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Knowledge, hierarchy and the selection of routines: an interpretative model with group interactions

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Abstract. The aim of this paper is to analyze the selection of routines inside an organizational structure characterized by different cognitive representations and facing hierarchical pressure leading to either truce or conflict. After a brief discussion of the role of hierarchy and the related problems of organizational practice selection in the evolutionary literature, we model the interactions between different groups within a firm trying to interfere with its coordination mechanisms in order to support their own practices. Numerical simulations highlight the different learning abilities present in various organizational set-ups and their related knowledge distribution. It is shown that networking designs are the most profitable organizational configurations because of their dynamics of learning, though they are very sensitive to the truce problem.

Keywords: Hierarchy – Knowledge – Routines – Selection – Complexity

JEL Classification: L14, L20, L22, B52, D83

Introduction

A lot of attention has been devoted to the social context of knowledge production, for example whether it occurs in a centralized or a decentralized context as stressed by Marengo (1992), because its effect on cognitive frameworks is deemed to be far from neutral (Garicano, 2000; Amin and Cohendet, 2004). Moreover, the idea that knowledge should not be understood simply as a pure cognitive process, but should rather also be seen as a locus in which the political dimension becomes critical, seems to be quite promising (Cohendet, Llerena and Marengo, 1998). However,

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attempts at formalization in the evolutionary literature, though interesting, appear to be in their infancy because the dynamics involved are always complex and therefore difficult to integrate (for some exceptions Dosi, Levinthal and Marengo, 2003). As Witt (1998) emphasizes, organizations are also social mechanisms in which the leadership plays a major part in the transmission of the organizational vision and in the building of shared knowledge.

Groups, teams or "communities of practice", which we could broadly refer to as horizontal communities (i.e. project groups, quality groups, etc.), while confronting hierarchical pressures, also play an important part in the creation of knowledge (Cohendet and Llerena, 2003). A number of empirical studies demonstrate the importance of such communities in the diffusion of organizational practices (such as quality circles, total quality management, kaizen or just in time production), their settlement and their replication (Becker and Lazaric, 2003). It has been shown that the persistence of such organizational practices may sometimes overcome the "inefficiency arising from the agency problems of diffuse ownership [. . .] [because] the development of operational routines may offer more promise of economic success than prescription of incentive alignment" (Knott and MacKelvey, 1999, pp. 380–381). However, knowledge creation by such groupings or network configurations can also prove problematic in the absence of appropriate intervention regulating their creativity (Miles and Snow, 1992; Miles et al., 1997; Foss, 2003).

The aim of this paper is to re-examine this issue by analyzing the selection of routines within an organizational structure characterized by different cognitive representations and hierarchical pressures. To do so, we put forward an evolutionary model of internal selection. Although selective processes have been largely explained through the driving force of the competitiveness of the external market (see notably Currie and Metcalfe, 2001), hierarchical attempts to regulate knowledge creation and the emulation of organizational practices within firms have yet to be fully understood. This kind of approach could, on the one hand, give more exploratory power to empirical research in economics and business and, on the other hand, help us observe the impact of social regulation on the cognitive dimension as it works out in practice.

The paper is organized in the following way. We first briefly discuss issues relating to the selection of routines within a hierarchical context. We then develop a model of internal selection combining political and cognitive forces. Our main numerical findings are presented in the third part, leading on to the concluding remarks set out in the final section.

1 The selection of routines inside a hierarchy: some key theoretical issues

The debate surrounding routines is quite extensive (see e.g. Cohen et al., 1996), so we will start by discussing the definition we have adopted in our model. We shall then turn to the question of the viability of routines in the presence of conflicts and discuss its reformulation by Nelson and Winter.

Selection and organizational routines: some methodological considerations

A range of different methodologies have been used to analyze routines. On the one hand, there have been a number of historical and ethno-methodological studies attempting to understand qualitatively the ways in which routines change and are disrupted (Lazaric and Denis, 2001; Edmondson et al., 2001). On the other hand, organizational practices can also be scrutinized from a quantitative perspective. While this approach does not reconstruct the historical and political context within which organizational practices operate, it provides a set of tools that can be used to compare different organizational set-ups. Laboratory experiments have also been conducted to shed light on the ways in which practices emerge at both individual and collective levels (Garapin and Hollard, 1999; Betsch et al. 1998). Moreover, the question of routine selection has been tackled through the use of econometric studies (Greenan, 2003; Caroli et al., 2001; Massini et al., 2002). In particular, Massini et al. focus on the adoption of new organizational practices, such as project-based work and decentralization, aimed at fostering and sharing knowledge. Massini et al. have captured this kind of strategy, which allows Western innovative firms to adopt Japanese managerial practices, through quantitative indicators that show the relative adoption levels.

In Nelson and Winter (1982) the term routines refers to both "routines in operation" (i.e. routines activated daily) and to the organizational memory, in which knowledge is permanent and can therefore be activated by an organization's members at any time. So, routines are both a set of inert and temporarily dormant repertoires and knowledge used and performed daily (Lazaric, 2000). The phrase "routines in operation" refers to the latter type of knowledge, which is embodied in the routines that materialise through and are activated by organizational practices.

Although different forms of knowledge are present within each firm, in what follows, we assume that the routine selection process refers only to activated knowledge and, more specifically, to "routines in operation" [see Lazaric and Mangolte (1999) and Lazaric (2000) on those specific aspects]. By concentrating exclusively on the organizational practices activated by a firm's members, we limit the notion of routines to actual performance, thereby ignoring knowledge that remains inert. This assumption is somewhat restrictive in that it inevitably excludes some of the dimensions encapsulated in the notion of routine, such as the idea of inert and tacit knowledge referred to by Nelson and Winter, but it has the advantage of providing us with a more workable definition.

In this framework, routine selection is related to the problem of selecting the practices managers believe are necessary to ensure a firm's survival. This kind of internal selection is the outcome of a complex and not always optimal process (Plunkett, 2002): whereas in organizations displaying low hierarchical pressure, groups promoting their own particular routines can co-evolve, in other organizational configurations, hierarchy can stop such a co-evolution from taking place. This latter case does not necessarily imply the selection of a particular practice; it simply means that some practices are more heavily promoted, thus potentially preventing different groups from persisting in their own routines. The perception of the impact

of competition on the firm and the preservation of internal coalitions play a major role in routine selection and in promoting the co-evolution of different groups. In practice, however, internal selection raises two further issues. Firstly, there can be a mismatch between external signals and managerial actions due both to the complexity of the information involved and to its potential ambiguity. Secondly, managers will often block attempts to preserve internal coalitions and oppose any political struggle that can affect goal generation and their chosen selective criteria (Miner, 1994). Groups here can play a major role in the selection process, because they may compete for managerial attention and legitimacy (Miner, *ibid*) in order to favor their own resources and projects by trying to draw attention to their own organizational practices (Warglien, 1995; Punkett, 2002). A situation of this kind can therefore lead to the emergence of conflicts.

The problem of conflict within hierarchies

The status of conflict has attracted the attention of many writers. Among them, March and Simon (1958) noted that the existence of a variety of aims in an organization can jeopardize the quick resolution of organizational problems. The concept of heterogeneity in organizations has taken different forms in the academic literature. Simon, for example, believed that some loyalty and a certain amount of "open-mindedness" exist among an organization's members and that these allow diversity to be channelled. Thanks to these features, a degree of selection takes place, so that a certain fitness emerges between the hierarchy's will and the individuals' ability to learn (i.e. members of the firm accept the hierarchy's recommendations passively and with docility) (Simon, 1991). This kind of argument has been recently further enhanced by a number of new suggestions.[1]

The problem of political influence on hierarchical set-ups is not new. Cyert and March (1963) thought of the firm as a "coalition" and saw potential conflicts as resulting from the divergence of interests between its members. This led to the idea of the firm as a mechanism for the "quasi resolution of conflict" achieved through bargaining on the allocation of resources and different payments (Cyert and March, 1963, pp. 27–36) within the organization. In this framework, bargaining generally results in more or less stable compromises, which are then institutionalized into semi-permanent arrangements (ibid, p. 34). As organizations evolve, they are never rid of this political dimension, and traces of the arrangements made over time can be detected in both their structure and their daily routines.

