Computational Analysis of Firms' Organization and Strategic Behaviour

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INTRODUCTION

Knowledge has become a crucial asset in modern production systems, and its creation has become a key process in order to sustain or increase competitiveness. The ensuing shift toward a knowledge-based economy has amplified research interests in geographical clustering of firms, for geographical proximity is supposed to ease inter-organizational learning.

Indeed, there is substantial empirical evidence claiming that firms located in geographical clusters are more likely to learn and innovate than isolated firms (Audretsch and Feldman 1996; Baptista and Swann 1998; Baptista 2000; Wennberg and Lindqvist 2008). However, this renewed attention to the subject of geographical proximity highlights how far we are from having a clear understanding of its influence on inter-organizational learning and innovation (Boschma 2005; Torre and Gilly 2000). In general, geographical proximity *per se* is not considered a sufficient condition for learning to take place (Boschma 2005: 62), though it is clearly able to strengthen other factors that facilitate learning processes (Boschma 2005; Boari *et al*. 2004; Breschi and Lissoni 2005; Greeve 2005). Many scholars starting from different perspectives converge to agree that all concurring factors should be related to one another in order to construct a theory of clustering processes where learning has a key role (Torre and Rallet 2005; Knoben and Oerlemans 2006; Malmberg and Maskell 2002: 429).

This chapter aims to make a contribution by investigating the relationships between geographical proximity and rivalry with respect to inter-organizational learning and knowledge creation. This is quite unusual in the literature, for most theoretical developments and empirical tests have focused on inter-firm cooperation, whereas far less attention has been paid to the interplay of geographical proximity, rivalry and learning processes.

This orientation is quite surprising, for rivalry is at the very heart of the concept of geographical cluster as a spatially concentrated group of firms that operate in the same industry. Indeed, claims that 'knowledge in clusters is created through increased competition and intensified rivalry' (Malmberg and Power 2005: 412) are widely shared.

In our contribution, we wish to explore the relationships between rivalry and geographical proximity at the very level of contacts between individual firms. In particular, we wish to highlight the influence of geographical proximity on rival identification, on the comparison of their knowledge and on the consequent elaboration of a strategy.

Our firms are assumed to be sufficiently small to be led by one single decision maker. Thus, all concerns regarding individual bounded rationality apply straightforwardly to organizational decision making.

In order to reproduce the interactions between firms, we made use of an agent-based model where the strategic choices of rival firms are derived from general assumptions on competitive behavior and learning processes. The aim of the model is to investigate the co-evolution of firms' knowledge, strategies and performances.

The rest of this chapter is structured as follows. The second section provides the theoretical and conceptual framework of our work. The third section explains the elements of the model. The fourth section illustrates the experiments and their results. The fifth section concludes.

THEORETICAL FRAMEWORK

According to Sorenson and Baum (2003) the last few years have witnessed a rapid rise in interest in the topics of place and space in the social sciences. Economists, sociologists and strategy scholars have become particularly interested in studying the implications of the spatial distribution of firms for economic growth as well as its consequences on knowledge production and diffusion. In general, their assumption is that a critical mass of co-localized firms can promote knowledge production and circulation (R. Cowan *et al*. 2004).

In particular, economic geographers have pointed out a need to understand the relationship between geographic proximity and the processes of localized learning and innovation, a relationship that has been overseen in the economic conceptualization of knowledge as an externality that spreads pervasively within a spatially bounded area (Giuliani 2007) and can be easily reproduced (R. Cowan *et al*. 2004). A reconsideration of the nature of knowledge and of the problems connected to its reproduction and diffusion has increased the concern about other non-spatial dimensions of proximity relevant in promoting knowledge production and circulation (Boschma 2005; Breschi and Lissoni 2005; Knoben and Oelemans 2006; Greeve 2005). While geographic proximity is the least ambiguous concept involved (Knoben and Oerlemans 2006), its explanatory power has been reduced by the possibility that organizational and relational proximities surrogate its effects (Gallaud and Torre 2005; Torre and Rallet 2005). These different dimensions of proximity should be better specified and related to one another (Boschma 2005: 62; Greeve 2005).

Contrary to economics, the strategic perspective has rarely considered geographical proximity *per se* as a factor enabling learning processes. Rather, it has considered geographical proximity as a dimension promoting other mechanisms, such as cooperation and rivalry, that may facilitate learning processes. These mechanisms are at the very heart of the concept of a geographical cluster as a spatially concentrated group of firms that compete in the same or related industries and are connected through a set of vertical and horizontal relationships (Porter 1990, 1998).

Although this general framework addresses both cooperation and competition, researchers mainly focused their attention on inter-firm cooperation induced by geographical proximity—see Knoben and Oerlemans (2006) for an extensive review—and its consequences on learning processes (Dyer and Nobeka 2000; Doz 1996; Inkpen 1998; Inkpen and Crossan 1995; Kale *et al.* 2000; Khanna *et al.* 1998; Powell 1998; Simonin 1999). Far less attention has been paid to the impact of geographical proximity on rivalry and competition, as well as on their combined consequences on organizational learning and innovation. The only exceptions—which do not address the issue of geographical proximity, anyway—are the studies on inter-organizational collaborations among rivals and learning processes (Dussauge *et al.* 2000).

