyzing* role of new, technology-based firms in national systems of innovation.

Network embeddedness is empirically explored in five case studies of Finnish new, technology-based firms. The systemic evolution model serves as an interpretative scheme for the case studies. The analysis of the organic relationship between new, technology-based firms and their systemic environment also serves to reveal the implications of embeddedness for new, technology-based firms.

1. Introduction

Research on national systems of innovation has expanded rapidly during recent years (Lundvall, 1992; Nelson, 1993; Porter, 1990; Vuori and Vuorinen, 1994). New, technology-based firms[1] constitute an important dynamic element in these systems. The firms have a significant role in the development and diffusion of technological innovations (Haour and Maïsseau, 1995). Empirical studies suggest that the importance of new, technology-based firms has been increasing since the 1980s (Autio et al., 1989; Lumme et al., 1992).

The traditional 'atomistic' approach to research on new, technology-based firms is not very well suited to the study of new, technology-based firms as an element of national systems of innovation. The traditional body of research has treated new, technology-based firms in relative isolation from their environment (e.g. Roberts, 1991; Slatter, 1992). In this tradition, the interrelatedness of new, technology-based firms and the other actors in their environment tends to be overlooked. Research has focused extensively on the direct organic growth of the firms. The catalyzing impact of new, technology-based firms, delivered through technology interactions in innovation and manufacturing networks, has not received the attention it deserves.

The traditional approach to research on new, technology-based firms fails to explain many peculiar characteristics of the population of new, technology-based firms, such as the rapid increase in their number, their small size, and their low growth orientation (Oakey, 1993; Autio, 1995c; Kamshad and Hay, 1996). To address these issues, a new, more systemic approach to research on new, technology-based firms is being developed.

The systemic approach to research on new, technology-based firms focuses on the interactive relationship between these firms and their operating environment. Rather than *operating in* this environment, the new, technology-based firm, through the management of cospecialized assets (Teece, 1986) and lock-in processes, becomes an *organic part* of it.

The present paper analyzes the mechanisms through which new, technology-based firms become immersed in innovation and manufacturing networks. In Section 2, the concept of embeddedness is developed and used to depict such mechanisms. In Section 3, a model of the systemic

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evolution of new, technology-based firms as part of networks is developed. The model serves as an interpretative scheme for five case studies of Finnish new, technology-based firms in Section 4. The case studies explore the applicability of the embeddedness concept. The analysis of the interactive relationship between new, technology-based firms and their systemic environment also serves to reveal the implications of embeddedness for new, technology-based firms. Exploring the systemic evolution of new, technology-based firms in their network environment is expected to contribute to the understanding of the functions, growth, and nature of these firms.

2. Embeddedness and new, technology-based firms

2.1. *The concept*

The notion of embeddedness has previously been used to refer to the social and cultural context of economic action. Polanyi (1957) used the concept to describe the social structure of modern markets. Granovetter (1985), criticizing Williamson's (1981) transaction cost approach, argued that most behavior of individuals is closely embedded in networks of interpersonal relations. Understanding economic behavior requires consideration of the social, cultural, and institutional structures in which economic actors are embedded. The term has been used in a similar meaning by the Uppsala school of researchers, who have extended the use to cover the set of industrial and social network relationships of relevance for the firm (Lundgren, 1992). Also the approach of the Uppsala school is very much rooted in the sociological research tradition. The concept of power occupies a central role in their analysis. More recently, Uzzi (1996) has used the embeddedness concept to characterize the level of social interaction in interfirm relationships.

Zukin and DiMaggio (1990) have classified embeddedness into four forms: structural, cognitive, political, and cultural. The last three forms mainly reflect the sociological perspectives of embeddedness. Structural embeddedness focuses on how the quality and network architecture of exchange relationships influence economic activity (Uzzi, 1996). The concept of embeddedness used in the present study primarily refers to structural embeddedness, restricting the concept to the industrial task environment.

In the context of new, technology-based firms, the concept of embeddedness has been proposed as *"the strength, intensity, and permanence of the links between a new, technology-based firm and its environment."* (Autio, 1995b) In this definition, embeddedness reflects the degree to which a new, technology-based firm is immersed in the business system in which it operates.

In the present paper, the notion of embeddedness builds on the resource-dependence perspective of organizations (Pfeffer and Salancik, 1978). According to this view, the key to organizational survival is the ability to acquire and maintain resources.[2] Firms enter into network relationships with other organizations because they cannot generate all the necessary resources internally. This interaction results in high interdependence of organizations, as they form relationships with those who control *external complementary assets* (Teece, 1986). Through this interdependence, organizations are embedded in an environment comprised of other organizations.

The process of becoming immersed into the business system can be expected to involve adjustments in the competence pool of the firm. The firm often adapts its routines and operations, acquires context-specific information and knowledge, makes context-specific investments, develops *relation-specific skills* (Asanuma, 1989), learns to know customers' systems, products, and processes, develops trust (Sabel, 1993), expands its contact network, enhances its reputation. Such assets are not easily implemented into new contexts. Instead, they become idiosyncratic, or *specific* to the particular use (Milgrom and Roberts, 1992, p. 307). In his analysis of complementary assets, Teece (1986, pp. 288–289) distinguishes between *specialized assets* (unilateral dependence) and *cospecialized assets* (bilateral dependence).