Nelson and Winter reformulated the original "quasi resolution of conflict" problem through their truce argument. According to their interpretation, conflict has to be stabilized in order to create viable routines within a firm. Indeed, "conflict, both manifest and latent, persists, but manifest conflict follows a largely predictable path and stays within predictable bounds that are consistent with the ongoing routine. In short, routine operation involves a comprehensive truce in the intra-organizational

[1] Adler and Borys (1996), for example, suggest that different types of bureaucracies can exist, some of which can be enabling (facilitating interaction and communication between individuals), whereas others can be coercive and therefore exert pressures that limit interactions between a firm's members.

conflict." (Nelson and Winter, 1982, p. 110). So, the truce argument goes, a certain degree of organizational predictability must be obtained before a suitable activation of routines and consistent coordination can be achieved. Accordingly, "a firm without a viable routine is a firm without a viable truce in intra-organizational conflict" (ibid, p. 122). Conflicts were thus reinterpreted in terms of potential troubles impeding the full achievement of coordination.

This point has two important consequences. First, conflicts are associated with great uncertainty in a firms' evolution: "Like a truce among nations, the truce among organization members tends to give rise to a peculiar symbolic culture shared by the parties. A renewal of overt hostilities would be costly and would involve a sharp rise in uncertainty about the future positions of the parties" (ibid, p. 111). Secondly, conflicts generate a certain degree of organizational inertia: "[. . .] the fear of breaking the truce is a powerful force tending to hold organizations on the path of relatively inflexible routines" (ibid, p. 112).

Nelson and Winter's truce argument led them to consider the motivational aspects of routines. This is a challenging issue for anyone examining the internal features of the evolution of firms and one that has been the object of renewed interest for evolutionary scholars (Coriat and Dosi, 1997; Dosi, Levinthal and Marengo, 2003). One of the most promising research paths in this area sees the combination of industrial relations arguments with the daily functioning of the firm through the firm's "internal" labor market (Doeringer and Piore, 1971 in Nelson and Winter, 1982, p. 110). This suggests that "substantial areas of behavioural discretion" exist within organizations. Starting from this premise, Leibenstein (1987) extended the argument to show that a hierarchical structure could not control the daily routines of its members because these were able to exercise discretionary power. The relevance of this argument to the selection of routines is clear: whatever the intention underlying an action taken in a particular circumstance, inertia may prevail because a firm's members may choose to resist the dynamic in question and decide to maintain their organizational practices and their autonomy (Stinchombe, 1965; Hannan and Freeman, 1984; Lazaric and Denis, 2001). Employees may have a different vision and keep to their own routines thus generating organizational conflicts based on the different interpretations of environmental pressures inside the firm. This problem has been illustrated in a number of case studies, which emphasize the difficulty of changing organizational routines (Postrel and Rumelt, 1992) or the capacity of individuals to mobilize defensive routines in the face of organizational change (Argyris, 1985). In fact, any attempt to establish new organizational practices, for example the implementation of an ISO norm, can be confronted with significant difficulties that go beyond the cognitive level (Lazaric and Denis, 2001). Consequently, the implementation of new organizational practices often tends to be correlated with the emergence of a new effort convention to facilitate the smooth adoption of such practices by the employees.

The implementation of an organizational practice is also the result of a compromise between hierarchical pressure and routines in operation in the firm, as they are carried out by its members. In this perspective, it is useful to refer to a distinction made recently by Feldman and Pentland (2003) between two levels of routines, the "performative" level and the "ostensive" one. Indeed as they argue, implementing

an organizational practice encompasses two intermingled elements, some concrete and objective factors and a subjective dimension. The latter is explained by the subjectivity of the diverse participants of the process in the description and the interpretation of the practice, according notably to their hierarchical position inside the organization. In this perspective, the "ostensive" level guides potential performance, whereas the "performative" one is defined by the actual and observed performance of the firm. A governance gap can be identified by contrasting routines in operation and how they should be carried out. However, these levels are mutually constitutive because real performances guide the description, along with rules norms and procedures. In other words, the "ostensive level" is the narrative or normative way of routines implementation, while the "performative level" refers to organizational practices in operation (Becker, Salvatore and Zirpoli 2005). This is precisely this latter level we have in mind in this paper, dealing with the level of activation of an organizational routine or practice.

Recent work on this topic is converging towards the idea that the nature of the hierarchy is a significant factor in achieving suitable coordination and avoiding chaotic situations. For example, Knott (2001) illustrated this problem by examining franchising and, more specifically, the franchisor/franchisee relation. She showed that "managers are not superfluous. Rather they are continually necessary to enforce routine, even after it has been assimilated and to introduce innovation even in this unique setting of perfect incentives" (Knott, p. 446). Her results underline the need to adjust daily routines in such a way as to give organizational legitimacy to the hierarchical relation between the franchisor and the franchisee. Her argument supports managerial action inside the firm, especially in the selection and renewal of organizational practices. This stance also complements Leibenstein's argument that trust between the different hierarchical levels is crucial for the smooth evolution of a firm and for the avoidance of conflicts among its members. Finally, Foss's empirical illustration provides an excellent synthesis of our argument by showing a network's superb ability to foster interaction when knowledge is being created and its great weakness in the presence of political tensions (Foss, 2003).[2]

Starting from this debate, we propose in the next section a model to shed some light on the performance and learning capabilities of the firm in the presence of different political configurations and in different organizational set-ups.

[2] The case study on Oticon shows the advantages and the limits of networking established in order to help implement new organizational practices. This company was famous for pushing organizational practices and human resources to extremes in order to be explicitly "knowledge based [. . .] with a multitude of non hierarchical structures [. . .] The aim was to construct a spontaneously working internal network that would work with only minimal intervention on the part of Kolind [the chief executive] and the managers" (Foss 2003, 333-34). During the 1990s this firm was considered very successful in terms of learning and innovation. Despite this fact, this organizational form was gradually abandoned after 1996 and replaced by a certain degree of hierarchical order. The successes of the early 1990s had been reversed and the financial difficulties that ensued were responsible for the organisational changes, which were imposed in order to avoid bankruptcy. As Foss (2003) has pointed out, conflicts arise mainly when management choices are not made clear. Motivation declines as staff face the inconsistencies produced by this kind of organizational form due to its impact on the allocation of resources, competencies, cost coordination, complex interactions, incentive systems, etc.

2 Knowledge, hierarchy and the selection of routines: a model

The aim of this model is to analyze the internal dynamics of routines inside an organizational structure composed of different interacting groups. Each group is characterized by diverse cognitive representations and tries to promote its own organizational practice, facing different levels of hierarchical pressure. This process eventually ends in diverse organizational set ups with truce or conflict and generates different performances in terms of learning and profitability.

From this standpoint, let us consider a firm organized around n interacting different groups i. Define by $x_i(t)$, with $\sum_{i=1}^{n} x_i(t) = 1$, the level of activation of organizational practice of group i. This variable refers to the level of "performative" routines of the group and captures the intensity of commitment of the members of the group engaged in an organizational practice. We assume that the level of effort of each group, $e_i(t)$, depends positively on $x_i(t)$. Thus we have for $i = 1, \ldots, n$:

$$e_i(t) = \{x_i(t)\}^{\alpha_i} \tag{1}$$

with $0 < \alpha_i \leq 1$.

In this framework, it is possible to consider two polar cases, truce and conflict.

Truce is characterized by an alignment of potential levels of effort between groups. That is to say, given its own practice, each group adopts the same effort convention. Accordingly, we have, $\alpha_i = \bar{\alpha}$, where $\bar{\alpha}$ is the mean of α_i. Thus we have, $e_i = \{x_i\}^{\bar{\alpha}}$, $(\forall)x_i$, $i = 1, \ldots, n$.

Conversely, conflict is characterized by a misalignment of effort conventions. We see discrepancies between the effort parameters α_i as a source of conflicts between groups, since in this case they do not react in the same way in terms of effort, and compete in order to promote their own practice. We define by the distance, $\varphi = \sqrt{\sum_{i=1}^{n} (\alpha_i - \bar{\alpha})^2}$, the intensity of conflicts between groups. Indeed, truce and conflict are directly connected to the governance issue (political dimension) discussed below. Hierarchical pressure tries to implement a certain level of activating routines by suggesting some managerial direction (the "ostensive" level of routine). This general policy is interpreted differently in each group according to the motivation and the subjective interpretation of its members about the way organizational routines are or should be activated. We consider that a certain state of truce exists in the firm if potential levels of effort are convergent among groups. By contrast, divergence of potential levels of effort means that groups compete to obtain a degree of organizational legitimacy, which sooner or later brings about conflicts.