These considerations suggested us to focus on rivalry. More specifically, the ensuing subsections deal first with the relationship between geographical proximity and rivalry and, subsequently, with the relationship between rivalry and learning.

Geographical Proximity and the Identification of Rivals

On the relationship between geographical proximity and rivalry, scholars have expressed two opposite views. On the one hand, long-term observers of industrial clusters have noted that clustered firms exhibit more competition than non-clustered firms (Becattini 1990; Dei Ottati 1994; Enright 1991). In fact, according to the theory of industrial organization rivalry involves a large number of local firms committed to a fight of all against all (Piore and Sabel 1984). Allegedly, this contributes to the competitive advantage of a geographical area and of the firms clustered on it (Porter 1990, 1998; Porter *et al.* 2000).

On the other hand, researchers from the resource-based view claimed that geographical proximity allows an extreme division of labor within the cluster, and consequently, firms' specialization. Thus, this reasoning suggests that rivalry is limited to a few competitors (Lazerson and Lorenzoni 1999). Unfortunately, both interpretations lack any empirical verification.

A further source of confusion is the fact that too many researchers on geographical clusters have taken rivalry and competition as synonyms. In reality, since the early days of economic thinking the term competition has been used to identify firms that depend on the same resources (Baum and

Korn 1996: 225). On the contrary, rivalry has been interpreted as a conscious struggle by each individual firm to establish its own supremacy in a specific market (Scherer and Ross 1990). Thus, rivalry and competition do not necessarily coincide.

Competition has been neglected because it is an "under-socialized" phenomenon occurring among actors that are anonymous to each other (Lomi and Larsen 1996: 1293). Competition would be determined by market forces not subject to the conscious control of individual firms (Baum and Korn 1996: 225). Consequently, it would not be influenced by geographical proximity (Torre and Gilly 2000).

However, rivalry does not deserve the same treatment. Albeit of the same relational nature (Baum and Korn 1999; Korn and Baum 1999) as market interactions between dyads of firms (Chen and McMillan 1992; Chen 1996: 100), rivalry depends on firm-specific competitive conditions (Baum and Korn 1996).

Among the two separate approaches to the study of rivalry, the rational-economic and the cognitive managerial (Baldwin and Bengtsson 2004; Chen 1996; D. Miller and Chen 1996; Farjoun and Lai 1997), it is the last one which contributed to the exploration of the role of geographical proximity as an explicit and implicit criterion to "market construction". According to Porac and Rosa (1996: 372), 'Defining rivals is not so much a matter of overt behavior as it is one of managerial attention and discrimination'. And as for Porac *et al.* (1995), 'Rivalry occurs when one firm orients toward another and considers the actions and characteristics of the other in business decisions, with the goal of achieving a commercial advantage over the other'. Consequently, rivalry implies mutual recognition and occurs only between paired organizations that are each identifiable by the other one (Lomi and Larsen 1996: 1293).

In rivalry, but not in competition, cognitive processes matter. While competitors may be regarded as a nebulous collective actor, rivals must be identified and comparisons with each of them must be made. Cognitive processes make rivalry a localized phenomenon. In fact, several authors (Baum and Haveman 1997; Baum and Mezias 1992; Gripsrud and Gronhaug 1985; Lant and Baum 1995; Porac *et al.* 1995) claim that firms are most likely to identify neighboring competitors as rivals. A quite common explanation is the observability argument (Cyert and March 1963), claiming that geographically proximate firms are most likely to be noticed and observed because proximity increases the availability of information and provides an incentive to attend to it (Porac *et al.* 1995).

However, Boari *et al.* (2003) did not find such a simple relation between rivalry and geographical proximity. These authors showed that, in an Italian cluster of producers of packaging machines, rivals were not necessarily selected among the competitors within the cluster. On the contrary, most rivals were identified among firms located outside the cluster. However, they also found that whenever firms did not cite any local rival, the total number of rivals they gave was consistently smaller. Thus, their research suggested a more complex relationship between geographical proximity and identification of rivals.

Boari *et al.* (2004) advanced the idea that sharing geographical space with rivals may help to extend managerial representations, spreading entrepreneurs' monitoring attention over a larger number of rivals. This can be readily explained if one accepts that geographical proximity eases the consideration of rivals, and that entrepreneurs are boundedly rational decision makers. Then, their fixed amount of cognitive resources can be employed to attend to either a large number of geographically proximate rivals, or a small number of geographically distant rivals, or any combination of both.

Geographical Proximity and Learning Processes

The relationship between rivalry and learning has been neglected by the majority of the literature on inter-organizational learning (Ingram 2002; Kim and Miner 2007). In fact, in the few studies on the impact of rivalry on learning, rivals have been aggregated (Ingram and Baum 1997; Aharonson *et al.* 2007). On the contrary, dyadic relationships should be considered (Darr and Kurtzberg 2000).