Traditionally, firm boundaries are determined by the hierarchic control of resources, or the "belonging principle" (Rizzoni, 1993). This view neglects the fact that many resources can be jointly controlled, that is, also assets invested in building a relationship between actors constitute a resource.[3] The belonging principle becomes inapplicable in the context of networks, since it does not consider the firm's resources arising from the relations and interdependencies inside a network. In a network, a continuous process of definition and redefinition of firm boundaries takes place (Sabel, 1993).

In her analysis of the role of small firms is innovation, Rizzoni (1993) argues that because of the resource interdependence between the firm and its operating environment, a distinction should be made between the exogenous task environment and the "shared" or interacted context in the environment of small firms. The exogenous task environment includes sectoral and technological variables connected with the innovative behavior of the firm. These variables include, for example, the stage of the industry life cycle, entry barriers, demand characteristics, as well as whether the technology is capital intensive or skilled labor and knowledge intensive. The shared context of the environment includes the continuous exchange relations and the mutual interdependence of activities, resources, and actors (Håkansson, 1990). This context is partly internal, partly external to the firm.

Pfeffer and Salancik (1978, p. 63) have made a similar distiction between various levels of an organization's environment. On one level, the environment consists of the *"entire system of interconnected individuals and organizations who are related to one another and to a focal organization. . . . The next level is the set of individuals and organizations with whom this organization directly interacts."* Pfeffer and Salancik do not, however, consider the processes by which the environment becomes partly internalized to the firm through specialized and cospecialized assets.

Figure 1 illustrates how a firm becomes embedded in a network of interdependent actors, through asset specificity, or the specialization and cospecialization of resources.

In the model illustrated in Figure 1, the actors' resources are bound together by activities, which form the links between the firm and the other actors in the network. Each firm in the network has a corporate network identity, based on the activity dependencies and resource linkages between the firm and the other actors in the network. The network identity refers to the image which the firm has formed of the network and its own individuality in the network. The image may be more or less conscious, more or less uniform, and more or less historical. It is the sum of the individual images that the persons in the firm have. (Håkansson, 1989, pp. 51–53) Pfeffer and Salancik (1978, p. 63) refer to a similar concept as the organizations' enacted environment, or the organization's *"perception and representation of the environment."*

The firm operates on the basis of how it per-

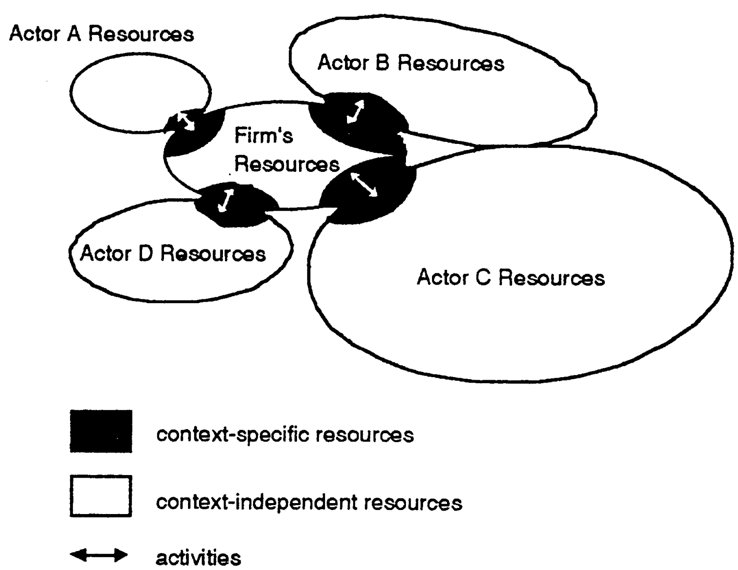


Figure 1. The firm's context-specific and context-independent resources.

ceives its relationship to the environment. In this way, the corporate network identity controls the behavior of the firm and indicates the directions for change. The identity is formed and reformed as a result of the continuous network interaction. Håkansson (1989, pp. 51–53) suggests that the corporate identity is not only a mental image, resulting from thought, but also a series of activities which are manifestations of the thought.

The network interaction influences the firm's actions and the opportunities available for the firm through

1. idiosyncrasy, or context-specificity, of the firm's resources
2. the corporate network identity, or the enacting of the environment; the image that the firm has of the network and itself in the network

A definition for the degree of embeddedness of a firm to be used in the present paper can thus be formulated as follows

> Embeddedness is the dependency of a firm on its links with other actors in an industrial network. This dependency stems from the idiosyncrasy, or specificity, of resources in the network linkages and the corporate network identity of the firm.

Embeddedness can theoretically be divided into two forms, manufacturing and technological embeddedness (Autio, 1995b), on the basis of the dominant type of activities connecting a firm into a network. If the activities are predominantly production intensive, then the dominant form of embeddedness is manufacturing embeddedness. If the activities are mostly research and development intensive, then the dominant form of embeddedness is technological embeddedness. In other words, manufacturing embeddedness depicts the degree to which a firm can be regarded as a traditional manufacturing subcontractor. Technological embeddedness refers to the degree to which the firm can be regarded as a diffuser of technology.

In reality, it is very likely that the two forms of embeddedness are overlapping. Just as it is difficult to distinguish manufacturing networks from innovation networks, it is likely that it will not be possible to clearly separate the two types of embeddedness from each other. Manufacturing activities often involve exchange of technological knowledge with other actors in the network, and vice versa. For example, in subcontracting, the customer and the subcontractor exchange technical product or production information. Sometimes subcontracting involves cooperation in product development and or design for manufacturing.