Accordingly, the hierarchy tries to regulate the efforts exercised by the different groups by promoting an average effort norm. Thus, the pressure of hierarchy for each group i, $H_i(t)$ is given by the following relation:

$$H_i(t) = \frac{e_i(t) - \bar{e}(t)}{\bar{e}(t)} \tag{2}$$

where $\bar{e}(t) = \frac{1}{n}\sum_{i=1}^{n} e_i(t)$**.** This hierarchical pressure, $H_i(t)$, defines the political dimension of the selection process.

The cognitive dimension is defined by the process of knowledge creation in each group. We assume that localized knowledge creation $\tilde{K}_i(t)$ is stochastic and modeled in each group by a Poisson process with an arrival rate $\lambda_i = \mu_i + \xi_i$, $i = 1, \ldots, n$.

The first element, μ_i, encapsulates the role played by the initial, or prior knowledge, $k_{i0} > 0$, $i = 1, \ldots, n$ of each group in the process of knowledge creation. These levels, which refer to both tacit and articulated knowledge, are supposed to be randomly distributed among groups at time $t = 0$ and are time invariant. Thus, for $i = 1, \ldots, n$, we have:

$$\mu_i\left(k_{i0}\right) = \frac{k_{i0}}{\sum_{i=1}^{i=n} k_{i0}} \tag{3}$$

The second element, ξ_i, refers to the role played by interactions between groups in the process of localized knowledge creation. Interactions are modelled by a graph with nodes (denoted by $i = 1, \ldots, n$) representing groups and links representing the cognitive interactions between the groups when two nodes are joined. The structure of interactions between the n groups in the firm is specified by the non negative time invariant $n \times n$ matrix, $\Omega = \{l_{ij}\}$, where, $l_{ij} = l_{ji} = 1$, if i and j are connected and $l_{ij} = 0$ otherwise.

We assume that i and j, $i \neq j$, are connected if and only if:

$$|i - j| \leq (n + 1) - \sigma n \tag{4a}$$

where $0 < \sigma < 1$ is a parameter which controls the range of interactions. For σ close to one, $-\sigma n + (n + 1) \sim 1$ and relation (3) gives birth to a nearest-neighbor connection topology without boundaries conditions. Conversely, when σ is close to zero, $-\sigma n + (n + 1) \sim n + 1$ and relation (3) gives birth to a complete graph connection topology. Different interactions structures obtain for intermediary values of σ. We think of parameter σ as an indicator of the organizational design, from classical hierarchies ($\sigma \sim 1$) to pure networking firms ($\sigma \sim 0$). Consequently, we suppose that the higherσ, the smaller the number of cognitive interactions (see below). The total number of interactions of group $i, i = 1, \ldots, n$, is $L_i = \sum_{j=1}^{j=n} l_{ij}$, then, we have:

$$\xi_i\left(\sigma\right) = \frac{L_i}{n - 1} \tag{4b}$$

The cumulative distribution function of knowledge creation in group i, (CDF) i.e. the probability that knowledge in group i is created before t, is depicted by the following figure:

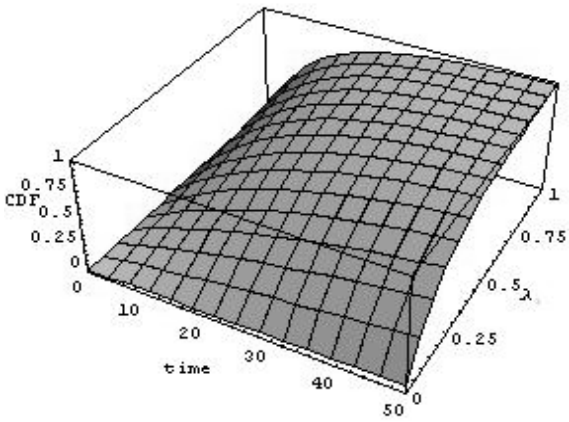

Fig. 1. Cumulative distribution function of knowledge creation in group i

The flow probability of knowledge creation in group i, that is the probability that knowledge creation occurs now is therefore $\lambda_i(k_{i0}, \sigma) = \mu_i(k_{i0}) + \xi_i(\sigma)$,.$i = 1, \ldots, n$. The knowledge component for group i, $\tilde{K}_i(t)$, finally comes down to:

$$\tilde{K}_i(t) = \lambda_i\left(k_{i0}, \sigma\right) e_i(t) \tag{5}$$

where $e_i(t)$ refers to the effort of group i at time t.

Production in the firm, $Q\left(t\right)$, is the outcome of the total level of effort $E(t)$ resulting from the different groups. Accordingly, we have:

$$Q\left(t\right) = B(t)\left\{E(t)\right\}^{\beta} \tag{6}$$

with $E(t) = \sum_{i=1}^{n} e_i(t)$, and $0 < \beta \leq 1$. The term $B(t)$ refers to a global learning mechanism that captures the accumulation of knowledge within the firm. The number of groups n exercises a positive effect on global learning. It is modelled by a function of knowledge creation in all groups $\sum_{i=1}^{i=n} \tilde{K}_i(t)$ over time. We have:

$$B(t) = n\left(1 - Exp\left[-\nu t\right]\right)\left(1 + \sum_{i=1}^{i=n} \tilde{K}_i(t)\right)^{\varphi_0 - \varphi} \tag{7}$$

where ν and φ_0 are two positive parameters such that, $0 < \nu \ll 1$ and $\varphi_0 = \frac{1}{n}\sum_{i=1}^{n} \alpha_i^2$.

Total profits of the firm are given by the profit function

$$\Pi\left(t\right) = pQ\left(t\right) - C\left(E(t)\right) \tag{8}$$

where p refers to the exogenous market price of the production and C stands for a cost function, with $C(E(t)) = \left\{E(t)\right\}^{\theta}$, $\theta > 1$. This cost function captures the direct cost of labour and the indirect costs produced by the incentive policies implemented by management. Indeed, the role played by the motivational dimension is crucial in explaining the ability of each group to promote its practices (Winter,

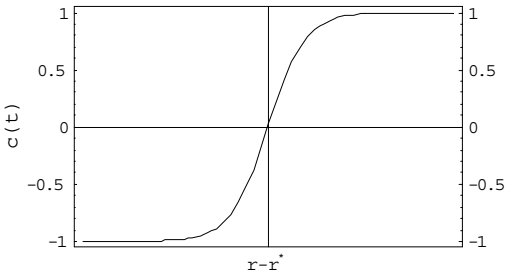

Fig. 2. Control function

1995; Lazaric and Denis, 2001). Motivation relates first to salary policy and secondly to the control implemented by the hierarchy in order to increase individual and collective skills in the firm.

Finally, we introduce a global level of control, $c(t)$, which represents the choices made by the ownership structure of the firm. Dividing total profits (8) by costs $C(E(t)) = \{E(t)\}^{\theta}$, we obtain the actual profit rate of the firm $r(t) = \frac{pB(t)\{E(t)\}^{\beta}}{\{E(t)\}^{\theta}} - 1$. Accordingly, we suppose that owners only pay attention to the performance of the firm by comparing actual profitability, $r(t)$, to some exogenous target, $r^*(t)$.[3] Thus, the level of control implemented at time t, $c(t)$, is given by:

$$c(t) = \Phi\left[r(t) - r^*(t)\right] \tag{9}$$

where Φ is an increasing function of $r(t) - r^*(t)$, such that, $\lim_{r-r^*\to-\infty} \Phi = -1$ and $\lim_{r-r^*\to\infty} \Phi = 1$. This function is shaped as follows:

That is to say, the owner's vision of the environment, which results in earning requirements, may induce the hierarchy to make a restrictive choice in the exploitation of idiosyncratic practices or may lead to the development and exploration of practices if the hierarchy chooses to fine-tune its human resource policy.

It is now possible to characterize the evolution of the structure of the activated practices in the firm. This process is captured by the dynamics of "performative" routines, $x_i(t)$, and is modelled by a kind of replicator system of n differential equations. Such models are often used to study evolutionary dynamics among mutually interacting populations or agents (cf. e.g. Kauffman, 1993; Sato and Crutchfield, 2002). As is well known, population dynamics with hierarchical structures of this kind are closely related to Lotka-Volterra equations (Metcalfe, 2003). Recently, Yokozawa and Hara (1999) and Sakaguchi (2003) developed replicator models with non-symmetric and non-linear population dynamics. Based on these assumptions, it is shown that both dynamically and evolutionarily stable solutions exist in a hierarchical structure. We adopt this perspective in this paper.

