

The Impact of Different Types of Innovations on Industrial

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Abstract:

In this paper, we analyse the implications of different types of innovations on industrial networks. In literature there can often be found great enthusiasm about the positive effects of networks or knowledge clusters on competitive positions of firms. However we argue that too close interaction between actors in a network can bring about severe consequences in situations of technological change. We use an innovation typology put forward by Henderson and Clark and illustrate our thoughts with the example of the market for Programmable Logic Controllers (PLC).

Introduction

Firms on industrial markets are increasingly confronted with high degrees of technological dynamics. In order to remaining able to fulfil the ever increasing demands of their customers, it is essential for every supplier to have the ability to supply solutions based on current technologies as well as developing and co-ordinating new technological knowledge in very short periods of time. The underlying reason why technological change represents a challenge for every industrial firm can be seen in its tendency to render obsolete technological knowledge that has been accumulated for years.¹⁵⁵

Literature on networks has emphasised the benefits that accrue for the individual actors belonging to such networks. According to key assumptions of the network perspective individuals are bounded in the amount of knowledge they possess and knowledge is unevenly distributed between individuals.¹⁵⁶ Sharing of the various knowledge elements can lead to spillovers and reduced vulnerability to technological change. A high degree of knowledge spillovers can be found in 'industrial districts' (e.g. Silicon Valley) or 'clusters'. It is argued that in such clusters, there exists a virtuous cycle of learning, innovation and development, whereby firms gain a greater ability to innovate constantly and enhance their competitiveness.¹⁵⁷ These effects are mainly achieved by a high number of close business relationships which can be described as non-random sequences of market transactions between a supplier and a customer being sustained by some kind of inner connection.¹⁵⁸

¹⁵⁵ See Tushman/Anderson (1986), p. 441-443.

¹⁵⁶ See Snehota (1990).

¹⁵⁷ See Schiavulli/Baker/Oburai (1999).

¹⁵⁸ See Plinke (1997), p. 23.

However we should be careful being too enthusiastic about the benefits of such regional networks. Economic history is full of examples of the failures of networks and their disability to perceive the impact of technological change in its entirety (e.g. the Swiss Watch Industry).¹⁵⁹ Facing this danger Håkansson and Snehota point out: a network of business relationships is both – a prison and a tool.¹⁶⁰ In the same manner mentions that too high degrees of interaction within a group of firms can render the group more vulnerable to radical technological change.¹⁶¹

The goal of this paper is to analyse the effects of different types of innovation on the various elements of a network structure. We focus on a technology-driven industrial network with three types of players: (1) component suppliers, (2) system integrators and Original Equipment Manufacturers (OEMs) and (3) customers. We assume that business relationships evolve from economic exchanges between component suppliers and system integrators and between system integrators/OEMs and customers. As an example the market for Programmable Logic Controllers (PLC) will be used.

The value of knowledge clusters

It has been argued that in industrial districts or clusters are characterised by knowledge connections that impact performance of companies. Literature on this issue dates back to Marshall, who stresses that there can often be found high degrees of knowledge diffusion between groups of geographically bounded firms.¹⁶² As mentioned in the introduction, this high degree of interaction can lead to competitive advantages for firms belonging to such clusters.

However literature is often not very specific about the reasons which account for competitive advantages of networks. Authors like Loasby and Foss argue that there may exist several types of capabilities on the cluster level, which are not fully reducible to the capabilities of individual firms.¹⁶³ Capabilities are defined by Richardson as “knowledge, experience and skills” of certain types of organizations.¹⁶⁴ Under competitive conditions it is essential that capabilities cannot be easily imitated otherwise they could not serve as a source of economic rents. In the following we will mention some characteristics of knowledge clusters:

- The most important advantage of knowledge clusters is their ability to promote the growth of knowledge. The capabilities of firms in a cluster are not completely similar but at the same time not totally different. These ‘small’ differences of firms in knowledge clusters make learning possible. The cluster thereby becomes an effective and efficient governance structure for collective learning, which takes place in a number of formal and less formal ways (e.g. joint ventures, personal ties, etc).
- High degrees of trust and cooperation are identifiable in knowledge clusters, which allow vertically disintegrated businesses to come into existence and to persist. This means at the same time, that the entirety of capabilities is not possessed by any single firm in the cluster and coordination has to be achieved by a mixture between competition and cooperation. Connectedness within the network serves as a bonding mechanism that makes transaction-cost-intensive formal agreements redundant.

¹⁵⁹ See Glasmeier (1991), p. 469.

¹⁶⁰ See Håkansson/Snehota (1995), p. 42.

¹⁶¹ See Loasby (1999), p. 99.