2.2. *Embeddedness as a new, technology-based firm phenomenon*

In theory, the embeddedness concept may be applied to firms of all sizes. Nearly all firms have some network linkages involving asset specificity. But the dependency implications of these links are less likely to be significant for a large firm with broad resources than for a new, technology-based firm.

Accessing external complementary assets is critical for new, technology-based firms for at least two reasons. One is simply the small size of new, technology-based firms. For such a firm, any shared resource, even small, can be important. Sapienza et al. (1997) suggest that leveraging firm-specific assets with external complementary assets is the relevant route of expansion for new, technology-based firms.

The other reason, and perhaps the more important one, is the nature of the firms as pools of technological competencies. Technological innovation is what new, technology-based firms do. The technology resource of a new, technology-based firm tends to dominate their other resources (Sapienza et al., 1997). It is likely that the innovativeness of new, technology-based firms stems, not only from their technological and scientific expertise, but from their capabilities to interact with the environment.The ability of a new, technology-based firm to develop extensive relations with the environment depends on the firm's internal competence pool. When the small firm has a sound internal competence base, it will be able to attract the interest of other organizations for collaborating and to develop interactive and complementary relations, supporting a virtuous process of competence development (Rizzoni, 1993). The organic and flexible organization of new, technology-based firms and their boundary-spanning activities (Lang, 1995) are factors facilitating the development of strong, knowledge-intensive relations with other actors in the environment.

In other words, the core technology resource and *relational flexibility* (Conner and Prahalad, 1996) make it possible for a new, technology-based firm to access external complementary assets through network relationships. The relationships are learning processes, which, in turn, contribute to the upgrading of the core technology resource and to the development of relational capabilities. Asanuma (1989, p. 21) points to a similar dynamic interaction between the formation of relation-specific skills and the development of general technological capabilities.

Gemünden, Heydebreck, and Herden (1992) have studied the "technological interweavement" of new, technology-based firms. The authors do not present a definition for "technological interweavement." They suggest that the more actively a new, technology-based firm taps into external sources of technology, the more products it develops, and the greater is the share of sales generated by new products. They do not consider the opposite possibility, however. It seems equally likely that innovation success leads to technological interweavement. If a firm is active in producing new products, it is likely to be more active in using external sources of technology.

Amendola and Bruno (1990) have studied the relationship of innovative firms and their environment. They contend that in the innovation process, especially in the case of "major" innovation, the borders between the firm and the environment fade out, up to the point of disappearing. The innovation is embodied in the fact that some of the elements previously external to the firm are made internal to its strategy through links with the environment. Amendola and Bruno (1990, pp. 420, 423) contend that innovation is essentially "*a learning process, which takes place both in the firm and in its environment and results in deep changes in both of them. . . .* [A]*n innovation has no meaning in itself but only in relation to the environment with which the innovating agent is establishing meaningful relations*". Consequently, the authors maintain that there is meaningful correlation between the way in which the firm relates to its environment and the behavior of the firm with respect to innovation.

We now proceed to develop a model of the evolution of new, technology-based firms in networks. We attempt to incorporate the systemic research perspective and the notion of embeddedness into a model of the evolution and growth of new, technology-based firms.

3. Systemic evolution model of new, technology-based firms

The traditional view of the evolution of new, technology-based firms largely reflects the obsolete linear sequential view of technological innovation (Autio, 1995a). First, the potential entrepreneur develops a technology-based idea that is perceived to have commercial potential. Then the entrepreneur gathers resources and possibly a management team and establishes a firm to commercially exploit the idea. If the business idea of the firm is viable, the firm becomes commercially successful. Commercial success is perceived as rapid organic growth.

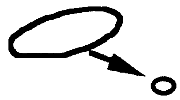
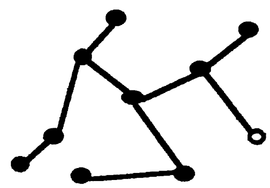
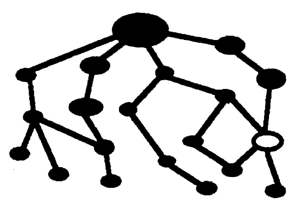
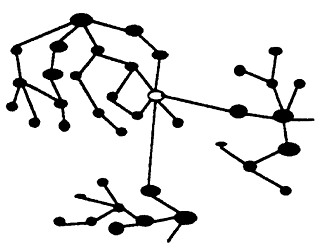
To be sure, there are examples of new, technology-based firms that have been able to obtain very rapid organic growth. Empirical studies suggest, however, that the rapidly growing new, technology-based firms are exceptions. The majority of new, technology-based firms seem to be technologically and or manufacturing embedded in value-creating systems. The system sets the opportunities and constraints for the survival and possible growth of new, technology-based firms. Table I illustrates our view of the systemic evolution of new, technology-based firms.

The model illustrates the evolution of new, technology-based firms as part of innovation and or manufacturing networks. A new, technology-based firm is founded as a spin-off firm or as a private venture. The firm's technology, application area, and the capabilities of the management team determine, whether the firm has potential to reach stand-alone growth. Most new, technology-based firms do not.[4] Instead, they become embedded in an innovation network or a manufacturing chain.