We suppose that the dynamics is driven, for a given level of global control, $c(t)$, by the interplay in each group between the cognitive dimension $\tilde{K}_i(t)$ and the

[3] Let us suppose that the norm $r^*(t)$, evolves according to the following motion $\frac{dr^*(t)}{dt} = r^*(t)(\rho r * (t) - (1-\rho) + \varepsilon_t)$ where $0 < \rho < 1$, and $\varepsilon(t)$ is a random variable with zero mean.

political dimension $H_i(t)$, as defined above. From this standpoint, we consider the following system of differential equations:

$$\frac{dx_i\,(t)}{dt} = x_i(t)c(t)\left[\sigma H_i^{(}t) + (1-\sigma)\,\tilde{K}_i^{(}t) - \delta x_i(t)\right] \tag{10}$$

with $i = 1, \ldots n$, and where δ, $0 < \delta < 1$, refers to the exogenous obsolescence rate of the practices. Finally, the range of interactions parameter, σ, $0 < \sigma < 1$, also captures the respective weight conferred to hierarchical pressure and knowledge creation in the dynamics.

In the rest of the paper we conduct numerical simulations to characterize the properties of this selection process. When σ is close to unity, the model depicts the dynamics of the extreme classical hierarchy. The structure of cognitive interactions is in this case rather sparse and limited to localized interactions. We have for instance Figure 3a.

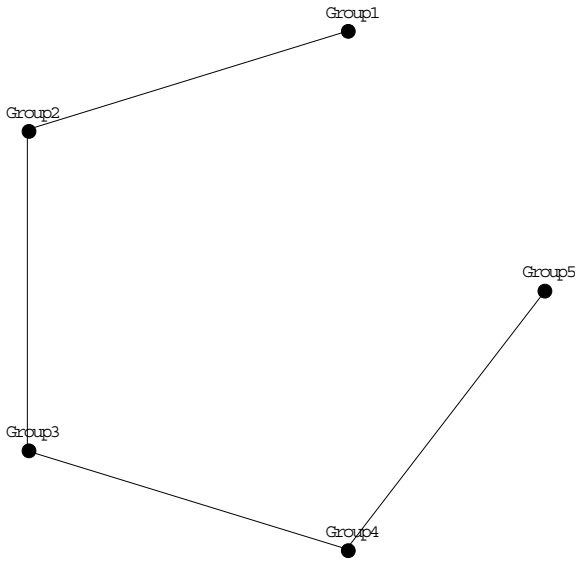

Fig. 3a. Strong hierarchical pressure and sparse nearest-neighbor interactions with $n = 5$, $\sigma \to 1$ (e.g. $\sigma = 0.9$)

The properties and robustness of this form characterized by inertia and political coalitions have largely been studied in the managerial literature.

Finally, when σ comes close to zero, the model depicts a so-called "pure network" firm. This configuration is modelled by a complete graph topology (see Fig. 3c).

During the last decade, a lot of attention was devoted to these patterns, which are characterized by a substantial degree of learning and innovative opportunities at the expense of robustness (see e.g. Miles and Snow, 1992; Foss, 2003). We believe it is interesting to focus our attention in this paper on the variety of intermediate

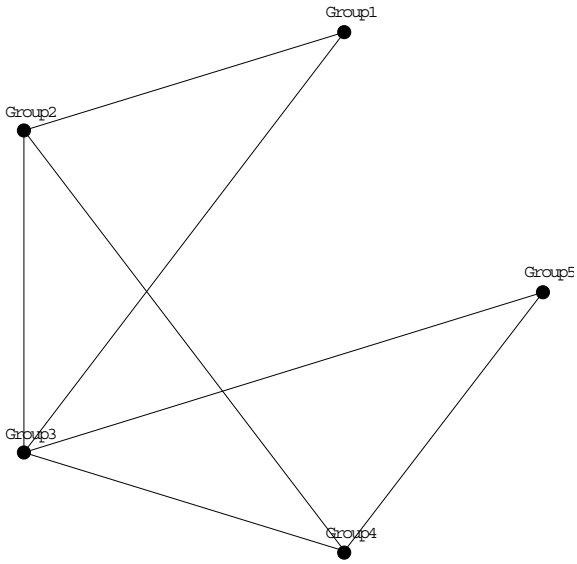

Fig. 3b. Intermediary hierarchical pressure with $n = 5$

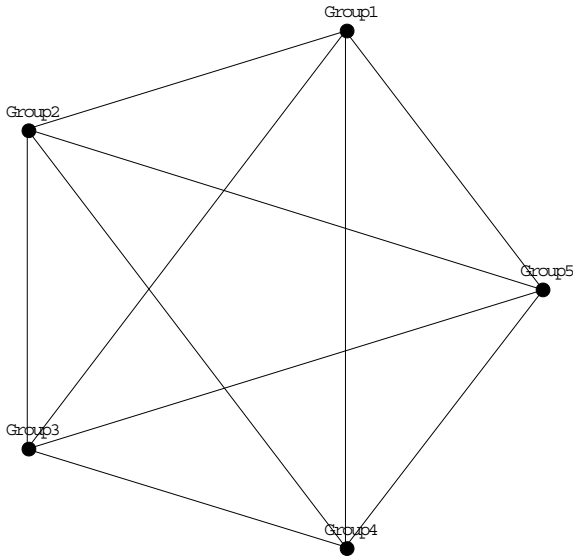

Fig. 3c. Small hierarchical pressure: Pure network configuration with dense structure of interactions, $n = 5\ \sigma \to 0$ (e.g. $\sigma = 0.1$)

configurations as they introduce a trade-off between the political and the cognitive dimensions in the selection process and should reduce the a priori degree of determinacy of the results in terms of learning capabilities and performance.

3 The political dimension, knowledge and performance in the selection process: some numerical results

We now turn to some numerical simulations of the dynamic system presented above by considering two polar cases, truce ($\alpha_i = \bar{\alpha}, i = 1 \ldots n$) and conflict ($\alpha_i \neq \bar{\alpha}$), as discussed above and where σ, $0 < \sigma < 1$, is the control parameter. The model is specified as follows.

First, we determine the values of technological and global parameters, the cost function parameter, θ, the elasticity of production with respect of total effort, β, and the obsolescence rate, δ; the price, p, is normalized to unity. Then, for a given total number of groups n, the sets of prior knowledge and of group-level efforts parameters are chosen randomly, according to two uniform distributions on $[1, 3]$ and $[0.1, 0.9]$. We make different simulations of the model for $n = 2$, $n = 3, \ldots$ to $n = 15$. They indicate that the qualitative properties of the dynamics are robust with respect to the number of groups. Similarly, the same qualitative results obtain when we test the model for different values, $\delta, 0 < \delta < 1$, for $\theta = \{2, 3, 4, 5\}$ and $\frac{1}{3} < \beta \leq 1$. The properties of the model are, on the contrary, sensitive to prior knowledge $\{k_{io}, i = 1 \ldots n\}$, effort parameters $\{\alpha_i, i = 1 \ldots n,\ \bar{\alpha}\}$ and σ.

First, high values of σ induce a limited co-evolution of practices with a clear selection, whereas smaller values of σ are associated with the preservation of diversity between practices.

Second, in the presence of truce (when $\alpha_i = \bar{\alpha}$), the final specification of selected practices is positively correlated with by the distributed levels of prior knowledge $\{k_{io}, i = 1 \ldots n\}$ (see Table 2 and Figs. 4–6 below). This property is not preserved in the presence of conflict. Indeed, the difference in effort parameters $\{\alpha_i, i = 1 \ldots n\}$ plays now a crucial role, but it is worth noticing that this distribution is not a sufficient indicator of selection (see Table 3 and Figs. 7–9 below).

