

2. Innovation and Industry Dynamics

Schumpeter (1911) puts innovation in the center of his theory of economic development. In the beginning, he linked innovative success purely to the entrepreneurial success of outstanding individuals in an economy. Thirty years later, Schumpeter (1942) – inspired by the development of US industries – identified a significant change in the organization of R&D processes in specialized R&D laboratories of large firms (routinized innovation). And another forty years later, again a significant change had taken place in the organization of R&D. This change refers to the interaction among firms and other innovative actors, such as universities and public research institutes, forming innovation networks. Nevertheless, only since the end of the 1980s has a certain interest in the theoretical explanation of this phenomenon of collective innovation begun to arise in economics and related scientific fields, and the prevailing view of technological knowledge as a quasi public good begun to be challenged. Accordingly, it is not astonishing that we observe differences in firm performance, even in cases where the codified parts of a technology are commonly known. Such differences can (at least partly) be explained with heterogeneous levels of embeddedness in innovation networks (Dosi and Nelson, 2010).

2.1 The Case for Network Embeddedness

The notion of an *innovation network* is frequently used in conjunction with agglomeration concepts such as clusters, industrial districts or (regional) innovation systems. The common underlying idea of these concepts suggests that spatial concentration matters for innovation activities on the micro level and for the related economic development from a macroscopic view. Marshall (1920) studied manufacturing firms that were located in the north of England when he brought forward the argument that their success is related to the localization within an industrial district that conveys the – intended or unintended – exchange of ideas: “If one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas” (Marshall, 1920, p. 271). Within an industrial district, he further argued, knowledge is easily accessible by everyone: “The mysteries of the trade become no mysteries; but are as it were in the air” (Marshall, 1920, p. 271). As sort of a virtuous circle, firms absorb ideas developed by other firms in an industrial district, elaborate on them, learn from them and combine them with their own knowledge, creating in this vein the seed for new ideas

which can be grown into even more ideas spreading all over a district. Marshall's discovery provides an argument for spatial clustering of firms. Furthermore, it shows that specialization within an industrial sector exerts the before mentioned externalities that favor the development of the entire spatially concentrated industry.

In contrast to the specialization argument of Marshall (1920), Jacobs (1970) stresses diversity claiming that the exchange of knowledge between industries is more beneficial than exchange within an industry. Diversity enables a spatial cluster to bring new products to the market that are based on a combination of the variety of knowledge which is found in the local economy, thereby increasing the diversity of products which indicates a high innovation output. Recent work on clustering indicates the importance of knowledge exchange with firms that do not belong to the same cluster. Being embedded not only in local clusters but also in global value chains or sources of knowledge is relevant, above all, for firms, regions and countries seeking to catch up with respect to their innovation performance (Bell and Albu, 1999; Giuliani and Bell, 2005). A purely within-cluster R&D orientation creates the risk of getting trapped in a situation of a lock-in as cluster knowledge tends to become gradually more and more uniform over time (Asheim and Isaksen, 2002) following a possibly unfruitful technological trajectory (Grabher, 1993; Cantwell and Iammarino, 2003). The formation of extra-cluster linkages enables a cluster to prevent this lock-in (Asheim and Isaksen, 2002). In addition, Wuyts et al., (2005) find that too close and stable relations are harmful for learning since they reduce the optimal cognitive distance and hence learning opportunities. The integration of less similar external knowledge is a way of increasing the variety of knowledge in a cluster and to counteract the tendency of moving towards uniformity (Ghoshal, 1987; Fleming, 2001).

Technological breakthroughs possibly require a lower degree of cluster or network integration than a potential "optimal" degree which is suggested by transaction cost economics. Uzzi (1997) explains the paradox character of embeddedness: While on the one hand it helps a firm to adapt to the conditions of an ecosystem, on the other hand it hampers adaptation due to decreasing diversity of partners and knowledge-bases. The feeding of R&D processes with external knowledge raises the quantity and variety of knowledge elements which can be recombined with existing knowledge-bases (Fleming, 2001). However, effective knowledge transfer requires some but not too much of cognitive or technological proximity between industries or knowledge-bases in a region. Frenken, Van Oort and Verburg (2007) find that the higher the *related variety* in a region is, the higher the observed regional growth. Boschma and

Iammarino (2009) confirm that inflows of extra-regional knowledge, which is related (but not identical) to the knowledge-base of a region, is an explanatory factor for regional growth. It is important to keep in mind that innovation does not only come from adding new knowledge elements to the knowledge-base but also from adding new links to knowledge elements (see on that point also chapter 7.4 on modularity). The importance of diversity to the consistent creation of novelty is found in a number of industry studies. For instance, Hoang and Rothaermel (2005) find for the biotechnology industry that the higher the observed fluctuation in R&D partnerships, the higher is the performance of the network. Wuyts, Dutta and Stremersch (2004) discover a similar result for the technological diversity among alliance partners. In contrast, Goerzen and Beamish (2005) find for the case of multinational enterprises that diversity in partners diminishes innovative performance. The preference for diversity, or rather conformity, in partner networks will be dealt with in the empirical study of this thesis.