However, the studies on inter-organizational learning and, before them, those on vicarious learning—i.e., induced by others' experiences (Bandura 1977; Manz and Sims 1981; Gioia and Manz 1985)—are indirect references to rivalry. A notable finding of these studies is that when learning is stimulated by the experiences of others, similarity is an orienting principle to choose from whom to learn (Darr and Kurtzberg 2000). In fact, similarity reduces information uncertainty (Farjoun and Lai 1997) creating a context of understanding. Since rivals are similar, their experiences are naturally salient (Ingram 2002).

In particular, strategic similarities such as market overlap and product commonality are useful to identify the competitive arena and to influence information flows and learning processes (Porac *et al.* 1989). Similarity in strategy is expected to have its greatest impact on knowledge transfer (Darr and Kurtzberg 2000), at least because it is the main criterion to identify a set of comparable firms that offer experiences useful to define one's own behavior and role (White 1981; White and Eccles 1987).

Cognitive distance is still another type of similarity, which is crucial to identify the rivals to imitate. Cognitive distance measures the different way to perceive, interpret and evaluate the world by two actors (Nooteboom 1992, 1999). The notable feature of cognitive distance is that it be neither too high nor too low for learning to take place. In fact, too high a cognitive distance means that the two actors have such different mental categories that each of them is unable to understand what the other is doing. At the other extreme, too low cognitive distance means that the two actors are so similar, that they have nothing to learn from each other.

The attention paid by many scholars to the concept of similarity implicitly concedes that, through monitoring and comparison, rivalry influences the learning processes (Malmberg and Maskell 2006). However, some scholars have expressed doubts about the quality of what can be learned from rivals. First of all, rivalry discounts the idea that learning from the experience of others may be less important than learning by direct search and experimentation. Moreover, learning by monitoring and comparing (as in rivalry) is considered to contribute less valuable knowledge with respect to learning by interacting (as in collaboration) (Lane and Lubatkin 1998). In fact, establishing comparability through sharing of strategic and cognitive repertoires is supposed to give access only to codified knowledge, whereas interacting with the other organizations may allow one to understand the more tacit components of knowledge.

Geographical proximity is supposed to ease learning. Boari *et al.* (2003) suggest that the depth of the comparison with rivals increases with the geographical proximity of rivals. Geographical proximity could increase the variety that firms perceive in the environment (Nooteboom 2006) and enlarge the number of strategic aspects that firms take into consideration (Bogner and Thomas 1993). In fact, when firms observe distant rivals the complexity of their cognitive representations gets lost (Morgan 2004), both because distance weakens the collection of information and their interpretation (Ghoshal and Kim 1986) and because it decreases the speed of any response (Yu and Cannella 2007).

However, some authors suggest that geographical proximity may have a negative side effect. In fact, if learning is limited to proximate rivals, myopia is likely to ensue (Levitt and March 1988; Levinthal and March 1993).

THE MODEL

We constructed a model of competitive interactions between clustered firms that enlarge or shrink their knowledge while undertaking strategic actions with respect to their rivals. This section illustrates the building blocks of our model and, in its final part, how they are connected to one another.

The Knowledge of Firms

We assumed that knowledge articulates into *knowledge fields*. Each knowledge field is a combination of a *product* and a *market*. For instance, if a firm produces one product A for two markets 1 and 2, this knowledge is expressed by two knowledge fields: one for the product A and market 1, the other for the product A and market 2.

Figure 7.1 illustrates knowledge fields as parallelepipeds composed by a product and a market. The number of knowledge fields owned by a firm is not constant with time. In fact, firms can start to operate in a new field, or

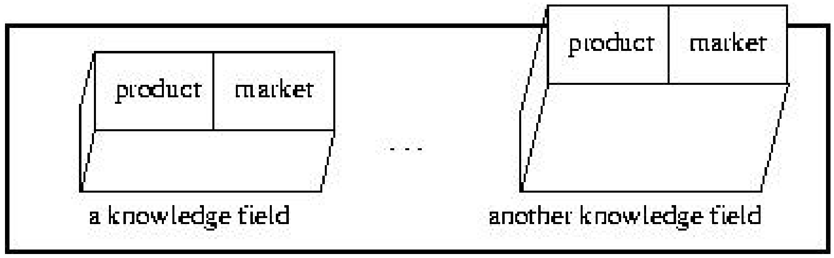

Figure 7.1 A firm's knowledge is entailed in knowledge fields, represented by parallelepipeds. Each knowledge field spans a product and a market. The height of the parallelepiped represents the depth of knowledge in a specific field.

they can leave a field if their managers deem that it is no longer worth pursuing. However, since we are modeling small firms with a limited managerial attention implied by human bounded rationality (Simon 1947), we assume the existence of a threshold on the maximum number of knowledge fields that a firm can manage.

Knowledge fields are characterized by a *depth*. The depth of a knowledge field owned by a firm represents how good a firm is in that field. In Figure 7.1, depth is represented by the heights of parallelepipeds.

The depth of knowledge decays with time or, conversely, is increased by efforts to develop in-house knowledge or by the imitation of rivals. Our model reconstructs the efforts to create, imitate and deepen knowledge fields against a natural tendency of knowledge to vanish with time.