Finally, the configurations can be ranked according to global learning and profitability. This ranking is sensitive to the truce problem. The more the cognitive and political dimensions are running in concert (truce), the higher the diversity (small σ), profits and global learning. Opposite results are obtained in conflict situations. Our main findings are summarized in the followings tables:

Table 1. Truce configurations

	Dynamics of practices	Learning	Profit
$\sigma \sim 0$	Co-evolution of n practices without a strong dominance according to k_{io}	High	Maximal
$\sigma \sim \frac{1}{2}$	The degree of co-evolutions decreases Practices with the lowest k_{io} die out	Lower	Intermediate
$\sigma \sim 1$	1 selected practices (with the highest k_{io}) n - 1 practices die out	Down	Minimal

Table 2. Conflicting configurations

	Dynamics of practices	Learning	Profit
$\sigma \sim 0$	n practices co-evolve with dominance according to α_i	Down	Minimal (negative)
$\sigma \sim \frac{1}{2}$	The degree of co-evolutions decreases	Slightly improved	Intermediate
$\sigma \sim 1$	Quick selection of 1 or 2 practices disoperation of the others	Higher	Maximal

Below, we reproduce an example with $n = 5$ that illustrates graphically these findings on the selection of practices, the actions of the hierarchy, local and global learning and profitability in the presence of truce or conflicts, for $\sigma = 0.1$, $\sigma = 0.5$ and $\sigma = 0.9$. Table 1 shows the values of the technological and global parameters in this example. Tables 2 and 3 display the distributions of prior knowledge and effort parameters. Finally, Table 4 indicates initial conditions and simulations time schedule.

Table 3. Technological and global parameters

p	β	θ	δ
1	0.66	2	0.1

Table 4. Prior knowledge

$k_{i0}, i = 1, \ldots n$ randomly selected on $[1, 3]$**:** $\{\, 1.38;\ \ 2.78;\ \ 1.37;\ \ 1.07;\ \ 2.35 \,\}$

Table 5. Effort parameters

Conflict	Truce
$\alpha_i, i = 1, \ldots n$ randomly selected on $[0.1,\ \ 0.9]$**:** $\{\, 0.52;\ \ 0.71;\ \ 0.69;\ \ 0.16;\ \ 0.45 \,\}$	$\alpha_i = \bar{\alpha}, i = 1, \ldots n$ $\bar{\alpha} = 0.5$

Table 6

Initial conditions	Time
$x_i\,(0) = \frac{1}{n}, i = 1, \ldots n$	$t = 0$ to $t = 2 \times 10^6$

The following results for $\sigma = 0.1$, $\sigma = 0.5$ and $\sigma = 0.9$ in the two configurations obtain Figs. 4–6.

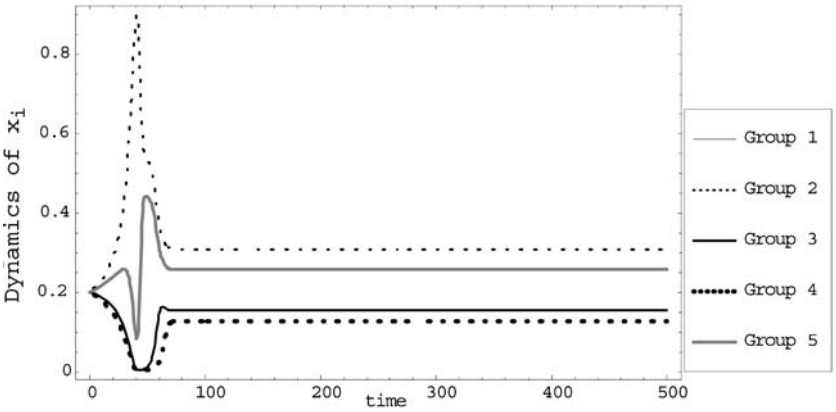

Fig. 4a–f. Truce with small hierarchical pressure ($\sigma = 0.1$). **a** Dynamics of x_i

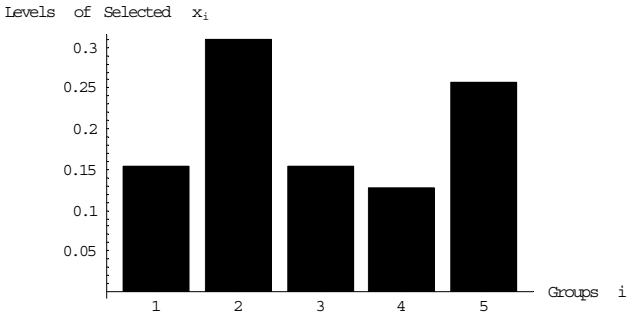

Fig. 4b. Levels of selected practices, $t = 2 \cdot 10^6$

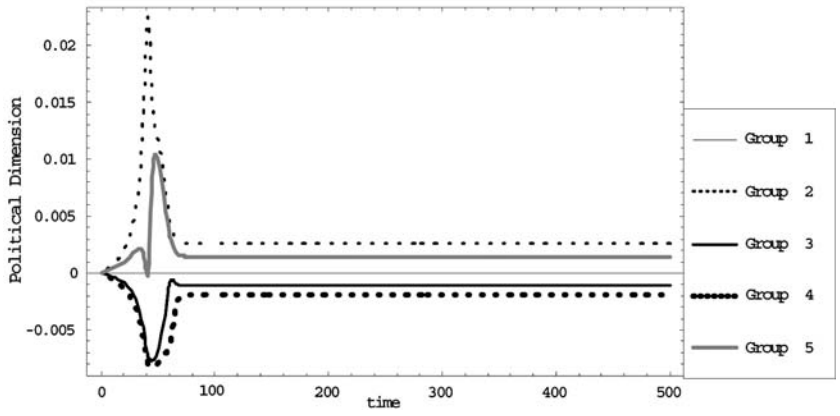

Fig. 4c. Political dimension

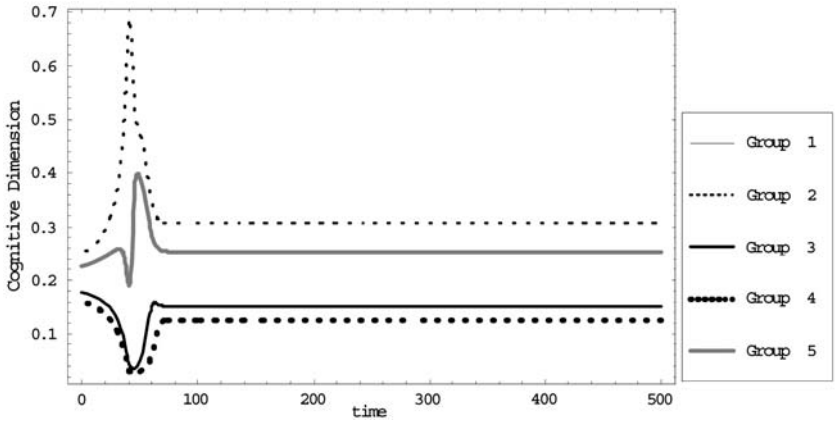

Fig. 4d. Cognitive dimension

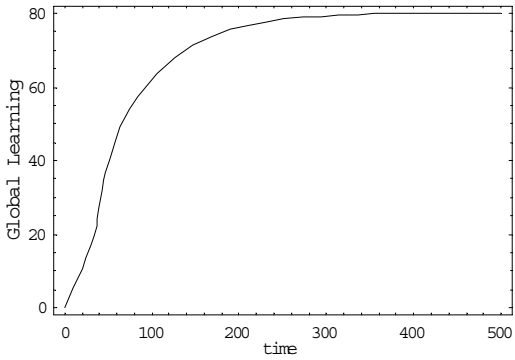

Fig. 4e. Global learning

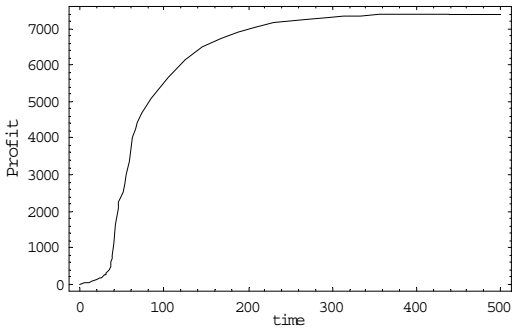

Fig. 4f. Profits

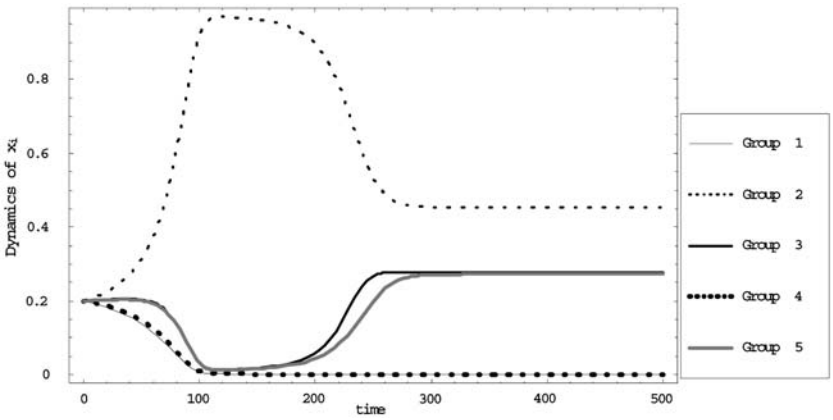

Fig. 5a–f. Truce with intermediary hierarchical pressure ($\sigma = 0.5$). **a** Dynamics of x_i

