The Role of Technological and Market Complementarities in Strategic Alliances

(DRAFT)

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Abstract

This paper is concerned with the formation and performance effects of collaborative relations between firms. The literature on interfirm relations posits that, complementarities between firm resources is a major motivation to form alliances. Although variety of approaches exist to measure complementarities, in the evolutionary framework, the technological distance (or overlap) between firms is usually taken. In this paper, we draw upon the Saviotti-Metcalfe model of innovation which distinguishes between service specifications and technical specifications of products. Through an agent based simulation study, we explore the evolution of networks when firms' preferences depend on their market distance and technical distance. We find that firms who are close in one dimension, and distant in the other, have higher returns from their partnerships.

Introduction

The two central issues addressed by the literature on strategic alliances are, why firms form alliances, and what their effects on firms' performance are. In addressing these questions, probably the most widely accepted theoretical framework has been the resource-based view (Pfeffer and Salancik, 1978), which explains alliances with respect to the complementarities between firms' resources. The importance of complementarities has been confirmed empirically, mainly during the 90s (Hagedoorn 1993; Shan et al., 1994; Mowery et al., 1998; Eisenhardt and Schoonhaven, 1996). By accessing the complementary resources of others, firms have the chance to exploit their own knowledge bases, and to explore distant knowledge beyond their boundaries.

In this paper, we analyze both the formation and performance effects of strategic alliances through positioning firms in a two dimensional space defined by technology and market. Technology distance refers to the overlap between the technical competences of firms. Market distance, on the other hand, measures the overlap in their market domains. The starting point of this paper is inspired from the Saviotti-Matcalfe (1984) model of innovation, which perceives innovation in two dimensions, the service specifications of products, and technical specifications.

Based on this framework, focusing solely on technological distance, as it is done in most of the studies in this tradition, falls short of explaining a very important phenomena that many of the real world alliances reveal; the cases when there are strong synergies between the products of firms, independent of their technical knowledge endowments.

We perform an agent based simulation study in which firms are positioned in a two dimensional space defined by a technology address and a market address. Firms have different preferences when they are selecting partners, depending on the distance between them in both spaces. They collaborate, after which their coordinates in this space change, as well as their profits. In this way, inter-firm networks form and evolve. We investigate the relation between firms' distance preferences and their final profit levels. We analyze the results with reference to the networks that form during this process. Our results show that those firms which prefer close connections in one dimension, but distant connections in the other have higher returns. In other words, an alliance strategy in which either market domain or technology domain is distant proves to yield the highest performance.

In this first section, the theoretical background is presented. The second section is devoted to the explanation of the model, including the analytical framework, assumptions and technical information on simulations. The third section presents results and modifications of the model. Fourth section includes some discussions and interpretations of the model, as well as some directions for future research.

1. Background

In this section, we review the literature on the measurement of complementarities. Then we utilise the Saviotti-Metcalfe model of innovation, to present an alternative way of measuring complementarities between firms.

1.1. Complementarities in Firm Resources

The role of complementary firm resources in alliances dates back to the resource based theory of the firm (Penrose, 1956; Wernerfelt, 1984). An extension of this view recognizes the most valuable resource of the firm to be knowledge (Kogut and Zander, 1992; Grant, 1996) and takes complementarities in knowledge as the key aspect of alliances. In this literature the complementarities between firms are taken either in terms of similarities or differences between them. A commonly used measure has been the non-overlapping niches between two firms' products, which is a difference based measure (Gulati, 1995; Chung et al., 2000; Rothaermel and Boeker, 2008). In other cases, similarities in firms' technological base (Mowery et al., 1998), similarities in overall innovative potential (Rothaermel and Boeker, 2008), the strategic groups which firms belong to (Garcia Pont and Nohria, 1991), similarities in management practices (Lane and Lubatkin, 1998), coherence in knowledge bases (Nesta and Saviotti, 2005) are among the measures which focus on the similarities between firms.

Two findings in the literature indicate that, firstly, the likelihood of an alliance between two firms is higher when their distance is at an intermediate level (Mowery et al., 1998). Secondly, an inverted-u relationship exists between technological distance between firms and their learning (Mowery, 1998; Gilsing et al., 2008, Schoenmakers and Duysters, 2006; Nooteboom et al., 2007). Moreover, this distance diminishes as firms further collaborate (Mowery et al., 1998). The underlying logic in this construct is that, when firms are too close in the knowledge space, they have few to add to each others knowledge, when they are too far, they can not access each others knowledge base, and learning is limited.

An important factor which has not been given attention in this literature is the market distance between firms. Usually, a firm's valuation of an alliance depends on the consumer's additional willingness to pay for the targeted new product. When a firm is not sufficient by itself to provide additional features based on its current technical competences, a strategic alliance can help the firms' to combine their resources. In this case, the targeted product features largely determine the level and type of knowledge complementarities which the alliance aims to exploit.

Based on this framework, firms are likely to take into account both their market complementarities and technical complementarities in forming alliances. While both market side and technology side of complementarities seem to be an important driver of partner selection process, there exist few studies which take into account both dimensions together (Rothaermel and Boeker, 2008). In this paper, our aim is to address this gap.

The foundations of the two-sided framework that we apply here dates back to the distinction between technical characteristics and service characteristics of products, as Saviotti and Metcalfe have explained (1984).

1.2. The Saviotti Matcalfe Model of Innovation applied to alliances

In this framework, the two dimensions of products are first concerned with their technological architecture, and secondly with respect to the range of service characteristics that users derive utility from.

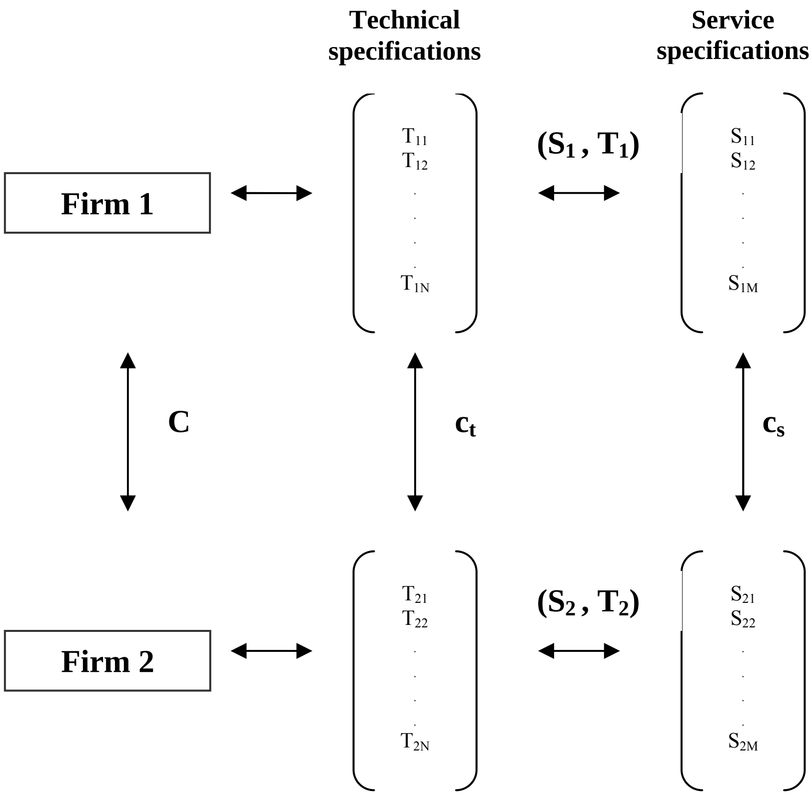

FIGURE 1. Saviotti Metcalfe model adopted from Windrum et al. (2009) to the case of alliances.