¹⁶² See Marshall (1925), p. 271.

¹⁶³ See Loasby (1999), p. 97-100 and Foss (1999), p. 5.

¹⁶⁴ See Richardson (1972), p. 888.

- Collective knowledge in clusters cannot easily be duplicated because the necessary learning processes require a great deal of time and effort. We can assume that knowledge sharing involves a great number of tacitness and social complexity. For this reason, capabilities of clusters are also to a large degree immobile in the sense that they cannot be easily transferred or copied.
- In a cluster there are a huge number of actors, which can all be seen as potential innovators. Especially Von Hippel shows that the source of innovation can vary depending on the differing rent expectations of actors. A cluster is a fruitful area for innovation because there is usually a high degree of informal know-how trading, which describes an inexpensive and flexible way to distribute innovation-related information.¹⁶⁵

We believe that the previous Marshall-inspired-ideas have a lot in common with the network approach of the IMP-Group. We conceive of a knowledge cluster with the characteristics described above as a specific form of network structure extensively described by authors like Håkansson/Snehota and Johanson/Mattson.¹⁶⁶ The knowledge of a cluster we will refer to as network capabilities in the following passages.¹⁶⁷

Network capabilities and degrees of technological innovation

The most important similarity between the Swedish network perspective and the Marshallian-inspired knowledge clusters can be seen in the recognition that within a network or cluster there exists at the same time stability and variety. Both conditions are crucial for fostering collective learning. In the previous passage, we have focussed on network advantages. However, in this section, we will discuss in how far discontinuous technological change can loosen or even destroy a network structure. Knowledge within a network often follows certain trajectories or paradigms, which can be described as patterns of solution applied to new technological problems.¹⁶⁸ The danger for a network can result of a loss of sensitivity for developments or solution patterns which evolve outside the existing paradigms.¹⁶⁹

In literature there is often to be found a distinction between incremental and radical innovations combined with the hypothesis that in the case of incremental innovations established firms have an advantage whereas in the case of radical innovations, new entrants tend to be the winners. In the network context this means that structure-reinforcing events, which are initiated by dominant players in the current network, can enhance and strengthen the existing bases of competition, while structure-loosening events, which are initiated by peripheral players, can radically change the base of competition.¹⁷⁰ This view is also supported by Ritter and Gemünden who emphasise that to assess the impact of network competence on success the degree of innovation has to be considered.¹⁷¹

We propose that a more differentiated view on types of innovation can give valuable insight in understanding the relation between technological change and network structure. A useful typology of innovation is offered by Henderson and Clark.¹⁷² The authors identify four types of innovations, which are linked to specific changes in knowledge. Products are seen as

¹⁶⁵ See Von Hippel, E. (1988), p. 6 and Schrader (1993), p. 168.

¹⁶⁶ See Håkansson/Snehota (1995) and Johanson/Mattson (1987).

¹⁶⁷ See Foss (1999), p. 5n.

¹⁶⁸ See Håkansson/Snehota, (1995), p. 13 and Dosi (1982), p. 151n.

¹⁶⁹ See Loasby (1999), p. 99 and Håkansson/Snehota (1995), p. 12.

¹⁷⁰ See Madhavan/Koka/Prescott (1998), p. 444-447.

¹⁷¹ See Ritter/Gemünden (1999) pp. 259-270.

¹⁷² See Henderson/Clark (1990) S. 13.

systems being composed of various components. The integration of the different components requires architectural knowledge, which defines the way in which the components are linked to a coherent whole. The design and production of components requires more specialised component knowledge. In the course of the evolution of an industry, one usually observes a process whereby architectural knowledge becomes more standardised leading eventually to the formation of a dominant design. Based on their impact on these kinds of knowledge Henderson and Clark identify four types of innovation:

1. *Incremental Innovation*: Improves component knowledge and leaves architectural knowledge unchanged.
2. *Modular Innovation*: Architectural knowledge unchanged, component knowledge of one or more components reduced in value.
3. *Architectural Innovation*: Component knowledge unchanged, architectural knowledge reduced in value.
4. *Radical Innovation*: Both component knowledge and architectural knowledge reduced in value.

In the remaining part of the paper we will show, how a network structure is affected by the different types of innovation. As an example we will use the market for Programmable Logic Controllers (PLC). We propose the following hypotheses:

H1. Incremental as well as modular innovations tend to enhance the value of a network structure. In both cases most relationships as well as resources are reinforced.

H2. Architectural knowledge brings about a significant change in the structure of a network. Especially the business relationships between the actors are expected to undergo significant changes. The most deteriorating effects on a network can be expected from radical innovations. Both relationships as well as resources of individual firms are heavily endangered.