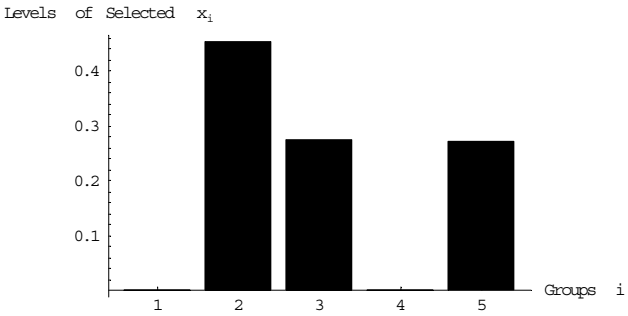

Fig. 5b. Levels of selected practices, $t = 2 \cdot 10^6$

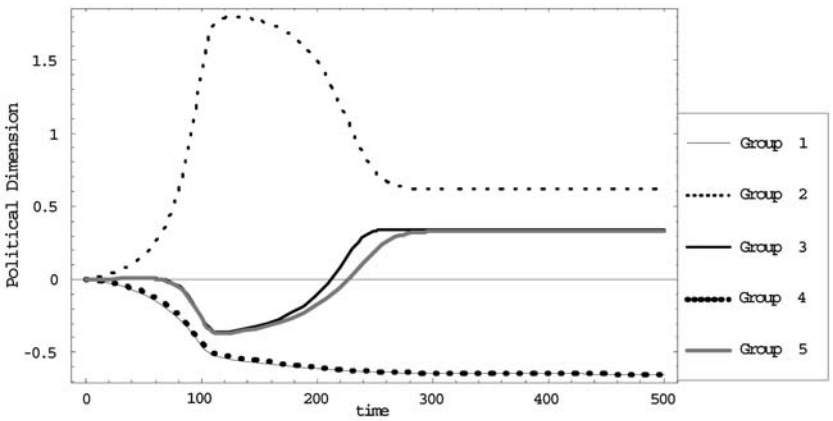

Fig. 5c. Political dimension

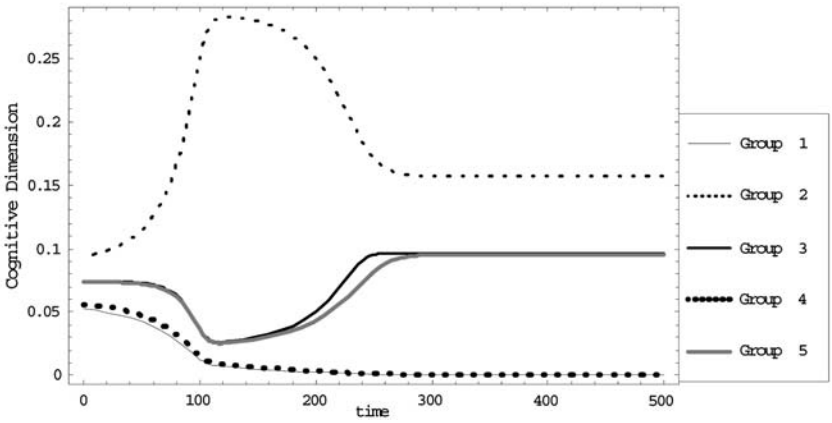

Fig. 5d. Cognitive dimension

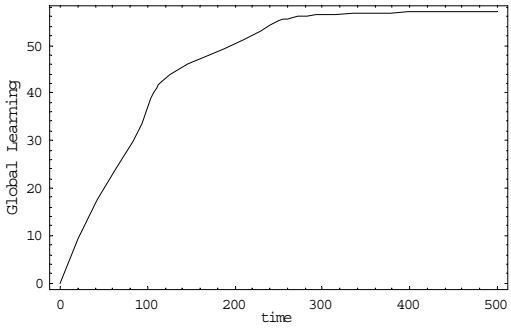

Fig. 5e. Global learning

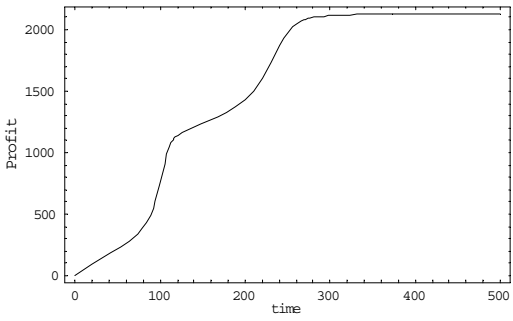

Fig. 5f. Profit

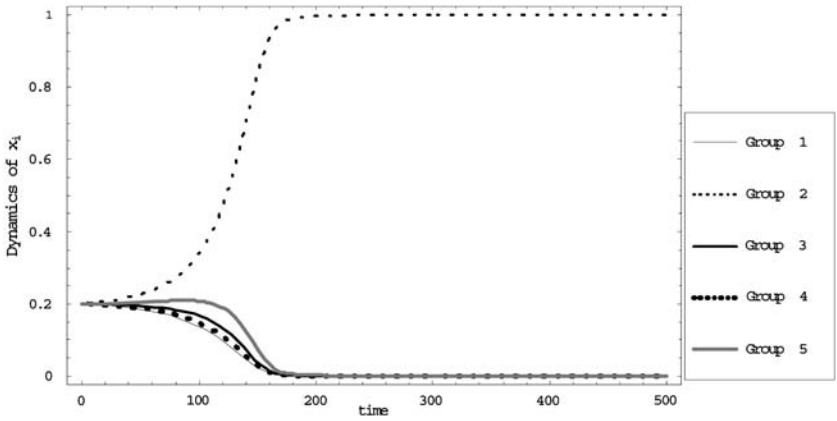

Fig. 6a–f. Truce with high hierarchical pressure ($\sigma = 0.9$). **a** Dynamics of x_i