The existence of a particular knowledge field, as well as its similarity to other knowledge fields, is common knowledge (Malmberg and Maskell 2002: 439). This means that all firms know that certain products exist and that they are sold in certain markets.

However, only the firm that owns a particular knowledge field knows its depth exactly. The other firms know only a fraction of this depth, depending on their geographical proximity. The farther away they are, the less they know concerning how a certain product is actually made and sold in a certain market (Bogner and Thomas 1993; Boari *et al.* 2003). We assume that depth decreases linearly from its original value, attained at maximum geographical proximity, down to zero for two firms that are as far as possible from one another as is allowed by the model.

Rivals' Identification and Geographical Proximity

Rival firms are selected among those firms whose knowledge is sufficiently similar. Similarity is measured by pairwise comparison of one's knowledge fields with those of a potential rival.

In particular, for each pair of knowledge fields it is observed whether they concern the same product (similarity ½), or they deal with the same market (similarity ½), or both (similarity 1). The sum of these numbers is normalized to the [0,1] interval to yield an index of the similarity of the knowledge of the two firms.

Our model rests on the assumption that considering a rival requires some cognitive effort by the main manager of a small firm, whose maximum cognitive effort is limited by the manager's bounded rationality (Simon 1947). In accordance with empirical findings by Boari *et al.* (2003), the cognitive effort for entertaining a rival can be assumed to decrease with physical proximity.

We shall assume that each firm entertains a list of rivals such that the sum of the cognitive efforts expended to entertain them is lower than an amount specified by an exogenous parameter. By this assumption, since cognitive effort decreases with physical proximity, firms who focus on geographically close rivals may typically consider a large number of rivals. This result is in accordance with our preliminary empirical findings (Boari *et al.* 2003).

Cognitive Distance from Rivals

At each simulation step, a firm picks up a rival at random from its list of current rivals. For each pair constituted by one of its knowledge fields and one of the rival's knowledge fields, it evaluates the cognitive distance between them.

The cognitive distance between two knowledge fields is measured by the extent to which knowledge fields do *not* overlap: Identical knowledge fields have cognitive distance 0; knowledge fields with identical products (markets) but different markets (products) have cognitive distance ½; knowledge fields with different markets and different products have cognitive distance 1.

Note that the fewer the rivals, the less likely that the evaluation of cognitive distance is different at each step. Conversely, firms with many rivals are more likely to measure diverse values of cognitive distance, depending on which rival they are picking up.

Evaluation of Performance

Past performances are considered a major explanatory variable of organizational learning (Cyert and March 1963; Lenvinthal and March 1981). However, measuring performances of changing knowledge is not a trivial task. In fact, since the outcomes of innovative activities cannot be foreseen, ex ante evaluation by means of utility functions makes little sense.

An alternative route is to conceive the usefulness of a piece of knowledge as deriving from its connections to other pieces of knowledge (Villani *et al.* 2007). For instance, a possible explanation of the success of innovations is their ability to connect with other products creating new markets (see Box 7.1). Following this interpretation, we are led to ascribe the performance of knowledge to its ability to bridge structural holes (Burt 1992).

Let us interpret common knowledge as a directed weighted graph, where nodes are knowledge fields and edges are common instances of business elements. Thus, the ability to bridge structural holes is measured by betweenness centrality:

$$g_i = \sum_{s \neq i \neq t} \frac{\sigma_{sit}}{\sigma_{st}} \quad (7.1)$$

where σ_{st} is the number of minimum paths between node s and node t, while σ_{sit} is the number of minimum paths between node *s* and node *t* passing through node *i*.

Figure 7.2 illustrates a network of knowledge fields, each composed of a product and a market. Knowledge fields are inscribed in dashed circles, which represent the firms that own them. A link is there whenever two knowledge fields concern the same product, or the same market. In general, the knowledge of a firm may span several fields. Occasionally, different firms may have the same knowledge field.

In Figure 7.2, firm ε owns knowledge fields that constitute the only bridge between the knowledge fields of firms α, β on the one side, and the knowledge fields of firms γ, δ on the other side. Thus, these knowledge fields are essential for the knowledge in the economy to be connected. It is knowledge fields of this kind that, according to Equation 7.1, have a high betweenness centrality and therefore a high performance. On the contrary, the only knowledge field of firm γ has a low betweenness centrality.

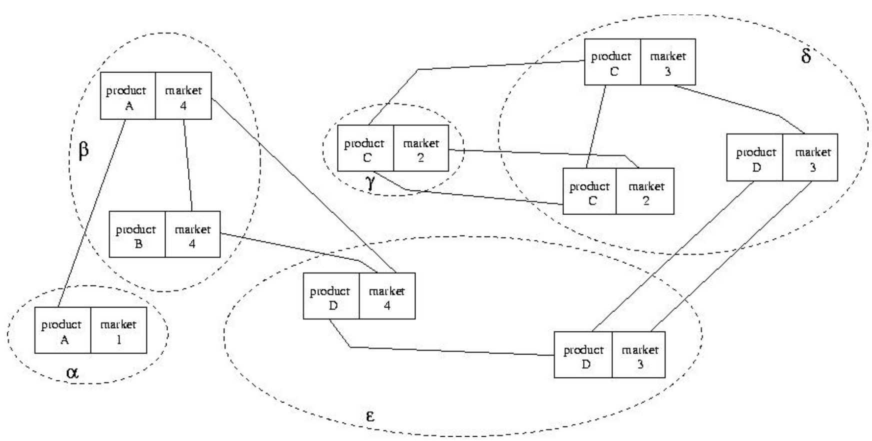

Figure 7.2 A network of knowledge fields (solid squares) owned by firms (dashed circles). Products are labeled by the letters A, B, C, D. Markets are labeled by the numbers 1, 2, 3, 4. Firms are labeled by the Greek letters α, β, δ, ε.