Research not only influences the development of technologies, but it is the discoveries in research that change the organization of the research process as such. For instance, new connections between disciplines may require close cooperation for exploration and further progress. Acknowledging the advantages of interdisciplinary research is one thing, organizing effective interdisciplinary research is, however, another issue. According to Rosenberg (2009, p. 241), “it is unlikely to be successfully planned. Success in the academic world has often failed when administrators have simply decided to form a committee, or program, of researchers from a variety of different disciplines.” The rate of success is often higher if there is a prevalent impression within a certain discipline that progress can only be made by integrating solutions stemming from other disciplines (Rosenberg, 2009).

While agglomeration and diversity are enablers for the innovative success of groups of firms, they cannot explain alone interfirm heterogeneity in innovative performance. Recent studies raise serious doubts about the existence of costless knowledge spillovers within a local district challenging the public good character of knowledge (Pyka, Gilbert and Ahrweiler, 2009). Gaining a sound understanding of the interaction between actors is seen as more promising for understanding the advantages of local clustering. Industrial districts are conducive for successful interaction as it is generally easier to talk to geographically co-located neighbors than it is to talk to a remote person. However, it is the development of network structures which explains successful agglomeration (Lechner and Dowling, 1999; Pyka, Gilbert and Ahrweiler, 2009). Even in fields from which we may expect that the relevant knowledge is highly

codified, networks as channels and conduits of knowledge transfer play an important role. In fact, “the particular content of the relationships represented by the ties is limited only by a researcher’s imagination” (Brass et al., 2004, p. 795). Breschi and Lissoni (2001) find for the mechanical cluster of the Italian region of Brescia that – despite the relatively high degree of knowledge codification – knowledge diffusion is rather limited to a small group of firms. Medda, Piga and Siegel (2006) discover for Italian manufacturing firms that collaborative R&D increases productivity. Also in science-based industries such as biotechnology, chemistry or computer science, it holds that what is publicly known among experts of the same field is only complementary to more tacit and specific knowledge which is essential for the creation of novelties (Dosi, 1988).

A conceptualization of knowledge which implies that knowledge can be acquired like a glass of *cornichons* from a supermarket shelf – but for free – is being replaced by a concept according to which a firm needs to be embedded in a network to absorb knowledge. On the other hand, it would be wrong to assume that a firm’s knowledge-base is totally private and secret without any evaporating knowledge elements (Nelson and Winter, 1982). In a nutshell, economically valuable knowledge is not flowing freely in the air but necessitates (costly) efforts to gain access and make use of it. Consequently, the network concept has a different connotation compared to the cluster or innovation system theory. The real value of a cluster, or respectively of an innovation system, is a function of the network ties that are created between the actors (Gulati, 1998). Relations spur innovation processes by providing access to the knowledge-base of other organizations, thereby constituting an element of a firm’s organizational capital. For this reason, network embeddedness is a vital asset constituting a firm-specific element of heterogeneity (Granovetter, 1985; Loasby, 2001; Buchmann and Pyka, 2012b). Technological spillovers are not freely available as in the standard models of growth theory but have to be acquired actively by participating in innovation networks. Moreover, Rosenberg (1990) suggests that access to a network of firms is not costless either. Given that a firm seeks to get something out of it, it also has to bring something in. The results of a firm’s own research serve in this sense as a ticket to enter a network.

While access to sources of knowledge requires embeddedness, firms also need to be able to absorb the knowledge that is accessed and exchanged through a network structure (Cohen and Levinthal, 1990). Thus, they need to develop a capacity which enables them to recognize valuable knowledge, to understand it and to make something out of it internally by combining it with existing knowledge. Understanding

this process is part of the answer which is asked in the title of an article by Rosenberg (1990): “Why do private firms perform basic research (with their own money)?”. Investing own money for research would be absurd if knowledge was a quasi-public good, i.e. absorbable without costs “from the air”. This would imply that own research results could not be protected and other firms could simply free ride. This “problem” raises the question about the appropriability of inventive outcomes. Moreover, it is often rather unclear – especially in basic research – if efforts will lead to any meaningful innovation that yields benefits in the form of new products or processes. A high level of uncertainty and the risk that the invested money is sunk without generating returns are strong arguments for a firm not to invest in R&D.