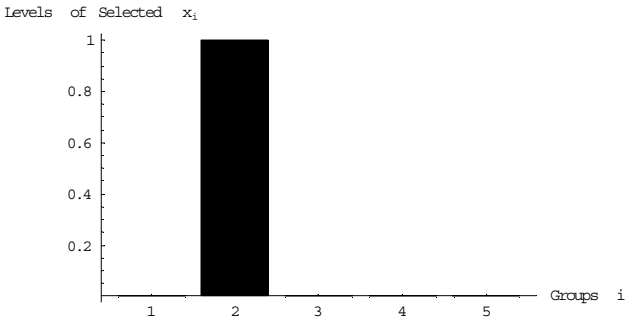

Fig. 6b. Levels of selected practices, $t = 2 \cdot 10^6$

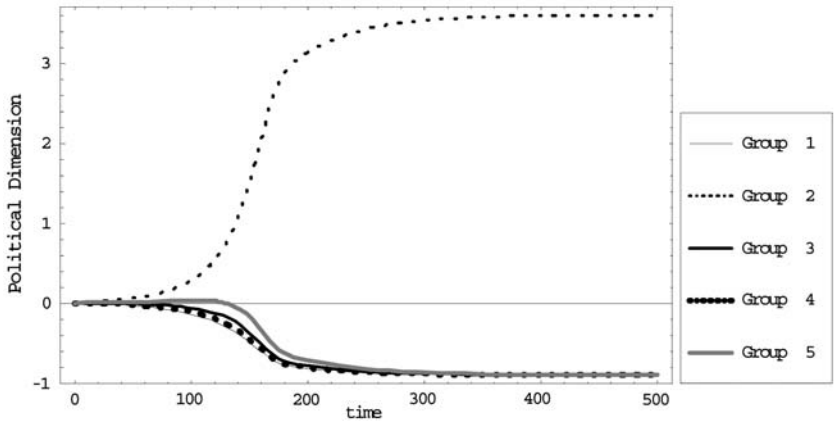

Fig. 6c. Political dimension

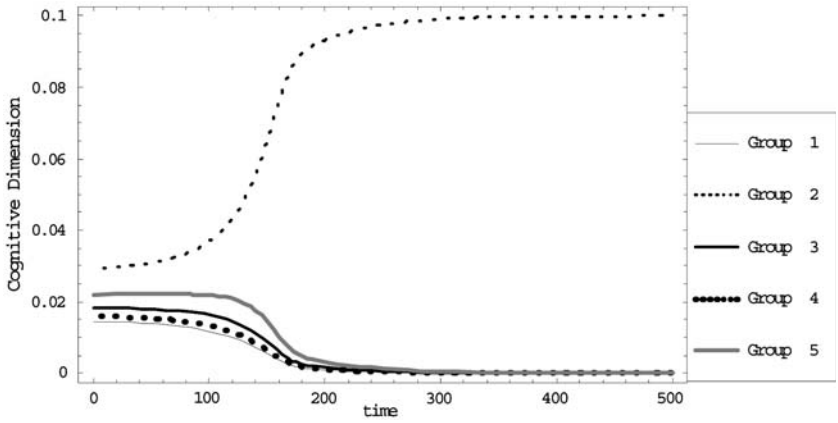

Fig. 6d. Cognitive dimension

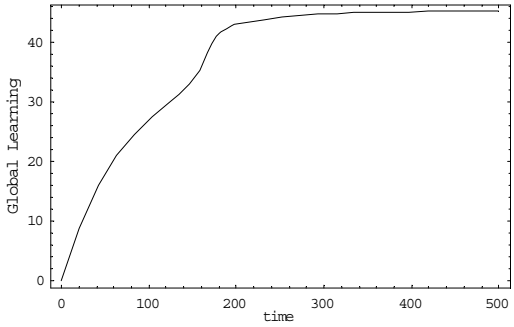

Fig. 6e. Global learning

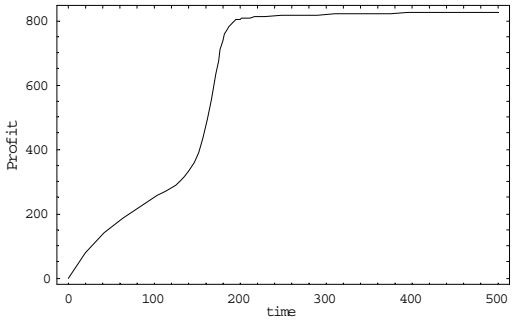

Fig. 6f. Profit

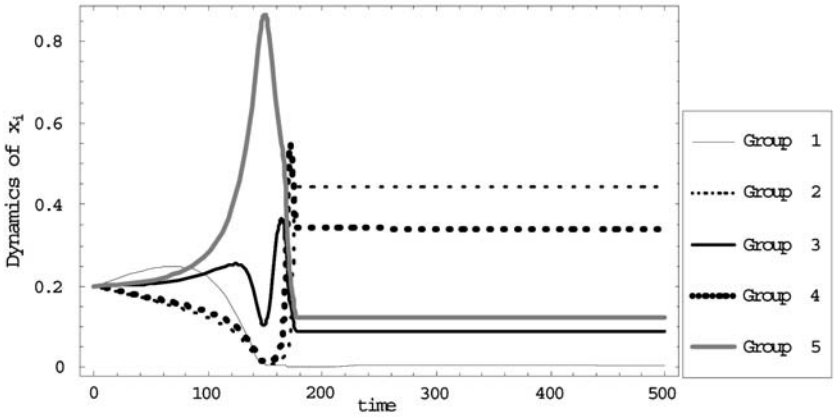

Fig. 7a–f. Conflict with small hierarchical pressure ($\sigma = 0.1$). **a** Dynamics of practices

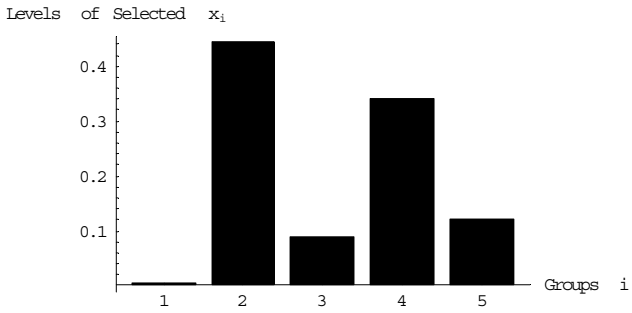

Fig. 7b. Structure of selected practices, $t = 2 \cdot 10^6$

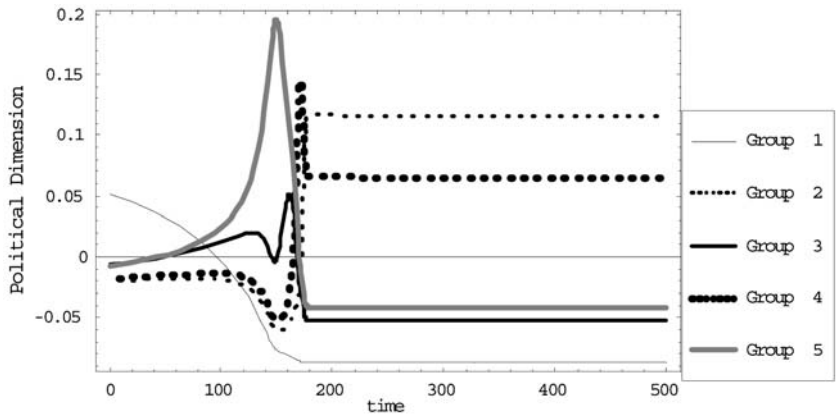

Fig. 7c. Political dimension

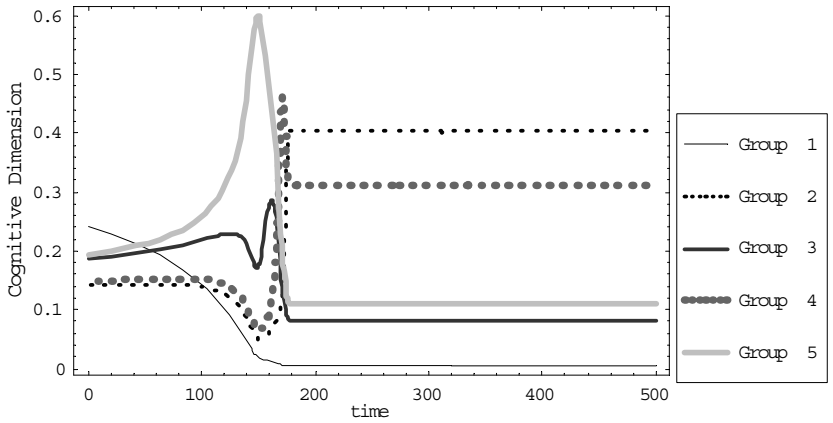

Fig. 7d. Cognitive dimension

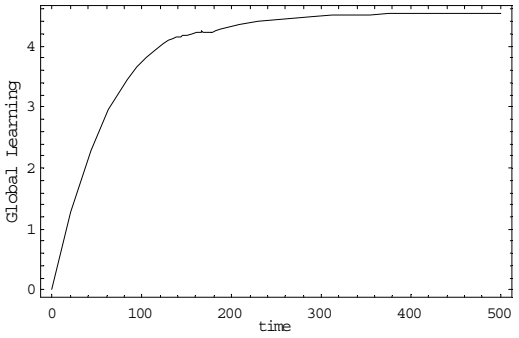

Fig. 7e. Global learning

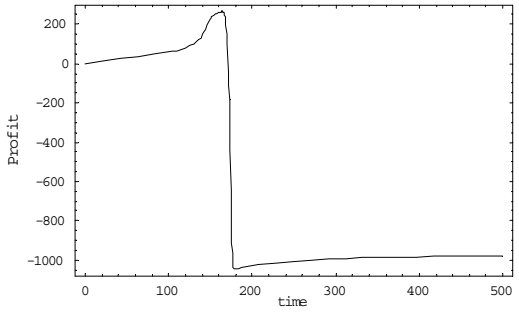

Fig. 7f. Profit

In the presence of truce, the dynamics exhibits sustainable cognitive and profitable set-ups. When hierarchical pressure is low ($\sigma = 0.1$, Fig. 4), all different routines coexist (Fig. 4a,b) with a high degree of profitability in a complete network. (Fig. 4e) The co-evolution of various routines predominates even when no intentional selection process is in place. Group creativity is also confirmed in this