As the network is established, in stage 2, the new, technology-based firm becomes embedded in it, by developing relationships with customers, suppliers, research institutions, financing institutions, and other possible actors in the environment. Some of the linkages become intensive and continuous in nature. Resource leveraging starts to take place, and the firm establishes itself in the network.

On the system level, the whole network starts

TABLE I
Systemic evolution model of new, technology-based firms

	1	**New, technology-based firm is founded** • a new, technology-based firm is founded as a spin-off or as a private venture to exploit new technological solutions
	2	**New, technology-based firm is linked to network or chain** • new, technology-based firm develops initial customer and other connections • some of these connections become intensive • new, technology-based firm starts to become embedded in an innovation network or a manufacturing chain
	3	**Cluster develops** • positive externalities develop in the network; development and growth starts to feed itself • many new, technology-based firms are founded • locomotive effect takes place • locking-in into paradigmatic technological stage • firm is manufacturing and or technologically embedded
	4	**New, technology-based firm is able to link into other networks and clusters** • new, technology-based firm has developed firm-specific distinctive competencies • new, technology-based firm has reached critical mass • it is possible for the firm to link into other networks and clusters and become less dependent on the initial cluster

to develop. There are usually many competing new technologies in this pre-paradigmatic stage. Gradually, the system shifts to the third stage of the evolution model. Many new, technology-based firms are founded in the network, often but not always in proximity. At some point, a locking-in into the paradigmatic stage (Teece, 1986) takes place. Abernathy and Utterback (1978) call this the emergence of a "dominant design." Positive externalities develop in the network. The growth of the network starts to feed itself. In Porter's (1990) terms, a cluster is formed.

The development of the cluster is often driven by a locomotive firm. The locomotive firm benefits from the technological network externalities, gaining competitive advantage over its competitors. It may expand through direct organic growth and by acquiring other firms. Dynamic complementarities (Rothwell and Dodgson, 1993; Acs and Audretsch, 1993) are exploited between the constituent firms of the network.

Thus for individual firms there is the opportunity to grow with the network, in this third phase of the model. External complementary resources are available, with which the firm can leverage its firm-specific resources. The firm establishes a continuous *resource generation* process (Garnsey, 1996).

In such a synergistic value-creating system, the new, technology-based firm develops distinctive competencies (Teece et al., 1992), to create value for its customers in the network. At this point, the new, technology-based firm is often very dependent on the locomotive firm and the development of the network. This has been observed in practice in many of Nokia Corporation's small supplier companies in the Finnish telecommunications industry.

To decrease its dependence on the development of the network, a new, technology-based firm may seek to establish linkages to other networks in new geographical or application areas. At this stage, the new, technology-based firm may be able to carry out this expansion, through a *growth reinforcement* (Garnsey, 1996) process, having developed its distinctive competencies in the initial network. These firm-specific competencies make the new, technology-based firm valuable to firms in other networks. Also, with the growth of the initial network, the new, technology-based firm has reached the critical mass necessary for moving into new networks. For example, several of Nokia's supplier firms have expanded into international telecommunications markets or gained new customers in other industries, such as home electronics. Some of these supplier firms may even become new locomotive firms themselves.

If, however, the favorable network evolution, as described above, does not take place, the new, technology-based firm may be trapped in its network position, with limited growth opportunities. It has not yet developed its distinctive competencies or reached the critical mass necessary for growth reinforcement. In some cases, the technology of a new, technology-based firm may be so specialized for a specific market niche, that it is very difficult for the firm to expand into other networks or clusters, despite the favorable development of the initial network. Also the growth orientation of the entrepreneur will have an effect on how actively the firm pursues expansion into other networks.[5] Less growth oriented entrepreneurs will be content in a safe and comfortable niche of the initial network.

Usually, the networks and clusters are geographically concentrated (Porter, 1990). Camagni (1991) argues that a common cultural, psychological and often political background facilitates the exchange of complex and tacit knowledge; that local resources of human capital account for much of the local learning process; and that informal, personal contacts and casual information flows contribute to innovation. Our view is that proximity is a catalyzing factor in the development of networks and clusters, but it is not a prerequisite of embeddedness. As many of the critics of Porter's industry cluster approach have pointed out, industries are becoming increasingly international in nature. The developing communication and transportation technologies are making it possible for networks and clusters to strech across continents (Dunning, 1993; Rugman, 1992).

The systemic evolution process described above is not a linear sequential one: one stage does not necessarily lead to another. The evolution takes place spontaneously, as a result of the actions of the actors in the network. New, technology-based firms are often born directly into the developing cluster, that is, the third stage in the model.

The systemic evolution model cannot be considered to apply to all new, technology-based firms. There are still the stand-alone exceptions. It is also likely that the evolution of new, technology-based firms and industry clusters varies according to industry sectors and technologies. In the next section, the applicability of the model will be explored in five case studies of Finnish new, technology-based firms.

4. Case studies of Finnish new, technology-based firms

In order to study qualitatively the phenomenon of embeddedness and its implications, five explorative case studies of Finnish new, technology-based firms were carried out. The purpose of the case studies is to explore the phenomenon of embeddedness among new, technology-based firms. The focus is on the degree and type of embeddedness, as well as on the implications of embeddedness for new, technology-based firms. The systemic evolution model is used to interpret the development of the case firms.