Figure 1 shows this framework extended to cover two potential partner firms. The technical specifications of firm i's product are given by (T_{i1}, T_{i2}, ... T_{iN}), and its service specifications are given by (S_{i1}, S_{i2}, ... S_{iN}). The mapping between technical and service specifications is given by (S_i, T_i) for each firm, which depends on the firm –specific characteristics, and the nature of products' knowledge requirements.

In this scheme, we define two dimensions of complementarities between the two firms. The first one is given by $\mathbf{c_t}$, which refers to the overlap of technological competences of two firms. The second dimension is given by $\mathbf{c_s}$. which refers to the overlap in the service specifications of the firms' products. In fact, contrary to what one might think at first hand, these complementarities are independent from each other. Two firms can serve the same market domain, yet draw upon different technical competences. This is usually the case when two firms' products are complementary, yet distinct competences are required for production. At the same time, two firms can have very similar technical competences, yet apply these in different market domains. This case is usually valid in the ICT sector, where there are increased opportunities to re-use existing knowledge in different designs (Steinmuller, 2007).

In this framework, the role of an alliance between two firms can be analysed in two categories:

1. A collaboration between two firms can aim to re-define the mapping between service specifications and technical specifications of products, without a *major* alteration in the desired service specifications. In other words, while S_i does not change, (S_i, T_i) is altered. In

this case, the features of the products which are "hidden" to the users are altered. This can be because of an additional capability that firm *i* does not have, but which the other firm provides. [1]

2. An alliance between two firms can aim to alter the service specifications (S_i) of a product, by adding desirable features to an existing product. In this case, the (S_i, T_i) may or may not be altered, depending on the extent of modularity of the innovation.[2]

In the second case, the additional service specifications of the targeted product shapes the extent to which firms are motivated to form the alliance, and their expected returns (S_+). In this case, an alliance between two firms adds new service specifications to an existing product, let us say, ($S_{i,n+1}$). The value of the added design feature, and consumers' willingness to pay for it, shapes the motivation behind the alliance. To the extent that the innovation is modular, meaning, the addition of ($S_{i,n+1}$) does not affect the existing mapping (S_i, T_i), limited technical overlap between two firms can be tolerated, yet the new product design creates significant value to the consumers. In this case, again there can be increased motivations to form an alliance between firms, regardless of their technological overlap, but because of a high market overlap. It is important to note that in both cases, the desired service specifications, or the methods by which they can be achieved, play an important role in shaping the motivations behind the alliance.

Based on this scheme of viewing complementarities, the model that we present below aims to explore which types of distance preferences have higher payoff when firms have different criteria for partner selection. In doing so, we look at the evolution of networks, and the accumulated profits levels among a heterogeneous population of firms, who form their linkages in accordance with their perceived complementarities in these two dimensions.

2. The Model

In the model, there is a randomly located population of firms on a two dimensional Cartesian space. Firms search for partners in this space considering the distance between them separately. [3] The first dimension measures their technological distance and the second dimension refers to the market distance between them. The firms' returns from an alliance depend on the value

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[1] Usually, there will be some change in the service specifications, but not necessarily. This is the case when the alliance targets a modification in the production processes. For example, in 1920's, an alliance between Ford Motor Company and Pilkington Brothers Glass company resulted in the continous processing of sheet glass, which significantly increased the efficiency of producing large amounts of glass suitable for automobile manufacturing.

[2] An example is the collaboration between Nike Inc. and Apple Inc. in 2006 for the production of smart shoes. An additional kit placed in the sole of the sports shoe permits the various performance measures to be recorded in the ipod of the user. In this case, while the service characteristics of the final product changed significantly, in the technical (or production) level, the only requirement was the addition of a modular pocket to the sole of the shoe, which did not require significant design changes in both company's products.

[3] A body of empirical work on strategic alliances positions the firms in some notion of space, and measure motivations behind alliances with respect to the distance between firms in the defined space. Some commonly used notions of space have been geographical space (Gomes Casseres et al., 2006), cognitive space (Nooteboom et al. 2007; Schoenmakers and Duysters, 2006), social space (Gulati, 2007) and strategic space (Garcia Pont and Nohria, 2001). Here, the distance between firms can be interpreted in any context. However, the fact that they become closer in space after the alliances restricts the possible interpretations.

they put to their distance in the two dimensions. The firms are idiosyncratic in their choices; some of them may prefer close partners in the two dimensions, and some of them may prefer distant connections in the two, and others may fall in between. As shown in Figure 2, we distinguish between four firm typologies. In the first group are the “absolute exploiters”, meaning that they prefer partners who are similar to themselves in both knowledge and product domains. In the third group are “absolute explorers”, corresponding to those firms who prefer distant connections in both dimensions. Finally, groups two and four belong to those firms that are in between (they search for distant partners in one dimension, and close connections in the other). [4]

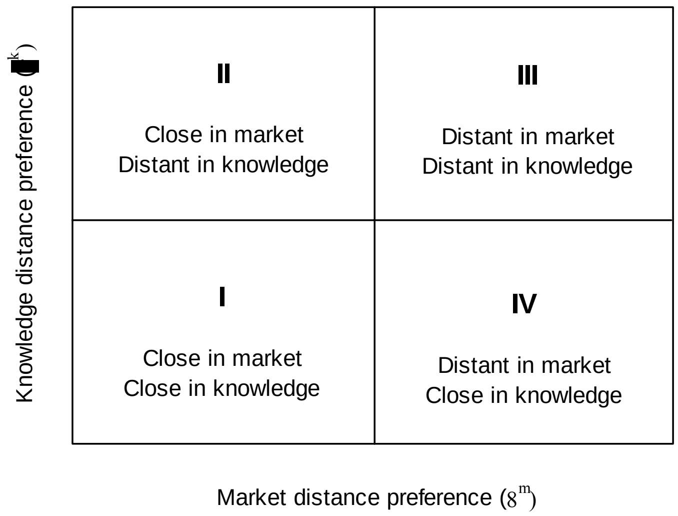

FIGURE 2. Typology of firms in terms of their connection strategy

Through a matching process, firms form alliances by forming pairs. The effect of performing an alliance is twofold; first they earn profits, and second, they become closer to their partners in the Cartesian space (Baum et al., 2009). With the updated levels of profits and their new location, the above procedures are repeated. We look at the structure of networks that emerge, and analyze the relationship between firm preferences and final profit levels. In short, can we identify a relationship between the connection strategy of the firm and its realized profits as the industry evolves?