2.2 Learning and Schumpeterian Competition

Network embeddedness for knowledge acquisition is of particular relevance if we assume a Schumpeterian competition. This type of competition is defined as a “process through which heterogeneous firms compete on the basis of the products and services they offer and get selected with some firms growing, some declining, some going out of business, some new ones always entering on the belief that they can be successful in this competition” (Dosi and Nelson, 2010, p. 96). Competition is driven by innovation, adaptation and imitation. Selection is an endogenous process in which the knowledge absorbing and learning capabilities are important selection criteria in that they create winners and losers in competition.

A firm’s abilities to learn, to innovate but also to imitate are regarded as central determinants of industry dynamics in evolutionary economic theories. In competition, two forces are setting the tone, namely idiosyncrasy of firms and market processes which generate profits or losses for firms and are thus selective in terms of survival probability. Learning processes are firm specific but also incorporate a strong collective element (Pyka, 1999). For instance, firms operating in the same industry have similar experiences when they are faced with emerging technological trends. In addition, the search process is a cumulative process: “What the firms can hope to do technologically in the future is narrowly constrained by what it has been capable in doing in the past” (Dosi, 1988, p. 1130). Firms learn from each other through different channels of interaction and from the part of knowledge which was generated within a firm and becomes publicly known (Dosi and Nelson, 2010). This is, however, not sufficient for successfully imitating other firms’ inventions. Also, tacit and idiosyncratic knowledge are essential for the development of any kind of technology,

be it an imitation or an innovation (Polanyi, 1967; Nelson and Winter, 1982). Such knowledge represents constituent elements of firm heterogeneity, yet they are not totally bound to a single firm but can be overarching such as labor mobility. Diverging learning capabilities, the ability to innovate, the adoption of external innovations, different propensities for investments and adaptation of the organizational structure lead to disparities in firm performance (Dosi and Nelson, 2010). Among the enumerated factors, the ability to innovate seems to be the one which is most unevenly distributed within any given population of firms. A confirming indicator is the distribution of growth rates (which is correlated with innovativeness) which is often highly skewed. This observation can be made across industries and sectors (Bottazzi and Secchi, 2003).

Learning is not only a prerequisite for innovation but also plays a role for imitation. Yang, Phelps and Steensma (2010) demonstrate that the original innovator may benefit from imitations which are often improvements of the original idea. The knowledge which is incorporated in the original invention gets recombined with complementary knowledge of the imitating firm. Thereby, a new pool of external knowledge is established which is related to the knowledge-base of the inventing firm. As a matter of fact, this pool contains knowledge which can be easily understood by the originating firm since it has a high degree of relatedness with the originating knowledge-base. Thus, the original innovator rather easily learns from what the recipient firm has added to the original idea. Learning vicariously from other firms is a type of heuristic search. Organizations learn vicariously by observing the behavior and associated performance outcomes of other organizations and imitate behaviors that seem successful and avoid behaviors that seem unsuccessful (Cyert and March, 1963). By observing the innovative activities and outcomes of other organizations' efforts, a firm can develop a cognitive model of how and why new combinations of knowledge are formed without the need for own experiments. Yang, Phelps and Steensma (2010) illustrate the example of Eastman Kodak. This firm developed in the 1980s an innovative light-emitting diode (OLED), a technology which is applied today in computer and TV screens. In the following decade, more than thirty firms (for example Sony and Xerox among others) benefited from this innovation and allocated own resources to further elaborate on the initial invention. This resulted in a number of additional innovations. Kodak, in turn, learned from these improvements of their original idea and was able to create additional own innovations.

This example also confirms the assertion that knowledge is not purely a public good. In order to make meaningful use of the ideas and developments of other actors, own

resources need to be invested. The fact that the transfer of knowledge is not free of costs limits spillovers and at the same time creates incentives for actors to invest in innovative activities. Firms should also be aware of additional learning opportunities which are created when others pick up their ideas and elaborate on them (Yang, Phelps and Steensma, 2010). Also, by introducing the concept of an external knowledge-pool which is related to a firm's original knowledge-base, the concept of spillover becomes highly firm specific in contrast to theoretical considerations which suggest that transfer happens within the same industry (Henderson and Cockburn, 1996) or by applying the same technology (Jaffe, 1986). Thus, innovating firms may even learn from the firms that imitate their products. This positive view of knowledge transfer for the inventor goes beyond a concept which considers knowledge transfer as harmful to the inventor and only beneficial to the imitator, and thereby lowering potential appropriability gains and thus the incentive to invest in R&D projects (Jaffe, 1986; Kogut and Zander, 1992). Learning from imitators and other attempts, such as hiring experts or reverse engineering, qualify as means for extending a firm's knowledge-base, even though they are often not comparably as effective as learning in innovation networks.