H3. Sources of incremental innovations are more likely to be found within a network, whereas the more discontinuous innovation types are more likely to originate outside the network.

Effects of technological innovations on the elements of a network

In the network perspective bounded knowledge about the use of resources is spread imperfectly among the actors. The resulting heterogeneity of resources implies that actors differ in their knowledge about the possible uses of resources. Accordingly, innovations may have different effects on the competence and assets of single actors, such as suppliers of components, system integrators and customers.¹⁷³ We will discuss these effects by drawing on the Programmable Logic Controllers (PLC) market, which can be seen as a typical industrial high-technology market.

The Programmable Logic Controllers (PLC) market provides a valuable field for analysis, since it is characterised by interconnected relationships as well as challenged by different types of technological change. Programmable logic controllers can be defined as devices used to implement process control or machine control. They are used by a diverse range of end-users, including applications within the automotive, food processing, chemicals and pharmaceuticals, metal and mining, pulp and paper, refining and water treatment industries.¹⁷⁴ In 1997 the market was dominated by a handful of international companies. These include AEG Schneider Automation, Allen Bradley, Mitsubishi, Omron and Siemens.

¹⁷³ See Afuah/Bahram (1995), p. 51.

¹⁷⁴ The market information is based on Programmable Logic Controller Market Studies of Frost&Sullivan (1996), Automations research Corporation (ARC) (1996) and MarketLine International (1997).

There are a large number of smaller companies, which tend to focus on specific geographic or end-user markets.

The European market for Programmable Logic Controllers (PLC) can be seen as a network of exchange relationships between component suppliers (manufacturers), intermediaries (system integrators, distributors, OEMs etc.) and users. Relationships between these actors are characterised by long-term oriented supplier-customer relationships (e.g. manufacturer-system integrator or system integrator-user relationships) as well by co-operative relationships between suppliers, such as alliances and partnerships. In *Figure 1* we have illustrated possible relationships within such a network by focussing on the main actors: suppliers of components, system integrators/OEMs and customers (end-users).

PLC suppliers deliver their products either directly to the end-users or – most common – indirectly to distributors such as system integrators or OEMs. System integrator firms are increasingly important companies in the PLC market, because end-users rely on them for their process and application expertise. Thus they have the potential to reduce uncertainty resulting from an increasing complexity in manufacturing processes. These firms buy PLCs from the PLC manufacturers, incorporate them into an entire control system and are responsible for designing, installing and often maintaining the process control systems.

In its most basic form, the classical PLC consists of a microprocessor – the architecture – and a number of components, which are inputs and outputs (I/O) to control a particular device and memories. Since the Programmable Logic Controller was invented in 1960 to replace the sequential relay circuits used in machine control, the market for controllers has been characterised by various technological changes. These changes had different implications for the network of suppliers, integrators (and other distributors) and customers. By using the classification of Henderson/Clark we are able to explain the different implications for the various actors.

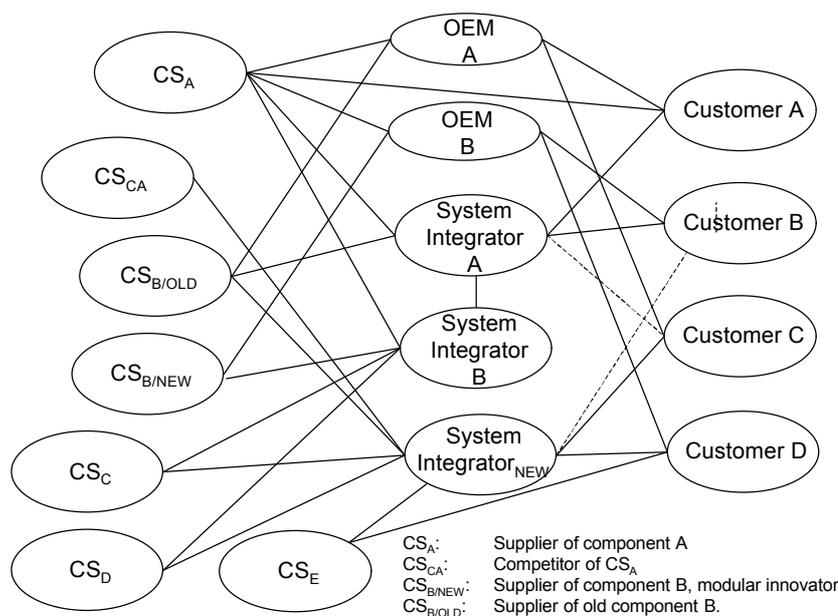


Figure 1: Main Supplier and Customer Relationships of the PLC Network

Technological innovations building on a given architecture where improved step by step along a given technological path. Starting from a ‘black box controller’ as the most basic

control tool, the first step in innovation process was a controller, which can be pre-programmed to control different devices and is therefore more flexible. Furthermore reliability and processing speed of the PLC could be improved. Such changes can be classified as incremental and thereby reinforcing the position of established suppliers. As the sources of these innovations were within the network, all actors could benefit from the innovation, relationships remained unchanged and the network structure was reinforced.