2.1. Before collaboration: Partner Preferences

Each firm has a location in the Cartesian space given by m_i and k_i showing its market address and knowledge address respectively. The profits that firm *i* expects from its collaboration with firm j, $\pi^e_{ij}(d_{ij})$, depends on the distance between them. We assume that each firm has a different criteria concerning how it selects partners. Some firms expect to gain highest profits through connecting to

[4] This typology is based on the organizational learning literature. While exploration refers to experimentation with new alternatives, exploitation aims at refinement and extension of existing competencies, technologies and paradigms (March, 1991: 85).

close firms, and some firms prefer distant connections. We assume an inverted-u relationship between expected profits and distance, where the optimal distance depends on a firm's own perception. Deviations from the optimal distance will only have the effect of reducing the potential profits of the firm. We assume that distant connections are more costly, because of increased costs of communication and higher risks of partnership. Moreover, expected profits from distant connections are more uncertain, which makes it difficult to judge among firms who are in more or less the same distance from the focal firm. These properties are satisfied with the Rayleigh probability distribution function, which is given in Figure 3.

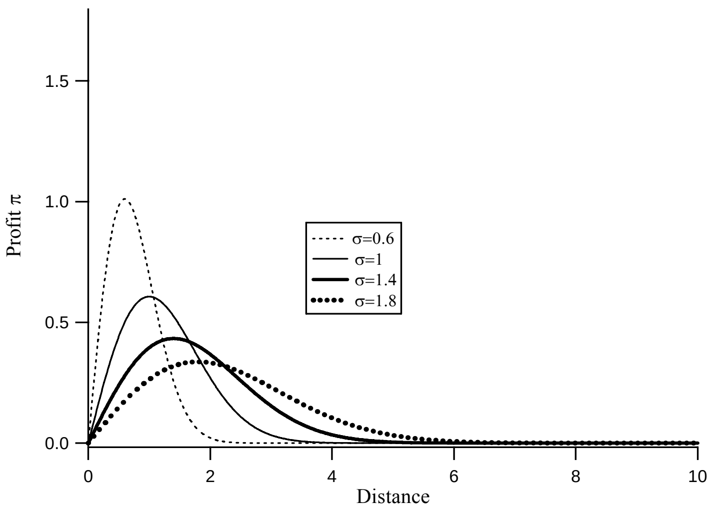

FIGURE 3 The Rayleigh Distribution

In Figure 3, profits are given as a function of distance between firms. Each firm is characterised by a different σ in market and technology domain. For a fixed σ, there is an optimal distance between two firms (as perceived by one of them) which maximizes profits. Changing the value of σ permits us to model the different preferences of firms in terms of distance. As σ increases, two things happen: first, the peak of the function reduces, which means that the maximum profits expected by high-σ firms are less then the maximum profits expected by low-σ firms.[5] But at the same time, as σ grows a firm has a wider range of choices with similar expected returns. [6] Moreover, when firms connect to distant partners, their post alliance movement is higher in the Cartesian space. In accordance with this function, the profits that firm *i* expects from its collaboration with firm j is given by:

$$\pi_{ij}^{e} = \frac{d_{ij}^{m}}{\sigma_i^{m\,2}} e^{-(d_{ij}^{m})^2 / 2\sigma_i^{m\,2}} + \frac{d_{ij}^{k}}{\sigma_i^{k\,2}} e^{-(d_{ij}^{k})^2 / 2\sigma_i^{k\,2}} \qquad (1)$$

[5] This assumption is released later on.
[6] Because the function is a probability distribution function, the total area under the curves are the same, which means that expected total profits are the same for all firms regardless of their σ.

According to Eq. (1), expected profits from collaboration with firm *j* has two components shown on the RHS. First, profits expected due to market complementarity, $\pi_{ij}^{m}(d_{ij}^{m})$; second, profits expected from knowledge complementarity $\pi_{ij}^{k}(d_{ij}^{k})$. In Eq. (1), σ_i^m and σ_i^k are firm *i*'s distance preference parameter in market and knowledge domains respectively. The distance between firms in the market and knowledge dimensions are given by d_{ij}^{m} and d_{ij}^{k}, and they are simple Cartesian distances taken separately in both dimensions:

$$d_{ij}^{m} = m_i - m_j \qquad (2)$$

$$d_{ij}^{k} = k_i - k_j$$

Therefore each firm *i* is characterized by two parameters. The first one is, its location in the Cartesian space, given by (m_i, k_i). The second one is, its preference for connections in both spaces, given by (σ_i^m, σ_i^k). For example, a firm who prefers distant market connections, and close knowledge connections will have $\sigma_i^m >> \sigma_i^k$. These two features are assigned randomly to firms in the initial period.

2.2. After Collaboration

We assume that, firms come closer to each other in the industry space after a partnership (Baum et al., 2009). In forming their profit expectations before collaboration, they foresee their change of location, and include a loss term in their expectation function, depending on the crowdedness of their new position. If the final point that they arrive is occupied by a number of other firms in the close vicinity, competitive pressure would increase, which we assume has a negative effect on expected profits. [7] Hence, the L^e_{ij} attempts to capture this effect by taking into account where the firm expects to find itself if the partnership is materialized. Then we modify the profit function given in Eq. 1 as follows:

$$\pi_{ij}^{e} = \frac{d_{ij}^{m}}{\sigma_i^{m2}} e^{-(d_{ij}^{m})^2/2\sigma_i^{m2}} + \frac{d_{ij}^{k}}{\sigma_i^{k2}} e^{-(d_{ij}^{k})^2/2\sigma_i^{k2}} - L^e_{ij} \qquad (2)$$

where the amount of loss is given by, $L_{ij} = \{\# j \in N \setminus \{\mathrm{i}\} : d_{ij} < 1\}$ which states that loss incurred is the number of firms which are within a unit of distance from firm *i*. The new locations of firm *i*, after its collaboration with firm *j* is given by:

$$m_{it} = m_{it-1} + \alpha(m_i - m_j) \qquad (3)$$

$$k_{it} = k_{it-1} + \alpha(k_i - k_j)$$

And the *realized* profits, if firms *i* and *j* match with each other is:

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[7] Note that, this happens when firms are close in both technical space, and market space, which means they serve the same market niche.

$$\pi_{ij} = \frac{d_{ij}}{\sigma_i^2} e^{-d_{ij}^2/2\sigma_i^2} - L_{ij} \qquad (4)$$

It is important to mention that, firm *i* cannot predict precisely its profits in advance because the realized profits depend on the extent to which other firms move in the space. If many firms move to a similar location, the realized losses can be more than expected.