Note that by measuring performance by means of betweenness centrality we never assign a positive performance to novel knowledge. In fact, novel knowledge consists of creating a novel product, or a novel market, or both. Thus, in the network of knowledge fields an innovative field corresponds to an isolated node or a node with one single link to the other nodes. In Figure 7.2, the knowledge field owned by firm α is one such case.

Both theoretical reasons and empirical investigations suggest that innovations are made by applying old knowledge onto uncharted domains (Nooteboom 2000). Thus, henceforth we shall assume that novel knowledge fields are constructed either by creating a novel product or by creating a novel market, but not both. So all nodes representing novel knowledge are created with one link to another node.

Box 7.1 Actor Network Theory

Actor network theory (ANT) is a sociological theory where the development and acceptance of artifacts and technologies is understood in terms of the interests of various social actors. ANT stssssresses that different actors may have a different understanding of the properties and potentialities of novel artifacts and technologies; nonetheless, their interests may align to support a particular innovation. In their turn, artifacts and technologies change the balance of powers and the network of relationships between social actors. Equipped with this view, scholars working with ANT have provided historical reconstructions where the development of particular artifacts and technologies is described as the—sometimes unintended—consequence of the work of a large number of actors rather than the visionary plan of an isolated genius (Hughes 1986).

In order to understand how ANT relates to our measure of performance, let us consider the following empirical investigations of successful innovations:

> Law (1986) explained the rise of Portuguese ability to exert long-distance control in the fifteenth century through certain simplifications of medieval astronomy that made it available to navigators, a new design of vessels that enabled them both to carry large freights and to resist armed attacks, and increased reliability of mariners through extensive drill. The Portuguese ability to exert control as distant as India would derive from the ability of a small committee set out by King John "The Navigator" to embed the results of medieval astronomy in a few simple tools that could be operated without prior knowledge of astronomy.

Latour (1988) described the rise of Louis Pasteur and the diffusion of vaccination as a collective outcome of several forces, of which the most important ones were the hygienist movement, that was seeking scientific support for its urban planning prescriptions, the surgeons, who could improve the effectiveness of their art by means of local disinfection, and the military, which did not want its soldiers to be decimated by tropical diseases. On the contrary, physicians opposed vaccination for several decades, until Pasteur proposed post-infection treatments and, most importantly, the state provided a role to physicians in the compulsory vaccination of the French population.

In both cases, we see one or a few actors—Louis Pasteur, King John and his astronomers—who were able to place themselves in a position from which they

(continued)

Box 7.1 (continued)

could exert a great influence because powerful allies are there to wait for their innovations—the hygienists in the case of Pasteur, the merchants with their improved vessels in the case of King John.

A consequence that we may drawn is that successful innovations are those that are able to bridge between existing bodies of knowledge. From this insight our choice follows, to measure the performance of a knowledge field by means of its betweenness centrality in a graph where nodes are knowledge fields, connected by edges if they have a product or a market in common—see e.g. Figure 7.2.

Inter-Organizational Learning

At each simulation step, the depth of knowledge fields decreases according to an exogenous decay rate. If the depth of a knowledge field decreases below a minimum, that field is canceled. However, a firm can increase the depth of its knowledge field, or it can even create new ones.

We distinguish four kinds of learning actions, that affect the depth of knowledge fields. The received literature makes the two following distinctions:

- *Experiential learning* can be distinguished from *vicarious learning* (Bandura 1977; Manz and Sims 1981; Gioia and Manz 1985). While the former rests on personal experience, the second takes place through the experience of someone else.
- *Exploration* of novel knowledge can be distinguished from *exploitation* of existing knowledge (March 1991).

Since these distinctions regard different aspects of learning, we can fruitfully cross them with one another as in Figure 7.3. *Experiential exploration* is the creation of novel knowledge out of personal experience. This knowledge is novel for its creator as for the whole economy. *Vicarious exploration* occurs when a firm borrows a piece of knowledge from another firm, that is novel for it though it is not novel for in the economy. *Experiential exploitation* occurs when a firm deepens its existing knowledge disregarding the experience of other firms. Finally, *vicarious exploitation* occurs when a firm deepens its own knowledge by learning from the experience of other firms.