4.1. *The case firms*

The case companies were selected on the basis of expert interviews. The companies were independent and from different industries. The size and the background of the firms varies. The purpose has been to make the exploratory perspective as wide as possible by choosing firms that clearly differ from each other. The material for the case studies was compiled by interviewing the key personnel in the case companies and by using annual reports, brochures, and newspaper articles. In order to protect the privacy of the case firms, their names have been disguised. The basic characteristics of the case firms are summarized in Table II.

AutoOptics is a spin-off firm from the Technical Research Center of Finland VTT. FireTech and ProdSystems are both descendants of their owners' previous firms. EnviroHeat is based on private research carried out by the founder. Telectron is a spin-off from a major construction company in Finland.

The driving force of each of the firms is an entrepreneur, who has the technological know-how which the firm's business is based on. AutoOptics, FireTech, and EnviroHeat have developed unique technologies, which are still young. ProdSystems' innovation is based on a combination of new technology and application and production know-how. Telectron is a technologically sophisticated subcontracting firm.

AutoOptics has not grown during its lifetime. FireTech is growing rapidly. EnviroHeat is still in the start-up phase. Both ProdSystems and Telectron have grown directly and through acquisitions. Especially Telectron's growth is extremely fast.

4.2. *Embeddedness of the case firms*

AutoOptics. AutoOptics was founded to exploit machine vision technology developed at the Technical Research Center of Finland VTT. The firm produces three-dimensional optical measurement systems for industrial purposes. The Finnish National Fund for Research and Development SITRA came to finance the firm in 1994 as a minority share holder.

The firm is an academically oriented research and development firm. Development work is the highest priority of the firm. Marketing has been viewed as secondary. The cheap marketing channel has been through universities and experts in the field. AutoOptics has tried to establish partnerships for marketing and distribution, so that it could concentrate on research and development. This identity of a technological expert organization is likely to have limited AutoOptics' commercialization efforts.

During its lifetime, AutoOptics has not become linked to an innovation network or manufacturing chain. The firm has had temporary technology-intensive relationships with a number of customers. Each customer requires significant modifications in the system. It takes approximately one year from the start of a project until the product has been adjusted, installed, and is working at the customer's facilities.

AutoOptics buys the components of the system, such as PCs, cameras, and displays from a number

TABLE II
Basic characteristics of the case firms

	AutoOptics	FireTech	EnviroHeat	ProdSystems	Telectron
Main business at present time	Optical measurement systems for car windshield manufacturers	Fire protection systems for ships	High-speed gas generator for housing heating	Circuit board handling systems for telecommunications producers	Electronics assembly for telecommunications industry
Year of founding	1987	1991	1993	1988	1991
Background	Technical Research Center of Finland VTT	Owner's previous hydraulics firm; hydraulics expertise	Private research	Owner's previous consulting business	Management-buy-out from large construction company
Sales 1994, million US$	0.2	8	–	11	92
Personnel 1994	3	40	3	45	1071
Growth	Sought through alliances with other companies	Rapid; relatively independent	Sought through alliances with other companies	Rapid; catalyzed by telecommunications boom	Very rapid; catalyzed by telecommunications boom

of suppliers in Finland and abroad. The heart of the system is the operating and calibration software, which the firm develops in cooperation with the Laboratory of Photogrammetry at Helsinki University of Technology. In this way, AutoOptics acts as a link between academia and industry. AutoOptics is technologically somewhat dependent on the relationship with Helsinki University of Technology.

AutoOptics has attempted to become an original equipment manufacturer for several large foreign corporations. These attempts failed, quite understandably. It is difficult for an entrepreneur of a newly-founded technology-based firm, with a young product technology, to establish cooperation with a large foreign or multinational corporation. The other customers have been end-users of the product. The marketing and development effort required of AutoOptics to acquire sales directly from end-users in a larger scale seems unrealistically high.

AutoOptics has recently started cooperation with a Finnish partner firm, which develops and manufactures car windshield production machinery. The cooperation involves a high level of technological idiosyncrasy. A product is being developed together with the partner firm. The firms have complementing patents on the product, resulting in interdependency. If the project proceeds as planned, AutoOptics can become an original equipment manufacturer for the partner. This suggests manufacturing embeddedness in the partner's manufacturing chain.

AutoOptics is trying to establish itself in the car component manufacturing network and become a part of the transportation cluster. It may be that in previous customer connections, AutoOptics has tried to establish itself "too far downstream" in the value chain. The firm has not been able to grow through these stand-alone efforts. Now AutoOptics seems to be finding its own niche in the car component manufacturing network as a technology supplier. In AutoOptics' case, it seems likely that a certain level of embeddedness is needed to facilitate growth.

FireTech. FireTech is an original equipment manufacturer of fire protection systems for ship manufacturers, thus being a part of its customers' manufacturing chains. The fire protection systems are based on an innovative technology, which combines standard hydraulic pressures and small amounts of fresh water. In other words, fires are extinguished by using high-pressure fog. FireTech has received funding from the Regional Development Fund of Finland KERA and the Technology Development Center of Finland TEKES.

FireTech's technological know-how has been developed internally, involving no development linkages with other organizations. The technology is transferred only through the firm's products. The idiosyncrasy of resources involved in the customer relationships is limited to investments made in the individual customer projects. The firm is loosely manufacturing embedded in a variety of customer relationships. FireTech uses subcontractors to install the systems. Suppliers provide piping and cabling. The components of the actual fire protection system, such as sprinkler heads and piping fittings, are manufactured by FireTech.