2.3 Matching

Based on Eq. (1), each firm calculates its expected profits from collaboration with each of the other firms. The matching process that we use is based on the Gale and Shapley (1962) matching process, and have been previously used in agent-based simulations (Cowan et al., 2007). In this process, two firms form a partnership, if and only if the mutual profit expectations are higher than the rest of the available partners, and their mutual expectations do not differ by more than a certain percentage. [8] After matching takes place, the coordinates of firm *i* change according to Eq. (3) and realized profits are calculated according to Eq. (4).

2.4 **Assumptions**

We assume firms select partners based on their perception of distance. This is a realistic assumption as most studies reveal. But we do not assume the existence of a unique optimal distance which is valid for all firms. In other words, we assume that how firms define "closeness" is different. We assume a heterogeneous population of firms where they have different criteria in selecting partners. In addition, because firms' distance preference parameters are set randomly, some firms are similar to each other. So there are group of firms who find it more beneficial to be close in both dimensions, etc. We also assume that being too close in both spaces implies higher competitive pressure. Losses are incurred because of the crowdedness of the area in which the firm finds itself in, after the alliance.

One of the important assumptions of the model is that, firms do not update their distance preference parameters. At first this might seem as a strong assumption. Nevertheless in the real world, this is exactly what happens. Previous studies found that, the stage in the life cycle of an industry determines the extent of connections between firms (Pyka, 2000; Nesta and Mangematin, 2002). Particularly in the beginning of a life cycle, relations are denser, and exploratory alliances are dominant. As a dominant design emerges, firms converge to a particular design (they come closer in the technology and market space), and relationships are predominantly exploitative, aimed at deepening competencies. Therefore we prefer to fix the distance preference parameter throughout the simulations, and characterize each firm by its connection strategy. This is also realistic in the sense that the network strategies of firms are rather stable, as being part of a broader set of strategic

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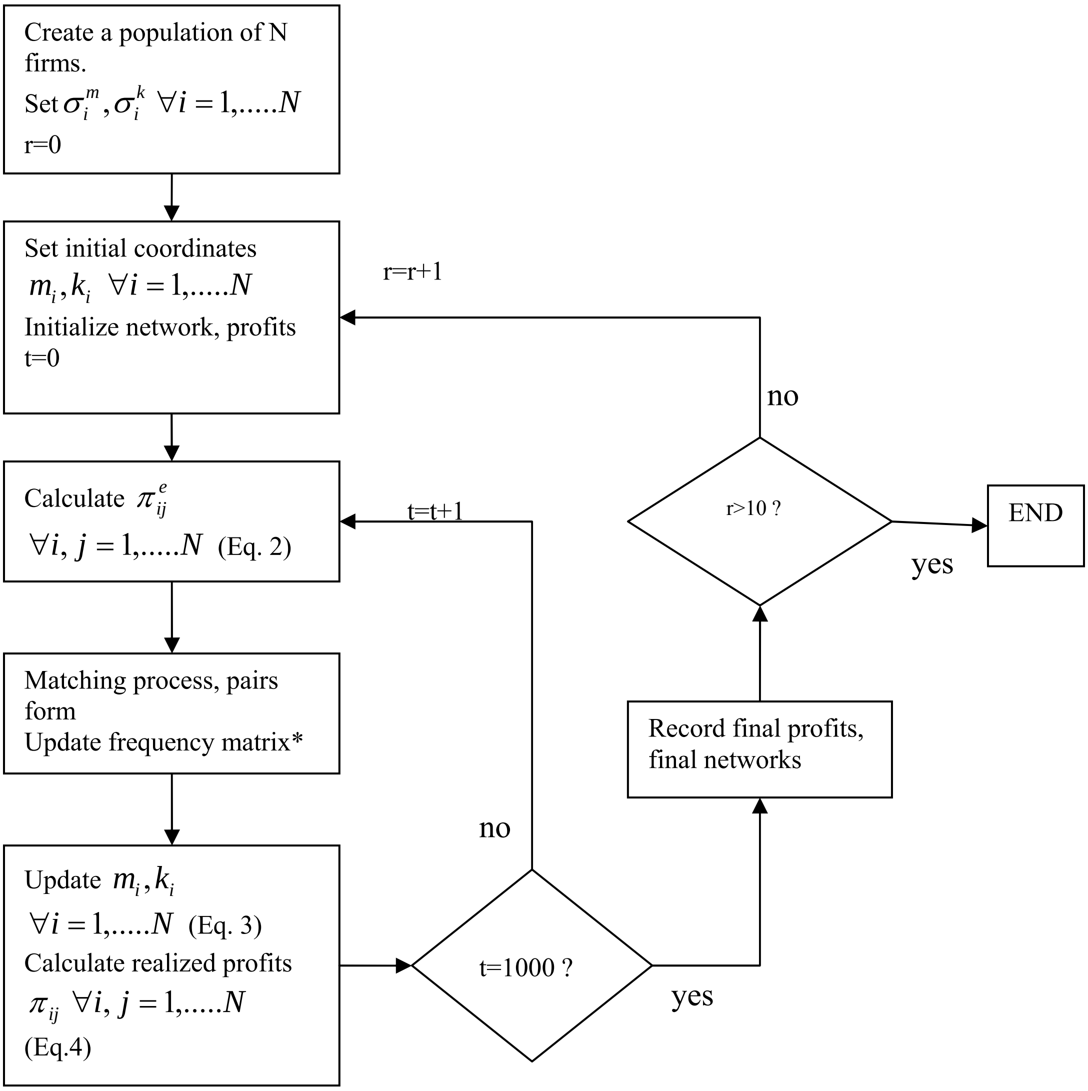
[8] In this model, the mutual profit expectations are not symmetric (what firm *i* expects from its collaboration with *j*, and what *j* expects from *i*), because their distance preferences might be different. Originally, Gale and Shapley matching is for the symmetric case. Here, we modify this algorithm, such that if the ratio of their profit expectations differ by less than 0.95, they do not form a partnership. We impose this constraint so as to control for extreme mismatch cases.

management practices, which are not expected to change frequently. In this case, the model should be interpreted in a particular industrial context, and analysis is from the beginning of life cycle to the more mature phases.