In our model, firms select one among the aforementioned actions according to the values attained by performance and cognitive distance. In particular, experiential learning is undertaken if either (i) a firm has no rival, or (iia) no rival has any knowledge field with greater depth than one of its knowledge fields and (iib) low or intermediate cognitive distance (i.e., equal to 0 or 0.5) from it. In fact, in these conditions a firm has nothing to learn from its rivals so it prefers experiential learning to vicarious learning.

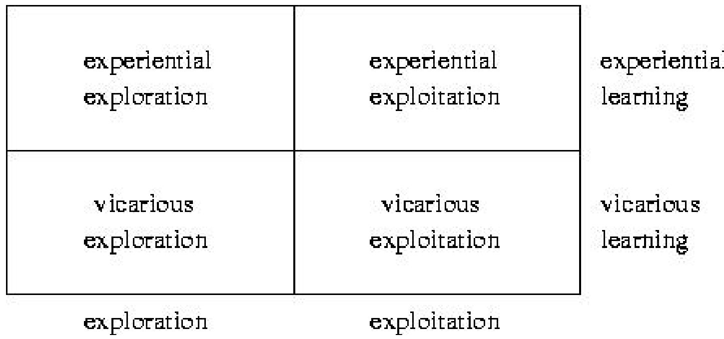

Figure 7.3 Experiential exploration, experiential exploitation, vicarious exploration and vicarious exploitation.

If experiential learning is selected, then the choice between experiential exploration and experiential exploitation is made depending on performance. In fact, poor past performances and rivals' pressure give firms the impetus to undertake exploration (Tushman and Romanelli 1985; Swaminathan and Delacroix 1991). On the contrary, average or high performances are most often responsible for exploitation, because: (1) they induce managers to believe they have gotten it right; (2) they induce managers to interpret past performances as a sign that less vigilance and less environmental scanning or search are required; (3) they assure leaders the status and resources to perpetuate their power; (4) they induce managers to attribute success to their own actions (D. Miller and Chen 1994; Lant *et al*. 1992). If performance cannot be evaluated because a knowledge field is not bridging between other pieces of knowledge, then the choice between experiential exploration and experiential exploitation is made randomly, with a probability equal to the ratio of the level of poor performance to the level of high performance.

Experiential exploration creates a novel knowledge field by exchanging the product or the market of an existing field with a novel one. The newly created field has a depth drawn randomly from the interval between zero and the depth of the starting field.

If, with the newly created field, the number of knowledge fields exceeds the maximum allowed, then the starting field is destroyed.

Experiential exploitation deepens the depth of an existing knowledge field by an amount equal to the decay of knowledge. It merely hampers depth to decrease.

Vicarious exploitation takes place between any pair of knowledge fields, one for the subject firm and one for its rival firm, such that their cognitive distance is low or intermediate (i.e., equal to 0 or 0.5) and the knowledge field of the rival firm has greater depth. Whenever this occurs, the subject firm increases the depth of its knowledge field by an amount equal to the depth of its rival's field, decreased by an amount inversely proportional to geographical proximity, and multiplied by the complement to one of the cognitive distance between the two knowledge fields involved. In practice we assumed that vicarious exploitation takes place whenever a firm meets a rival with a sufficiently similar knowledge field to be understood, and more competent than oneself on that field.

Vicarious exploration has a different rationale, for it consists in the creation of a new knowledge field out of its observation in a rival's knowledge. As in the case of vicarious exploitation, cognitive distance should not be too high (i.e., equal to 1) otherwise a rival's knowledge would not be understood. However, cognitive distance should not be too low either (i.e., equal to 0), for a new knowledge field that is too similar to the existing ones would be uninteresting. Thus we require intermediate cognitive distance for vicarious exploration to take place (Nooteboom 1992, 1999). More precisely, a rival's knowledge field that does not exist in one's knowledge can be imitated only if it has intermediate cognitive distance (i.e., equal to 0.5) with at least one of one's knowledge fields.

The Flowchart

The previous building blocks are arranged together in a sequence of operations illustrated in Figure 7.4. For simplicity, only two firms have been considered.

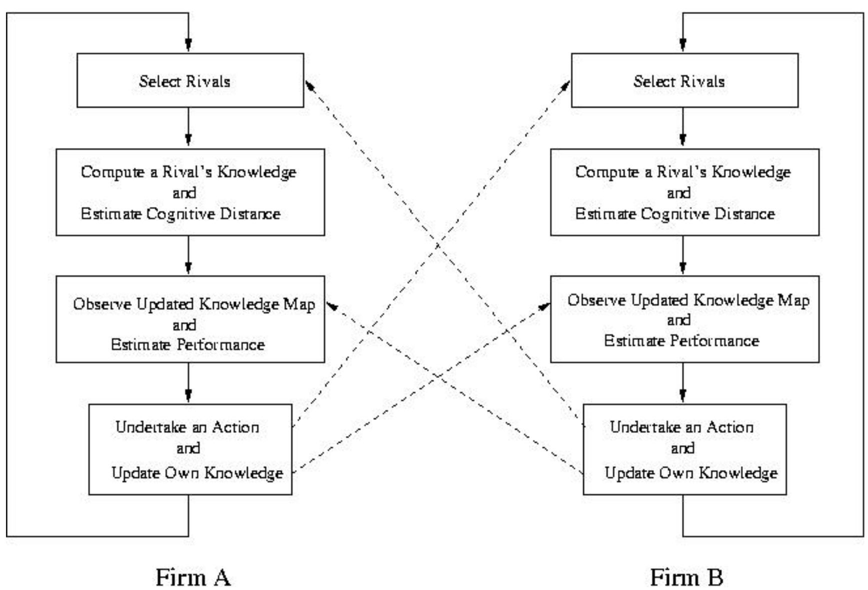

Figure 7.4 The sequence of operations carried out by a firm A and their relationships with the analogous sequence carried out by another firm B. Influences of a firm on another are marked by dotted arrows.