FireTech sees itself as an innovator firm, ready to tackle any technical obstacles coming in its way, but with a commercial, money-making attitude. The firm reflects the innovator mentality of the founder. This identity has been a facilitating factor in passing the required fire extinguishing tests and obtaining the necessary certifications. The corporate identity drives the firm into continuing research and development in other areas of fire extinguishing, while the results of the marine side development work are being exploited. For example, at the moment the firm is developing gas turbine fire protection systems. FireTech's growth has been relatively independent. FireTech is not dependent on any single customer, but it is very dependent on the ship-building industry.

EnviroHeat. The business idea of EnviroHeat is to develop environmentally friendly power generation technology. As a very young firm, EnviroHeat's linkages with other organizations are few. At the moment, it is very dependent on the realization of its cooperation with a large industrial partner. EnviroHeat has committed itself to the relationship. As a small firm with limited resources and few connections, EnviroHeat cannot exploit its technology alone. The technology needs to be incorporated into the products of the large partner firm, who has the complementary technological knowledge and access to the markets.

EnviroHeat has developed a product for the needs of the partner firm. Contacts with other possible partners have not been maintained, as this would be understood as mistrust by the partner firm.

EnviroHeat has not developed a clear network corporate identity yet. The entrepreneurs see themselves as newcomers trying to find their niche in the business environment dominated by large competitors. The major obstacle to growth has been the difficulty of developing the relationship with the partner, that is, obtaining the initial link to an innovation network. EnviroHeat aims at remaining a mainly technological asset management company. To protect its core technological knowledge, it will become the manufacturer of the core component. In EnviroHeat's case, it is clear that technological and manufacturing embeddedness go hand in hand. In the beginning, becoming technologically and manufacturing embedded is the only way to achieve sales.

ProdSystems. ProdSystems develops and manufactures equipment for handling circuit boards in circuit board assembly. In the beginning of its lifetime, ProdSystems provided manufacturing equipment to customers in a variety of industries. Customer linkages were one-time projects, which involved extensive modification of the products.

With the growth of the telecommunications industry in Finland, ProdSystems specialized on the needs of the various divisions of Nokia Corporation. As a result, ProdSystems has grown very rapidly. In 1995, ProdSystems bought a Finnish competitor firm, which possessed complementary technology. ProdSystems is now one of the leading companies in its business globally. The firm's customers include, in addition to Nokia, also Ericsson and Motorola.

ProdSystems is technologically embedded in the telecommunications cluster. The firm aims at making the production process of its customers more efficient by providing them with advanced manufacturing technology and production know-how. ProdSystems' customer relationships involve exchange of highly confidential product and production information. Development cooperation with customers is intensive. The customer relationships do not involve idiosyncrasy of resources, other than the investment in the development time for each project. But the interaction with customers is an interactive learning process, where ProdSystems improves its capabilities to better meet customer needs. ProdSystems' network identity is that of a leading-edge problem solver. The firm is known to solve each customer's problems individually. ProdSystems uses a number of suppliers, for example, component manufacturers, mechanics importers, and surface handling services.

ProdSystems' embeddedness in the innovation network of the telecommunications cluster has facilitated the firm's growth. ProdSystems is very dependent on the telecommunications cluster, but not very dependent on any single customer. The firm is seeking growth through geographical expansion.

Telectron. Telectron is a contract electronics manufacturer, embedded in the manufacturing chains of Ericsson, Nokia, and ABB. The firm is a traditional subcontractor, providing its customers with full-service electronics production. Telectron also develops production know-how and transfers it to the customers. In Telectron's case, some technological embeddedness seems to be associated with the manufacturing links.

Telectron's investments in production capacity have been motivated by the very rapid growth of its few largest customers. These investments are not customer-specific and therefore do not involve idiosyncrasy of resources. Telectron's network identity is that of a growth-oriented "servant." Telectron has not been afraid to aggressively invest in new manufacturing capacity. The emphasis has been on providing holistic services for customers. Telectron's supplier linkages are numerous. Telectron is dependent on those suppliers which the customers prefer. Being embedded in the manufacturing chains of the rapidly growing telecommunications cluster has been the growth driver for Telectron. A future challenge for Telectron is to establish itself on a more independent footing in relation to its large customers.

The findings concerning the embeddedness of the case firms are summarized in Table III.

AutoOptics is technologically embedded in its relationships with Helsinki University of Technology, the Technical Research Center of Finland, and the partner firm with which it has comple-

TABLE III
Embeddedness of the case firms

	AutoOptics	FireTech	EnviroHeat	ProdSystems	Telectron
Links with technology sources	Helsinki University of Technology, Technical Research Center of Finland VTT, partner firm	None	None	Customers	Helsinki University of Technology in a minor degree
Functional contribution for customer	Improving customer's product with new technology	Part of customer's product	Licensing new product technology; part of customer's product	Improving customer's production process	Providing customer with production capacity and know-how
Number of significant customer linkages	One	Numerous	One	Several	Several
Idiosyncrasy of resources in customer links	Partner: high	Low	Partner: high	Moderate	Low
Idiosyncrasy of resources in supplier links	Low–moderate	Low	None yet	Moderate	Low–moderate
Corporate network identity	Development organization	Innovator	Newcomer technological expert	Problem solver	Growth-oriented servant
Level of dependency on certain customer(s)	High	Low	High	Moderate	Moderate
Level of technological embeddedness	High	Low	High	High	Low
Level of manufacturing embeddedness	Low, probably increasing	Moderate	None yet; expected to become moderate	Low	Has been high; is decreasing

mentary patents. Through collaboration with the partner, AutoOptics is trying to establish itself in the manufacturing network of the car industry. In a similar manner, EnviroHeat is technologically dependent on its partner firm, and will probably become manufacturing embedded, as well. FireTech is part of the ship manufacturing chain, but only loosely embedded in its customer relations. ProdSystems is part of the innovation network of the telecommunications cluster. The development-intensive relationships with customers imply a high level of technological embeddedness. Telectron is embedded in the manufacturing chains of a few large telecommunications and electronics manufacturers.