2.5 Simulations and Parameters

The population consists of N=100 firms. The coordinates of firm i in period t=0 is drawn from a uniform distribution such that $(m_i, k_i) \in$ [0,10]. The initial values of distance preference parameter is given as $\sigma_i \in [0.1,4]$ and for 100 firms, they are randomly distributed. The parameter measuring the amount of distance travelled after the collaboration is α=0.05. We run 10 simulations. In each simulation, we keep the initial distance preference parameter (σ) of firm *i* fixed, but assign a different beginning coordinate for the firm. In this way we have the chance to confirm that the results do not depend on the initial position of firms in the space, and we can isolate the effect of preference parameter on profits. There are 1000 periods in one simulation run. The results presented are the average profit levels of firms for the 10 different runs. In the model, there are only bilateral links in a single period, but after 1000 periods, we obtain a network (Cowan et al., 2007) through the accumulation of relations. Figure 4 shows the algorithm of the model in the form of a flowchart.



* Frequency matrix shows who interacted with whom, and how many times.

FIGURE 4 Algorithm of the model

3. RESULTS

Figure 5 shows the distribution of firms in the two dimensional space defined by their preference parameters (σ_i^m, σ_i^k). The size of the circles show the final profit levels achieved after 1000 periods elapse. The results reveal that, firms who prefer partners who are close in at least one dimension have higher profits than others. In addition, those firms who prefer very close connections in both dimensions are profitable.

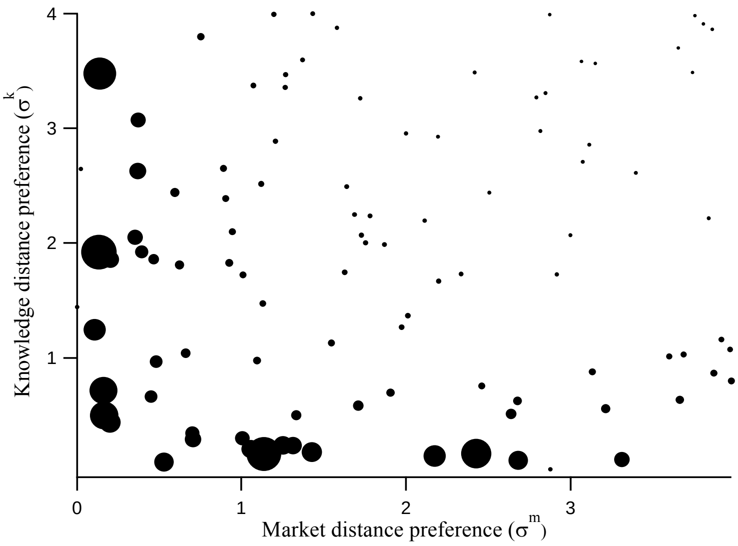


FIGURE 5 Profits (size of circles) and Distance Preference Parameters: spread of firms

A linear regression analysis between profits and distance preference parameters confirm the significant interaction effects between the two dimensions. Figure 6 shows the fitted functions.

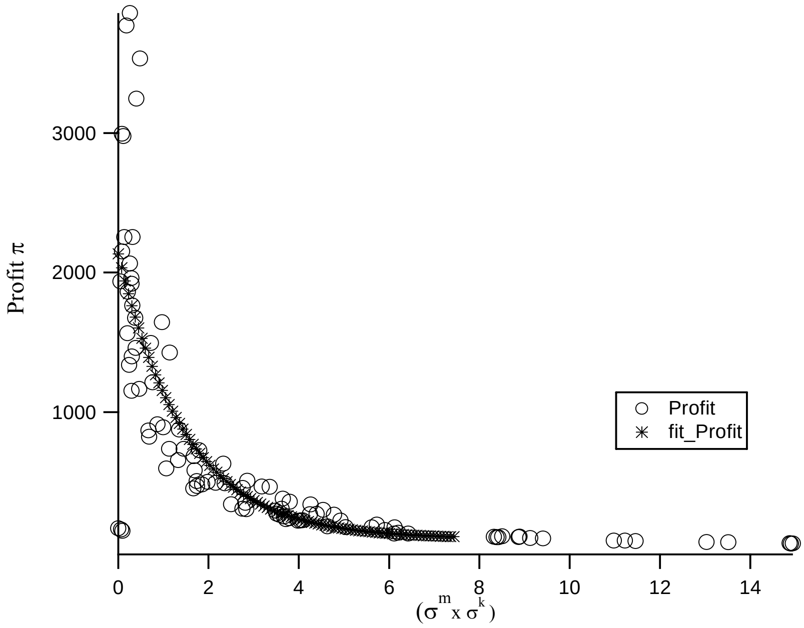


FIGURE 6 Estimated Profit Function

Figure 7 shows the physical location of firms at the end of the simulation runs, where size of circles are profits.[9] It can be seen that firms converge to each other in the Cartesian space in further periods (note that the scale of the graph in Figure is between 4 and 6). This is because, their losses from partnership exceed their profits and they can no longer find partners sufficiently profitable

[9] Because initial coordinates are different for each of the 10 simulations, the final coordinates are also different. Therefore we show only one of the simulations here, as an example of convergence.

and/or, who is equally willing to form partnership with them. In other words, firms become so similar to each other in the market and knowledge space that, losses because of competitive pressure is higher than the gains from collaborating.

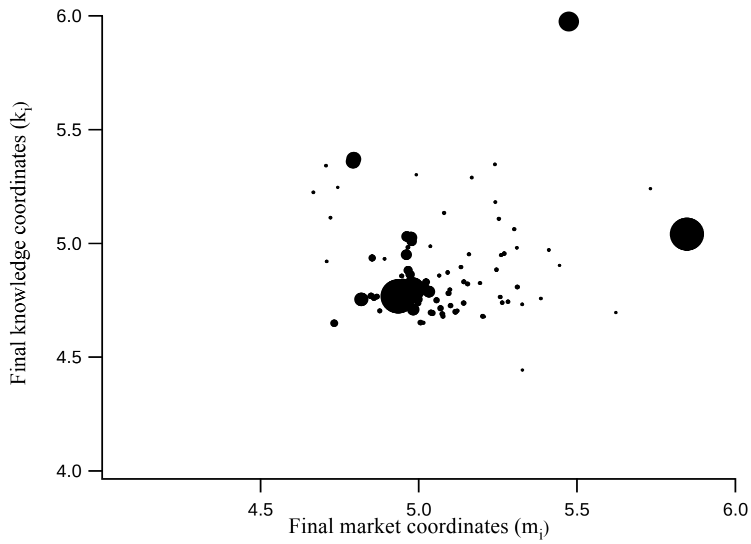
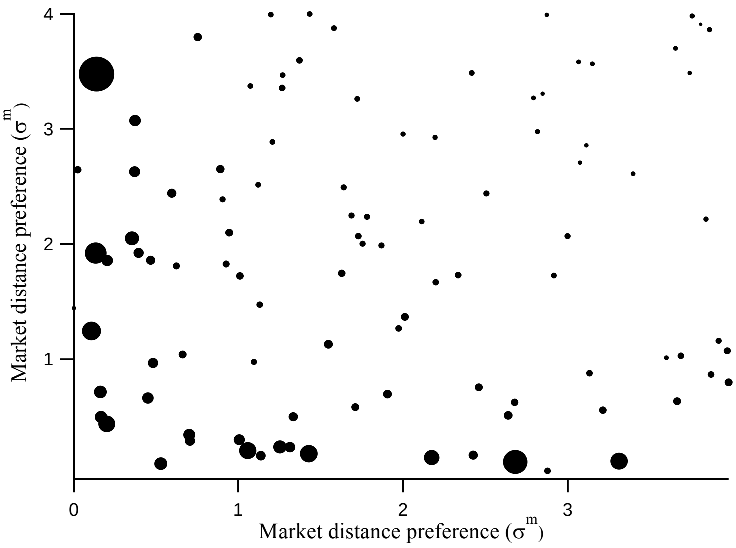