Consider firm A in Figure 7.4. Top to bottom, the squares describe the sequence of operations that it carries out. First, it identifies its rivals. Subsequently, it randomly selects one of them and estimates the cognitive distances of its knowledge fields. Then it observes the graph of all knowledge fields present in the economy and calculates the performance of its own fields. Finally, it undertakes an action and, consequently, its own knowledge changes. Before repeating this sequence, firm A must wait until firm B has gone through a similar sequence.

Note that the selection of rivals and the evaluation of performance depend on the actions that were undertaken by all other firms in the previous steps. This is the meaning of the dotted arrows in Figure 7.4.

Initialization

Firms are placed on a torus obtained from a square of 100 x 100 pixels. Firms do not move on this space.

In order to evaluate the effects of clustering, both clustered and isolated firms are considered at the same time, and the number of isolated firms is set equal to the number of clustered firms. Isolated firms are distributed uniformly in space.

Our model allows one to choose the number of clusters, the number of firms in each cluster and the geographical proximity of clusters. The number of clustered firms is obtained by the product of the number of firms in a cluster by the number of clusters. The geographical proximity of clusters depends on the variance of a normal distribution of the position of clusters.

Firms are created with an initial wealth. Following the empirical evidence on the distribution of (however measured) size of firms, wealth is initially distributed according to a Zipf law (Axtell 2001; Gaffeo *et al.* 2003). The values obtained by the Zipf distribution have been scaled by the length of the square from which the torus is derived, where firms are placed (see the aforementioned). In fact, the absolute size of firms depends on the size of their market, and the size of the world where firms operate is a proxy for market size.

Firms are initialized with a random number of knowledge fields drawn from a uniform distribution. The maximum number of knowledge fields per firm is a parameter of the model. The initial depth of knowledge fields is drawn randomly in the [0,1] interval.

The number of different products and the number of different markets by which these initial knowledge fields are composed are also drawn from a uniform distribution. The maximum number of initial products and markets is obtained multiplying the number of knowledge fields per firm by the number of firms.

Population Dynamics

Each learning action (experiential exploration, experiential exploitation, vicarious exploration, vicarious exploitation) has a cost, which decreases the wealth of firm. Wealth is also subject to a natural decay according to a fixed rate. However, each knowledge field provides a performance to its firm, which increases its wealth.

If the wealth of a firm becomes lower than the cost of a learning action, the firm dies. A dead firm is immediately replaced by a new one that occupies the same geographical position. Its wealth and knowledge are initialized as discussed previously.

THE EXPERIMENTS

We carried out simulations in order to compare the actions undertaken, results obtained and knowledge learned by clustered firms with respect to isolated firms. Since we were interested in long-term regularities, for any chosen parameters combination we let the model run with different seeds for 1,000 steps and observed its behavior at simulation end. Reported results refer to 1,000 steps after allowing transitory dynamics to settle down during the initial 100 steps.

The Choice of Parameters

Our simulations highlighted that clusters of firms are efficient only if they reach a critical mass in terms of the number of firms that they entail. According to our model, only if a cluster entails at least 40–50 firms do these firms obtain substantial advantages with respect to isolated firms.

Our model is a simplification of reality so the aforementioned value should not be understood as the minimal size a cluster should have in the real world. However, it implies that in the real world a threshold exists, above which a cluster is viable.

Some experimentation with the parameters that regulate the number, size and geographical proximity of clusters highlighted that small but geographically proximate clusters offer the same advantages to their members as one large cluster (e.g., 5 clusters of 10 firms each, at a distance of less than 10 pixels from one another, are equivalent to one single cluster of 50 firms). On the contrary, small clusters far from one another offer no advantage with respect to isolated firms.

We focused our simulations on the comparison between one single cluster of 50 firms and another 50 firms scattered around. The number 50 was chosen because it is roughly the minimum cluster size where the advantages of clustering become evident.

Parameters were chosen making use of all available empirical information, as well as constraints between parameters:

- The model makes sense if the number of firms that make bankrupt (and are replaced) is quite low. We found that with a decay rate of 5 per cent and a cost of undertaking an action equal to 0.01 roughly 0.21 per cent of firms are replaced at each step.