Driven by the need to enable communications between PLCs of different suppliers and by the threat of the industrial computer controlling an automation system more efficiently, PLCs that have third party I/Os were introduced. The third party I/O is a new component in the system, which changes the core design concepts while relationships between them remain unchanged. As a result of this innovation new actors with new resources were integrated in the network. While value for customers was enhanced, the competences of some component suppliers were destroyed. While some relationships – e.g. between established component suppliers and system integrators/OEMs – were destroyed, the value of the network as a whole was reinforced, as exchange with others led to the emergence of new resource combinations.

The introduction of a Personal Computer (PC) into the system represents an architectural innovation since through the PC the way in which the components are linked together has changed. This innovation (called PLC&PC Rack) destroys the usefulness of PLC supplier's architectural knowledge but preserves their knowledge about the product's components.¹⁷⁵ This technological trend presents a critical challenge for established suppliers because much of the firms knowledge is useful and needs to be applied in the new product, but some of what they know may handicap the firm. Customers will benefit from the new possibilities but they face higher uncertainties. Under the current system manufacturers of PLCs, which provide the basis of the system, must be able to guarantee performance to the customer or pay the consequences. Business relationships between established suppliers and system integrators, OEMs and/or customers are now threatened, but new entrants have to overcome switching barriers. However, if established suppliers fail to adopt the new technology their position is strongly endangered, as the change represents a new 'paradigm' and has its source outside the network.

The shift from this architectural innovation to the radical innovation can be observed currently. The introduction of the industrial 'hardened' PC, which is created by the use of soft logic systems, which enable a PC to emulate the task of a PLC in an open hardware format, represents a further step to the complete removal of the PLC from the system with the PC doing all of its tasks. Although there are still some question marks over the robustness of WindowsNT and the use of proprietary software clouds some of the issues of openness, there is no doubt that software is becoming increasingly acceptable in the automation world.¹⁷⁶ The large installed base is likely to slow the breakthrough of the industrial PC somewhat, especially when combined with continuing uncertainty about reliability. It is more likely however, that Greenfield manufacturing sites may take up the opportunity to use entirely PC based control systems, while customers within the network will not switch as long as the old system works. But this is just a question of time. If established suppliers are not able to acquire the necessary technological knowledge during this time the own capabilities will be destroyed, relationships within the network will break down, followed by devaluation of network capabilities and by the failure of the whole network.

¹⁷⁵ Henderson/Clark (1990), p. 10.

¹⁷⁶ See MarketLine International (1997), p. 41.

We suppose that developments as described for the PLC network can be observed in other networks as well. Other case studies and empirical investigations are needed to confirm or reject our hypothesis. In *Figure 2* we have summarized the possible effects of technological innovations on firms, relationships and on the entire network.

	<i>Firms</i>	<i>Relationships</i>	<i>Network</i>
<i>Incremental Innovation</i>	Position of CS_A (Innovator) enhanced, position of CS_{CA} (competitor) deteriorated Value for customer firms slightly enhanced	Relationships remain unchanged	Network structure unchanged Resources of network slightly enhanced
<i>Modular Innovation</i>	Value of resources of $CS_{B/OLD}$ destroyed New Resources are integrated in the network ($CS_{B/NEW}$) Value for customer firms enhanced	Relationships of Integrators with $CS_{B/OLD}$ destroyed. Establishment of relationship with $CS_{B/NEW}$ has to be established. (low transaction costs)	Network structure slightly changed Resources of network enhanced
<i>Architectural Innovation</i>	Value of resources of established integrators threatened New Resources are integrated into the network ($Integrator_{NEW}$) Customer Value enhanced, but period of uncertainty	Relationships of established integrators with component suppliers threatened/destroyed New Relationships with component suppliers and customers have to be established (high transaction costs)	Network structure considerably changed Resources partly sustained, partly destroyed
<i>Radical Innovation</i>	All existing resources threatened/destroyed Value for customers significantly enhanced, but period of strong uncertainty	All relationships threatened/destroyed	Network endangered in its entirety (resources and relationships)

Figure 2: The impact of different types of innovation on firms, relationships and the network

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