FIGURE 7 Final coordinates of the firms (scale between 4 and 6, size of circles are profits)

3.1 Network Dynamics and Interpretation of Results

The most important question that we need to address at this point is concerned with the explanation of these results. In relation to the nature of the model, why do we observe these patterns? We present this analysis in relation to the evolution of the networks.

We look at the relation between the number of partners of the firm, its strength of connections and its final profit levels at the end of the simulations. We define connection strength as the average number of times two firms interact with each other. The firm's degrees refer to the number of different partners it has throughout the 1000 periods. Connection strength and degrees of firms are given in Figure 8. Comparison of Figure 5 and 8 reveals that, firms in the range of maximum profits also have high connection strength and high degrees.



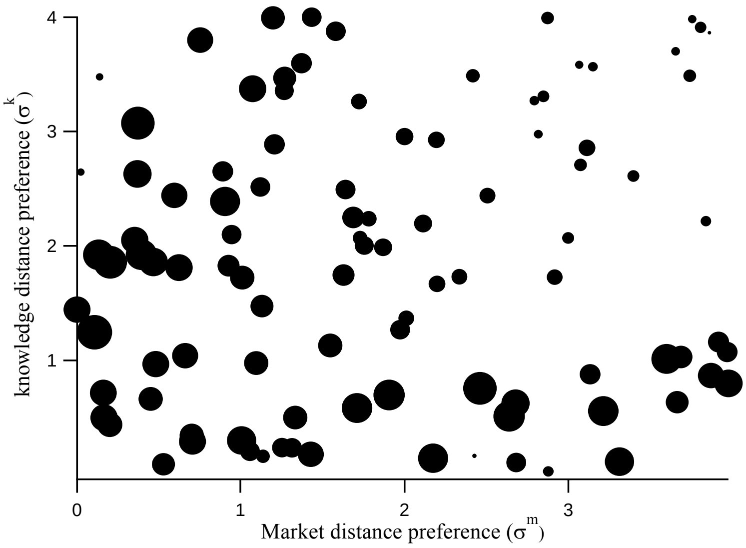


FIGURE 8 Strength of Ties (a), degrees (b) and Distance preference parameter

As Figure 8 reveals, firms with high profits are also the ones who repeat their ties with their partners and who form partnerships with different firms. According to our initial model specifications, the only way to earn profits in the model is through having relations. This is why, the degrees of firms are positively correlated with their profit levels. In other words, the more a firm can find partners, the more is its profit levels.

But the possibility to find partners depends on the distribution of firms in the space at a given period, and the firms' preference parameters. Naturally, those firms who prefer distant partners in both spaces (absolute explorers) are at a disadvantage towards the end, since convergence occurs, and all firms come close to each other. On the other hand, absolute exploiters are at a disadvantage in the beginning, since firms are more scattered. Let us analyse the dynamics of linkages throughout the simulations to understand what happens in the other cases. For this purpose, we carry out the analysis based on the initial grouping of firms, shown in Figure x above.

According to our simulation results, the firms in regions II and IV earn the highest profits, as well as some of the firms in region I (those that prefer significantly close connections). We analysed the evolution of linkages with respect to this categorization firms. Figure 9 shows the breakdown of relations according to this categorization.

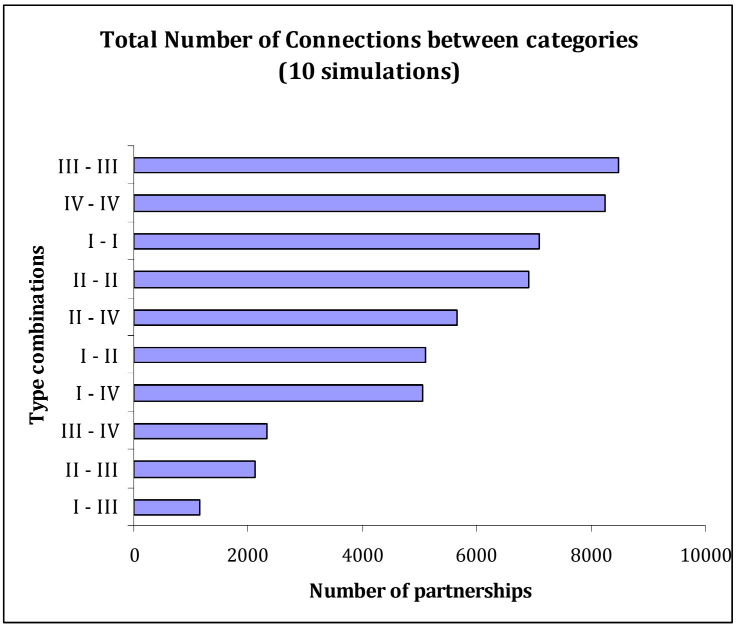


FIGURE 9 Inter-group connections

Two points are immediately clear from the Figure 9. Firstly, the highest number of partnerships occur when both firms are of the same type. This is expected, since in this case two firms have a nearly perfect matching in their distance preferences, so they find each other. On the other hand, the lowest number of connections occur when one of the firms belong to region III. These firms are by definition at a disadvantage, because as industry matures, they are not able to find partners who are sufficiently distant in both dimensions. This can be also be confirmed in Figure 10, which shows the evolution of linkages between the groups. The relations between groups III – III are very frequent in the beginning, and fall sharply after a while.

The case of relations among group 1 firms is just the opposite. In the beginning, they are less advantageous in terms of finding partners which are sufficiently close to them in both spaces. Nevertheless, interactions in this group is the highest during the end of simulations (Figure 10).