2.3 Learning Patterns Shape Industry Structures

The establishment of new solutions frequently necessitates that firms reach beyond the frontiers of established knowledge. The pioneering search strategy differs across firms and industries. It is a function of the individual experience of a firm, its internal organizational rules, its product portfolio, and its suppliers and clients (Dosi and Nelson, 2010). And even though the importance of technological leadership is prevalent, it is eventually on the market place where the successful firms are selected from the less successful ones (Nelson and Winter, 1982). The sources for successful innovation are scattered and industry specific. This is, among others, the reason why I focus in the empirical part of this dissertation on one specific industry-network composed out of automotive firms. Industries comprise firms in this approach not because they share ex-ante a common technology, managerial techniques or potential customers, but because common characteristics emerge through the interaction between firms. While formal R&D investments may play a role for developing new goods and services, it is a firm's learning capability that can make the difference in performance (Freeman, 1994). Firms are learning organizations which learn from various sources, including the environment, their rivals as well as from their own successes and failures. Competitive success is thus a function of learning success. In addition, the learning process as such is specific and related to the underlying

technological paradigm. Consequently, the evolution of an industry is shaped by the learning patterns (Dosi, 1988).

Learning in networks can be referred to as “social learning” which means that actors learn from others by observing their behavior and above all by directly interacting with them. This type of learning is widespread in nature and is hence expected to be advantageous in the evolutionary process of species. To a large extent, knowledge can only be acquired within a social context and it is often the cheapest way since it reduces efforts and risks which are prone to trial and error learning of own R&D. Yet, there is still the risk that things are learned which are misleading, outdated or not fitting to a firm’s knowledge-base. Rendell et al. (2010) organized a simulation tournament on learning strategies with the aim to identify the best performing strategy in competition. In this game, actors could learn or imitate decisions from other actors and the simulated agents could choose between three possible moves in each round, namely innovate, observe and exploit. The innovation strategy consisted of asocial learning which refers to learning through interaction with the environment. Trial and error would be an example for this category. The second strategy, observe, represented the social learning strategy which allows actors to imitate the behavior of other actors by observation or by interaction. The last strategy, exploit, referred to the performance based on an agent’s own repertoire. The result of this experiment demonstrates that social learning is a remarkably successful strategy, leading to the highest payoffs even if the costs for asocial learning are not higher than costs for social learning. The winning strategy in the experiment relies almost solely on social learning even though the established view suggests that social learning should be applied occasionally only in order to avoid the absorption of irrelevant or misleading knowledge. It is well known from evolutionary biology that the species which can exist with the lowest level of resource demand has the highest chances to survive. This concept transferred to and tested with the social learning experiments suggests that the dominant strategy is the one which keeps working with the lowest frequency of the very resource intensive asocial learning (Rendell et al., 2010).

2.4 Conclusions

If we consider knowledge as a (partly) private good rather than a (pure) public good, then there are learning opportunities or rather necessities for firms which are costly and time consuming. We can conclude that “industrial performance and industrial structures are endogenous to the process of innovation, imitation and competition”

(Dosi, 1988, p. 1157-1158). Learning is related to the exploration of particular fields of (perceived) technological opportunity, to the elaboration of search routines and skill improvement in developing and producing new solutions. Differences in the ability to learn and to innovate are main drivers for asymmetries in industry structure. Firms which come up with successful innovations are able to improve their position in competition.

The diffusion of an innovation and the imitation by competitors should in theory allow all firms to catch up which would result in a convergence process and finally in a balanced industry structure. However, the extent to which a convergence process actually takes place depends on individual firm capabilities limiting the overall tendency for convergence. Often, even a process of increased divergence rather than convergence takes place. The best performing firms forge ahead and force low performing ones to leave the market, a process which increases the aggregate performance of the industry (Dosi, 1988; Rendell et al., 2010). Learning capabilities are not the only technology related feature which influences the industry structure. Also different technological opportunities influence the extent to which the better leaning firms can exploit the potential to improve their performance. Within an environment that offers many opportunities the good learners can distinguish themselves more easily from the bad learning firms which are consequently faced with a high selective pressure. The emerging result is a concentration in industry structure diminishing the chances for firms that are lagging behind to survive (Dosi, 1988).

Static, formal and closed ways of firm organization hamper the process of mutual learning. Instead, open boundaries enable firms to gain access to the external sources of innovation: The networks of research institutes, suppliers, customers and competitors (Powell, 1990). Openness not only concerns firm boundaries but also network boundaries in order to channel new knowledge to the network and increase its variety. Various studies suggest that there is a positive correlation between the intensity and quantity of cooperation in a sector and its R&D intensity, respectively technological progressiveness (cf. Freeman, 1991 and Hagedoorn, 1995). To make use of the learning opportunities which networks provide, firms need to invest in their absorptive capacities and learning capabilities.



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