- The maximum number of knowledge fields per firm has been set at 5 in accordance with psychological experiments pointing to some point between 4 and 7 as the maximum number of items that can be managed by a human mind (G.A. Miller 1956; N. Cowan 2000). Though we are conscious that the aforementioned experiments are quite distant from our setting, we deem that they nevertheless provide an indication of the relevant order of magnitude.
- The available empirical evidence suggests that the average number of rivals of firms located in a cluster may be in the order of 2, 3, 4 or 5; only exceptionally a firm may mention something like 8–10 rivals, or no rival at all (Boari *et al*. 2003; Russo and Pirani 2001). We found that by setting the maximum cognitive effort at 1.2 and the similarity threshold at 0.2 the simulations are in good accord with the empirical evidence.
- The lower threshold of the depth of knowledge fields was set at 0.1. This value is much lower than average values attained by depth and, at the same time, sufficiently high to ensure that sufficiently many low-depth fields are destroyed so the average number of fields is below the maximum allowed (set at 5, see previous discussion).
- The upper threshold of the depth of knowledge fields is necessary in order to avoid that a few fields increase their depth indefinitely. This threshold was set at 10 with the idea that, by setting it high, it would seldom operate. Indeed, this threshold is eventually attained once or twice during a simulation, and quite often it is not attained at all.
- The threshold of performance that decides whether experiential exploration or experiential exploitation was set at 20 per cent of average past performance, calculated over the past 10 simulation steps. Exploration is meant to be carried out in special circumstances (March 1991), so we deem that this threshold should be well below 50 per cent of past performances.

The Results

We expound the results of our model following the same sequence illustrated in Figure 7.4.

Identification of rivals

Clustered firms have, on average, many more rivals than isolated firms (3.30 vs. 0.30 rivals). Moreover, most rivals of clustered firms are inside their own cluster (3.28 inside, 0.02 outside).

Cognitive Distance

Clustered firms are at a higher average cognitive distance from their rivals (404 per cent higher) than isolated firms are from their rivals. In other words, more clustered firms watch rivals whose knowledge is more different from their own knowledge, than isolated firms do.

Performance

Our simulations confirm all empirical evidence claiming that clustered firms have an advantage over isolated firms. In fact, we find out that clustered firms have a higher performance than isolated firms (38 per cent higher). Consequently, in our model isolated firms die (and are replaced) more often than clustered firms.

Learning Actions

Experiential exploitation has the highest frequency (2.03), followed by experiential exploration (1.27), vicarious exploitation (0.96) and finally vicarious exploration (0.02). Experiential learning is more frequent than vicarious learning, and exploitation is more frequent than exploration.

Knowledge Development

We introduced two indicators of knowledge development: the number of knowledge fields managed by a firm (scope of knowledge), and the depth of these knowledge fields (depth of knowledge). On both indicators, clustered firms perform better than isolated firms. Clustered firms have on average more knowledge fields than isolated firms (18 per cent more), and their knowledge on these fields is deeper than the knowledge of isolated firms (114 per cent deeper).

CONCLUSION

This study addressed the link between geographical proximity and rivalry as a cognitive and social dimension of competition. In particular, we investigated the relationship between geographical proximity and rivalry with respect to their impact on the development of knowledge by both agglomerated and isolated firms.

As we mentioned before, the relationship between geographical proximity and rivalry has been considered a crucial issue in the explanation of the competitive advantage of the geographical clusters and of clustered firms. In particular, geographical proximity is supposed to foster innovation and diffuse best practices through rivalry. However this is a presumption rather than the result of empirical investigations. In our model we take this presumption together with the thesis of those scholars that, adopting a cognitive approach to the study of rivalry, considered geographical proximity as a powerful cognitive tool used to "construct" the market through rivals' identification and comparison. In particular, in our model geographical proximity influences rivalry by reducing the cognitive effort necessary to entertain a rival, as well as by increasing the capability to appreciate the depth of a rival's knowledge. Rivalry takes the characteristics of a localized phenomenon, where nearest competitors may become rivals because geographical proximity increases information availability and provides an incentive to attend to it.

We believe this study can improve our understanding of the role played by geographical proximity in the cognitive representation of a market. In particular, according to our simulations geographical proximity allows the borders of the constructed competitive environment to be expanded by affecting the scope and the depth of the knowledge developed. Thus, geographically clustered firms have an advantage over isolated firms with respect to their ability to develop knowledge and adapt it to changing circumstances. For this reason, in our model as in the real world, clustered firms perform better than isolated firms.

According to our simulations, clustered firms excel both in the number of knowledge fields and in their depth. Thus, our model suggests that it is possible for clustered firms to improve the scope and the depth of knowledge at the same time. It is possible because clustered firms observe many more rivals than isolated firms, but most importantly because clustered firms have almost complete access to the depth of their rivals' knowledge, so imitation is quite easy.

Our simulations highlight that even in the knowledge economy, geographical clustering matters. It matters because geographical proximity helps establishing and maintaining social relations and, among them, rivalry relations. It is because of rivalry relations that knowledge is created, and it is through rivalry relations that knowledge is imitated. Our model, even in this basic version, reproduces these mechanisms.

Future versions may include other aspects of decision making, such as heterogeneity of behavioral capabilities, or different geographical arrangements of both clustered and isolated firms. However, preliminary experiments suggest that these modifications are unlikely to change the overall results reported herein.

NOTES

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