The middle group of firms in Figure 8 involve the cases in which when there is a partial mismatch between pairs. For example, the relation between an absolute exploiter, and another firm which prefers high market overlap and low technological overlap. In this case, there is only a partial match between preferences. Interestingly, this case also involves the combinations whereby there is an absolute mismatch between pairs (cf. case II-IV). This means that, there is a relatively higher payoff from forming a partnership, when the alternative is no profits at all. So these cases are the result of satisficing. It can be seen from these patterns that, the advantage of being in the II and IV the group is because their preference gives them a certain flexibility in their capacity to find partners from beginning to the end.

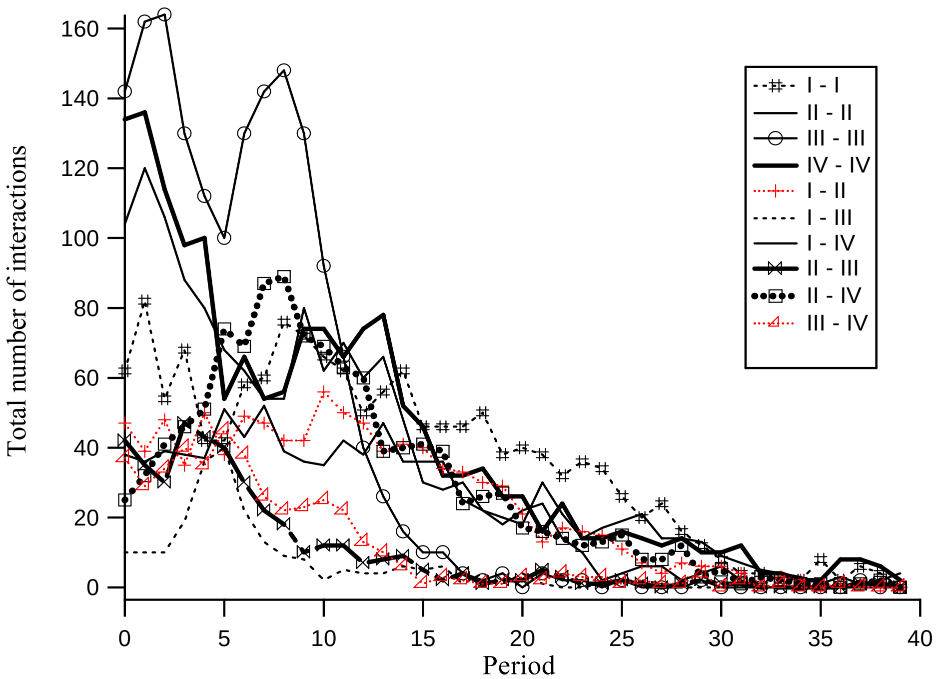


Figure 10 Evolution of linkages between groups (covers 200 periods, data taken every 5 period).

Although this analysis gives the overall network picture, we need to clarify how these network dynamics relate to final profit levels. Profit levels are determined, firstly by the profit function, and secondly by firms ability to find partners (and thereby their degree and strength). In Table 1, we show summary statistics belonging to each group. We further split group 1 firms into three subgroups, according to the profit levels (in particular, groups IA and IB correspond to high profit earners among the group 1 firms, shown in figure 2). Firms in group III have low profit levels because their degrees and strength are low compared to others. Contrarily, firms in groups IA and IB have significantly higher profits than others in group I. Their high profits can be explained in two ways. Firstly, they have few degrees, but high connection strength (which means they repeat their links). This is because, their relative movement in space is not significant after an alliance, since they select close partners.

Therefore their total number of interactions are quite high, which raises their returns. Secondly, the high profits can be explained by the profit function itself. It can be seen in Fig. 2 that, the peak of the function is very high for absolute exploiters. Therefore, to isolate the effect of preferences only, we repeat the simulations with a modified profit function below. Finally, firms in groups 2 and 4 are advantageous mainly because of their high capability in finding partners at all stages, even in the case of partial mismatch.

Type	0-1	0-2	1-2	2-4	Strength of connections	Degree	Degree / strength	Profits
I			σ^m, σ^k		63.24	30.03	0.47	41.58
II		σ^k		σ^m	87.05	33.17	0.38	52.08
III				σ^m, σ^k	60.54	26.48	0.44	36.28

IV		σ^m		σ^k	91.72	33.58	0.37	52.07
IA	σ^m, σ^k				92.14	32.22	0.35	56.70
IB	σ^m or σ^k		σ^m or σ^k		93.28	31.93	0.34	55.41

3.2 Modification of Profit Function

One of the assumptions above is that, distant connections are more costly, so that the maximum expected profits are less, as distance grows (Eq. 1 and Figure 2). In this section, we release this assumption, and assume the following functional form for the expected profits, as also shown in Figure 11:

$$\pi_{ij}^{e} = \frac{d_{ij}^{m}}{\sigma_i^m} e^{-d_{ij}^{m}/2\sigma_i^{m^2}} + \frac{d_{ij}^{k}}{\sigma_i^k} e^{-d_{ij}^{k}/2\sigma_i^{k^2}} - L^{e}_{ij}$$

FIGURE 10

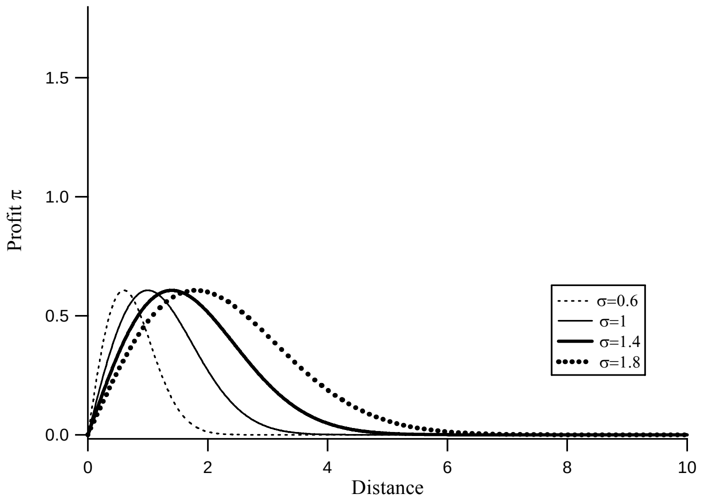


Figure 11 Revised profit function

In the new simulations with the modified profit function, the distribution of linkages between firms follows the same ordering, as in the previous case, as shown in Figure 12.