The network identities of the firms are difficult to observe in practice. The case studies suggest that the concept of network identity, or the way in which the firm enacts its environment, is perhaps useful only as a theoretical concept, and that its practical applicability is limited. We will try to make a few general observations in any case. The identity of an entrepreneurial firm seems to stem from the identity of the entrepreneur. The entrepreneur creates the "spirit" of the company. The entrepreneurs of AutoOptics and EnrivoHeat are very technically oriented people. Their main enthusiasm is clearly research and development. Perhaps this is why they are seeking external relationships to gain the complementary market knowledge. In FireTech, ProdSystems, and Telectron, the entrepreneurs are also technically oriented, but their primary concerns are financing, marketing, and expansion. It is difficult to say, whether their growth-orientation is a result of growth, or vice versa.

Manufacturing and technological embeddedness of the case firms can be distinguished from each other. Manufacturing embeddedness is manifested as an emphasis on the production function of the new, technology-based firm. FireTech is clearly a supplier of a product. Telectron is distinctly a contract manufacturer. Technological embeddedness is manifested as an emphasis on development-intensive relationships. ProdSystems' function is to develop new production technology and spread it into the telecommunications cluster.

Although manufacturing and technological embeddedness can be distinguished from each other, the case studies indicate that the two types of embeddedness are somewhat overlapping. In the cases of AutoOptics and EnviroHeat, it is likely that their technological embeddedness will lead to a certain degree of manufacturing embeddedness. Although Telectron is clearly manufacturing embedded, its customer relationships also involve development-intensive functions.

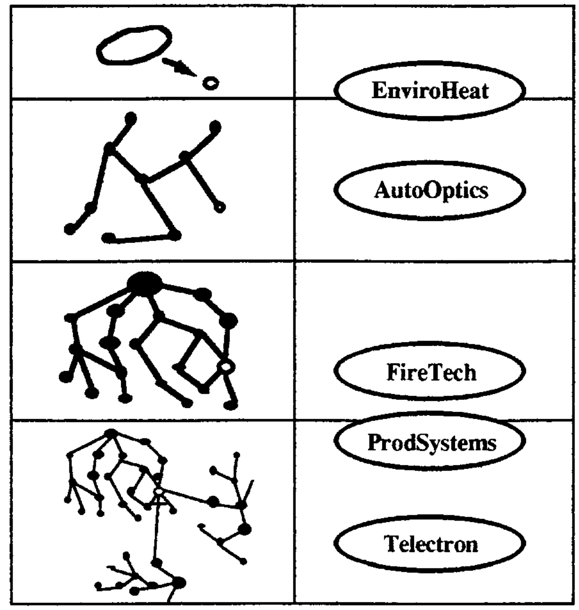


Figure 2. The case firms according to their stages of systemic evolution.

4.3. *The systemic evolution of the case firms*

In this section, we relate the development of each of the case firms to the systemic evolution model presented in Section 3. Figure 2 illustrates our perception of the case firms' stages of evolution.

For all the case firms, it seems that being able to establish the initial links to an innovation network or a manufacturing chain is crucial. EnviroHeat's future is very much dependent on how the relationship with the large partner works out. As a very young company, EnviroHeat's relations are few, and the firm is still relatively isolated. Through cooperation with the partner firm, EnviroHeat may be able to secure the complementary assets it needs, such as, financing, market access, production know-how, and complementary technology.

AutoOptics has intensive relations with the complementary sources of its basic technological knowledge, but the firm lacks the capabilities and financial resources for commercializing the technology by itself. Until recently, it has not been able to establish continuous customer relationships. It is our view that AutoOptics has now managed to connect itself into the car manufacturing chain, through the cooperation with the partner firm. The car manufacturing cluster in the Nordic countries could provide AutoVision with a comfortable niche. The future development of AutoOptics will then depend on whether the firm is able to develop new competencies which will enable it to diversify into new networks. Perhaps the product development process being carried out with the partner firm could be replicated with other partners or other product applications.

FireTech's evolution path involves perhaps the least embeddedness of the case firms. FireTech has developed its technology independently, and its customer relations are numerous. The firm is clearly part of the Finnish ship building cluster, and the growth of the firm has been fuelled by the growth of the entire cluster. But the relationships with customers and suppliers are less intensive in nature; they are project-based and do not involve cooperation in product development. The question for the future of FireTech is whether it will be able to expand into new product application areas with the same kind of relationships, or will it have to become more embedded. Will it be able to generate all the required complementary assets by itself or through arms-length transactions, or will it have to form more interactive relationships, make context-specific investments, and develop more customer-specific skills?