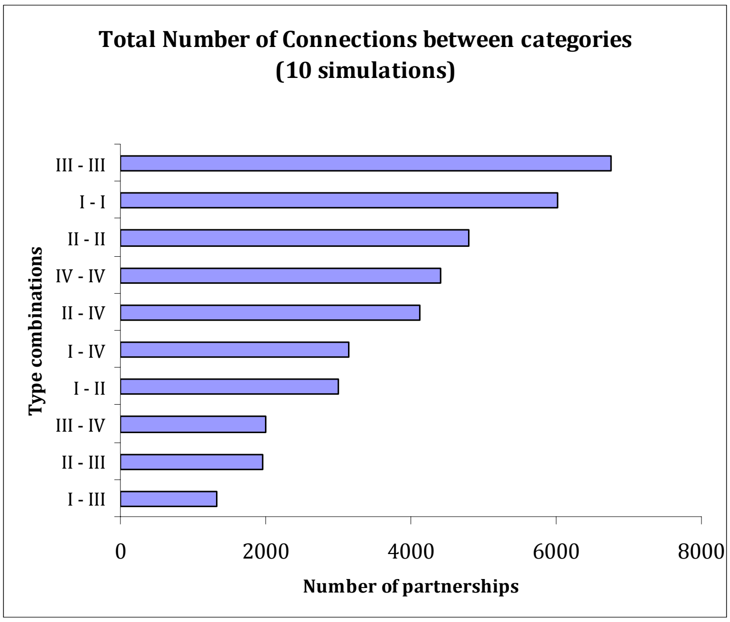


Figure 12 Distribution of total links between inter-group partnerships – revised profit function

Additionally, Table 2 shows the distribution of degrees, strength and profits in the six firm groups considered. The main difference between the previous version of simulations and this one is concerned with the distribution of profits to group I firms. In this case, it can be seen that profits of group 1A are significantly reduced. In this version, the highest profit group is also the group which has the highest connections. These are the firms which belong to the groups II and IV.

Type	0-1	0-2	1-2	2-4	Strength of connections	Degree	Degree / strength	Profits
I			σ^m, σ^k		51.13	22.80	0.45	32.23
II		σ^k		σ^m	54.52	22.64	0.42	36.48
III				σ^m, σ^k	48.24	17.96	0.37	31.03
IV		σ^m		σ^k	56.41	24.08	0.43	35.23

IA	σ^m, σ^k		29.60	15.48	0.52	17.72
IB	σ^m or σ^k	σ^m or σ^k	53.48	23.10	0.43	31.23

4. Discussion of the Results

Our results can be interpreted from the perspective of two theoretical frameworks. These are the industry life cycle approach and creativity research. According to the life cycle analysis (Utterback, 1996), the industrial structure and nature of strategic alliances depend on the stage in the industry life cycle. In the beginning of life cycles, the industrial environment is characterised by highly tacit knowledge, uncertainty, and the coexistence of many firms competing for rival designs (Utterback, 1996). In such environments, firms may prefer distant connections to increase their access to novel sources of knowledge. Indeed, previous research has confirmed that exploratory alliances are intensive in this stage (Rowley et al, 2000; Pyka, 2000; Rosenkopf and Tushman, 1998; Nesta and Mangematin, 2002). This corresponds to the initial periods in our simulations, where firms are largely scattered in the technology and market space, and where exploratory alliances are dominant in the industrial system. As a dominant design emerges, it is accepted by the firms as the standard, which marks the beginning of a period in which the environment becomes more stable. Relative weight of exploitative alliances increase in the industry during this phase (Rowley et al.; 2000), as firms converge to each other in terms of their technologies and products.

The organizational learning literature traditionally focuses on the trade-off between firms' investment in exploration and exploitation. While exploration refers to experimentation with new alternatives, exploitation aims at refinement and extension of existing competencies, technologies and paradigms (March, 1991: 85). It is now widely accepted that these two dimensions of organizational learning are not substitutes but complements with each other, which is called the ambidexterity hypothesis (Tushman and O'Reilly, 1997; Lavie and Rosenkopf, 2006). In other words, for higher innovative performance firms should have the capability for, and invest in, both exploring and exploiting. In this paper, we took into account two dimensions in which exploration and exploitation can take place. Our results reveal that, a successful firm can be an explorer in one dimension, and an exploiter in the other dimension. An interesting feature of the model is that, we arrive at these results without incorporating context specific parameters about knowledge and markets, but just with respect to the relative positioning of firms in space, and how this space evolves as the industry matures.

The second framework through which we can explain our results is based on the creativity research. According to this framework, breakthrough innovations are likely to occur when knowledge in one context is applied to different contexts. Being close in one aspect facilitates communication, being distant in the other has potential for novelty. This approach has been studied in the individual level through the power of analogical thinking (Gassman and Zeschky, 2008;

Kalogerakis et al., 2010, Hargadon, 2003) . In the context of inter-firm networks, it has been found in various studies that there is an inverted-u relation between learning and overlap (Mowery et al., 1998). In this paper, we show that this overlap does not necessarily happen in one dimension, a high degree of similarity in one context, and a high degree of distance in the other context produces similar results.

Finally, one of the difficulties in simulation studies is concerned with our abilities to interpret abstract notions in real life situations. For this model it will be useful to present some real world examples in which these results can be interpreted. In some cases, a strategic alliance between two firms from completely different market and technology domains can result in a completely new design. This is the case when there is a strong complementarity potential between the two firms' markets, and the aim of the alliance is usually to exploit this complementarity. Examples are plenty; the collaboration between Nike Inc. and Apple Inc. in 2006 for the production of smart shoes; the alliance between the publishing company Conde Nast and software company Adobe Inc. for digital magazines can be cited. Both these alliances aim at a completely new product/service by combining their competences in different technological and market domains. These firms correspond to absolute explorers in our study, and such alliances are not many (as also revealed by the low degrees of group 3 firms in the simulations). .

Alliances between firms which are very close in both domains are also not very frequent, since they usually involve firms which are in strong competition. These alliances usually occur to strengthen/sponsor a certain standard in the industry, especially when there are strong network effects. Majority of the alliances in the real world correspond to the cases in which firms complement each other in different domains. A very common example is the alliances in the biotechnology sector. While small and dynamic firms contribute with their knowledge and skills, the big firms offer advanced marketing opportunities (Arora and Gambardella, 1990). Examples to the cases in which firms that operate in the same market, but draw upon different technical competences are usually confined to complementary products. The alliances between video game designers and video game console producers can be cited as an example. Production and design of hardware have few common competences with software design. Yet, the complementarities between their market domains provide increased opportunities for these firms to collaborate. Finally, some of the alliances serve completely different markets, yet they have a joint knowledge base. This case is common in ICT industries, where reusability of knowledge in different designs is a common feature. Another example is when the markets that the firms serve are in different geographical locations, and through an alliance they have the chance to explore different markets.

The main emphasis of the paper is the necessity to incorporate different dimensions of complementarities in alliance analysis. In this paper, we focused on market distance and technical distance, but the complementarities between firms are not limited to these, and they can be equally important in shaping the motivations behind, and performance effects of alliances.

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