ProdSystems started out with a general technological knowledge base. In the first years of its lifetime, the firm had a variety of one-time customer projects in various industries, each project involving product adjustments. Eventually, ProdSystems started to develop knowledge specific to its customers in the telecommunications industry, and formed linkages with the various divisions of Nokia Corporation. With the rapid growth of the industry in Finland, Nokia as the locomotive firm, ProdSystems was able to focus exclusively on manufacturing systems for the needs of the telecommunications industry. For some time, the firm was very dependent on Nokia. But as ProdSystems has developed its products and gained more competence, the firm has started providing systems also for Ericsson and Motorola. In other words, it has been able to expand into new clusters.

Telectron's evolution is a case of exceptionally rapid growth. The firm was founded as a management-buy-out from a large corporation. Consequently, the firm already had a network of linkages and significant resources, when it was established. It has been able to exploit the growth of digital telecommunications networks to the fullest, and has grown to employ over 1000 workers. In Telectron's business, scale constitutes a clear competitive advantage. Telectron is a first-tier (Asanuma, 1989) supplier to Nokia, Ericsson, and ABB. It seems that Telectron is itself becoming a locomotive firm, driving the development of its suppliers. In case the growth of the Nordic telecommunications cluster slows down, Telectron is looking for opportunities to expand internationally and into new application areas.

It seems that the type of technology and the application area of the firm are important in determining how embedded a firm becomes and how embeddedness affects the firm. For example, EnviroHeat's high-speed technology is such that a small firm cannot exploit it alone, while FireTech's technology allows for more independent growth. Naturally, the firm's size and resources are important factors affecting embeddedness.

Embeddedness has directed the case firms in developing their distinctive competencies. FireTech has improved fire extinguishing systems with regard to weight and other characteristics so that they would be better suited for use in ships. This has an effect on determining the other possible application areas. Telectron has developed its subcontractor competencies for telecommunications and electronics. The firm's competencies are in the management of the component suppliers and in the production know-how of advanced circuit board assembly. It is questionable to what degree these competencies could be applied in other areas.

An embedded new, technology-based firm can only grow as fast as its network is growing. In ProdSystems' and Telectron's cases this has been very rapid. Without the embeddedness in the telecommunications cluster, the firms would probably not have grown. The type of embeddedness does not seem to play a crucial role in growth.

The purpose of the case studies was to explore the phenomenon of embeddedness in practice and to demonstrate that the systemic evolution model can be applied as an analytical tool to understand the development of new, technology-based firms as part of network structures. The above analysis was a highly exploratory evaluation of the embeddedness and evolution of the firms. The different starting points of the firms, as well as their differing sizes, industries, modes of operation, and evolution stages naturally affected the level of aggregation used in the analyses.

5. Conclusion

In this paper we have argued that a more systemic approach is needed in research on new, technology-based firms. Because of their small size and their nature as pools of technological competencies, the firms need to access external complementary resources (Teece, 1986). The new approach should take into account the dependency of new, technology-based firms on cospecialized assets, stemming from relationship-specific investments (Hart, 1988).

We analyzed the mechanisms of resource-dependence (Pfeffer and Slanacik, 1978) between new, technology-based firms and their environment. On the basis of the analysis, we developed the concept of network embeddedness and constructed a systemic evolution model of new, technology-based firms. The model is a descriptive framework, which can be used in analyzing the development and growth of new, technology-based firms as part of innovation and manufacturing networks.

Five exploratory case studies of Finnish new, technology-based firms were carried out to investigate embeddedness and systemic evolution in practice. On the basis of the case studies, it is evident that embeddedness is a significant factor in the evolution of new, technology-based firms. How embedded a firm becomes seems to depend on the type of technology and application area, as well as on the resources of the firm. In becoming immersed in a network, the crucial step seems to be establishing the initial intensive linkages, or finding the right niche in the network. The system-level evolution of the entire network, in which the firm is embedded, clearly has an effect on the growth of the new, technology-based firm. Growth of the firm may be facilitated or constrained by the network.

Naturally, there are exceptional "stand-alone" firms, which are able to achieve growth independently, without becoming embedded. But we suggest that the concept of embeddedness and the systemic evolution model may be applicable to the numerous new, technology-based firms, which are small, highly specialized, and which lack the financial resources and capabilities for stand-alone growth.

Notes

[1] In the present paper, the term "new, technology-based firm" is used to refer to independent entrepreneurial firms, which develop, transfer, and or commercialize advanced technology.
[2] Resources are defined as "anything which could be thought of as a strength or weakness of a given firm. More formally . . . those tangible and intangible assets which are tied semi-permanently to the firm (see Caves, 1980). Examples of resources are brand-names, in-house knowledge of technology, employment of skilled personnel, trade contracts, machinery, efficient procedures, capital, etc." (Wernerfelt, 1984, p. 172)
[3] The implications of this argument have been studied by Grossman and Hart in S. Grossman and O. Hart, 1986, 'The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration', *Journal of Political Economy*, 691–719.
[4] See, for example, R. Oakey, 1993, 'High Technology Small Firms: A More Realistic Evaluation of Their Growth Potential', in C. Karlsson, B. Johannisson and D. Storey (eds.), *Small Business Dynamics, International, National and Regional Perspectives*, Routledge, London and New York, pp 224–242.
[5] For an analysis of the growth aspirations of small and medium-sized enterprises, see, for example, K. Kamshad and M. Hay, 1996, 'Measuring the Value of Growth: The SME dilemma', *Journal of Economic Literature* (May).

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