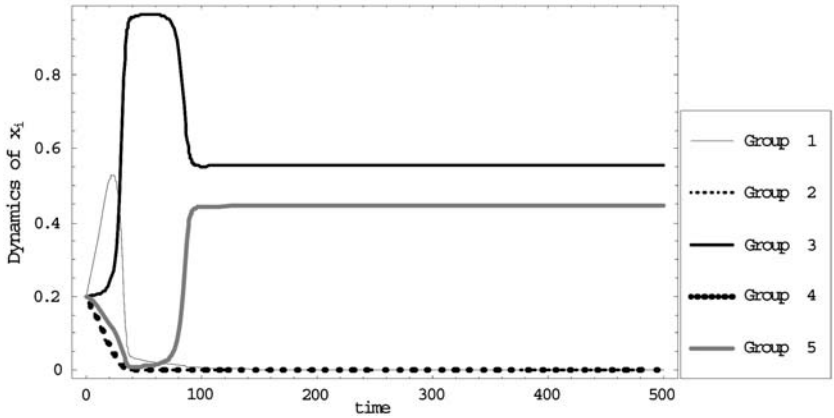

Fig. 8a–f. Conflict with small hierarchical pressure ($\sigma = 0.5$). **a** Dynamics of practices

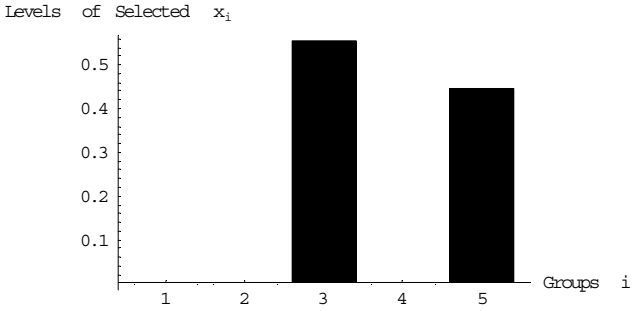

Fig. 8b. Structure of selected practices, $t = 2 \cdot 10^6$

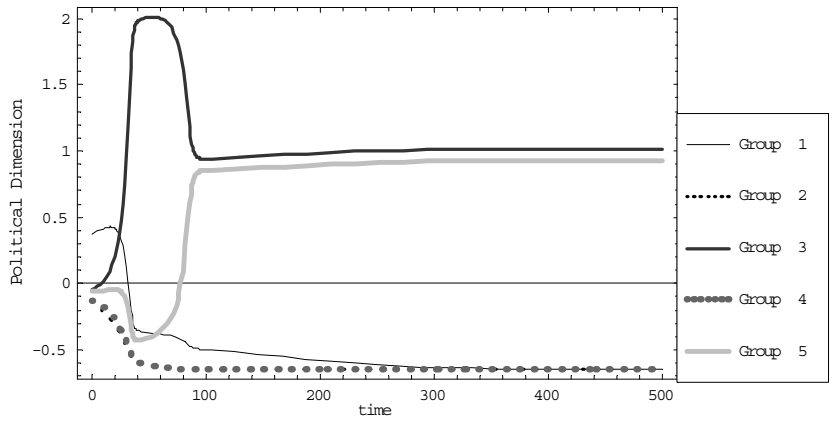

Fig. 8c. Political dimension

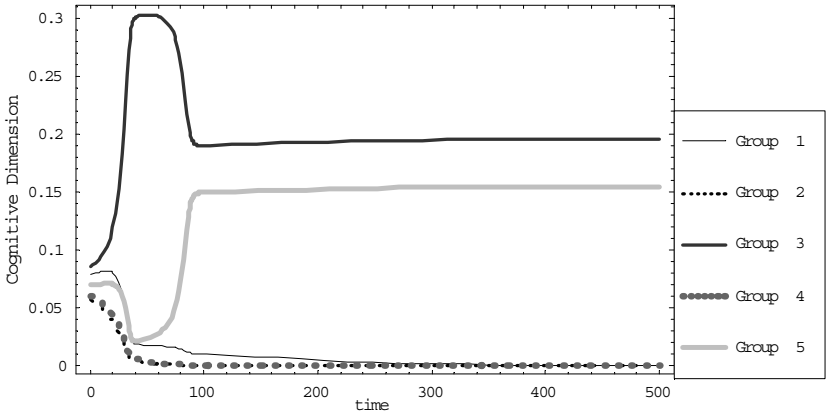

Fig. 8d. Cognitive dimension

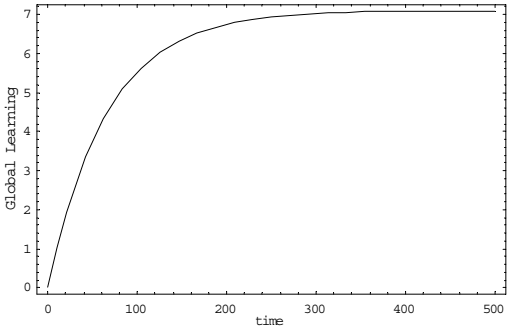

Fig. 8e. Global learning

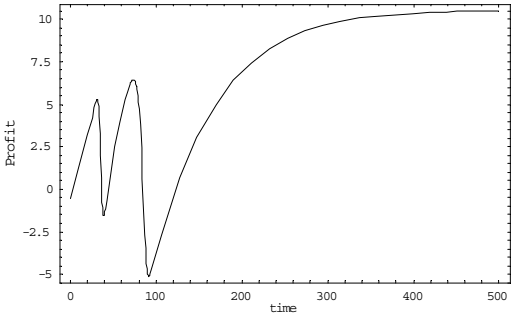

Fig. 8f. Profit

type of situation (Fig. 4f). Higher hierarchical pressure (increased σ, Fig. 5), reduces the space for learning and depletes the level of profitability (Fig. 5e,f). In this kind of organization, coordination mechanisms are sufficiently powerful to create an efficient selective process for the routines in operation. Coherent actions by the hierarchy induce a selection mechanism characterized a degree of co-evolution

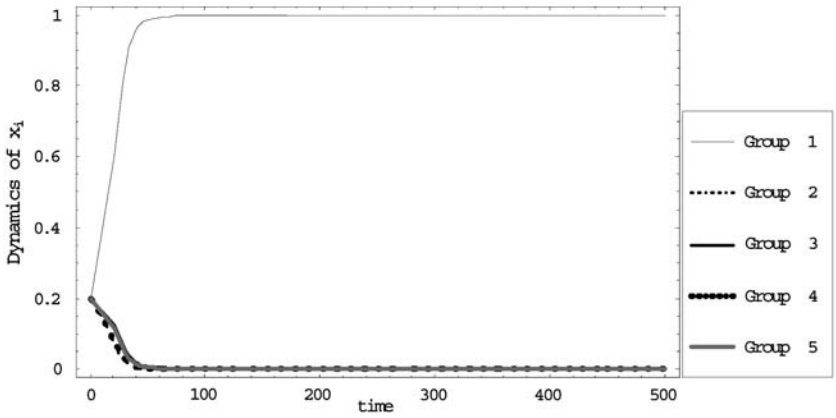

Fig. 9a–f. Conflict with high hierarchical pressure ($\sigma = 0.9$). **a** Dynamics of practices

which is decreasing with σ (5 to 1) (see Figs. 5a,b, 6a,b). If global learning mechanisms are still rather efficient, the level of profitability becomes quite inferior to the one obtained in more horizontal organizations (Figs. 5e,f, 6e,f). The richness of learning and knowledge is counterbalanced by sluggish selective mechanisms, which can create short-term efficiency problems. This tends to show that hierarchical pressures are indeed very costly to monitor and may generate unintended effects in terms of profitability in the truce case.

In conflicting situations with low hierarchical pressure, groups have a sufficient degree of autonomy to promote their own organizational practices (Fig. 7a and 7b). However, the practices of the group devoting the highest level of effort to promote its own routines become dominant. Moreover, it appears that conflict entails significant coordination costs, which reduce learning and profits as compared with the previous case (Fig. 7e and 7f).

The presence of hierarchical pressure here is crucial not only for the selection of routines but also for the performance of the organization. Increased hierarchical pressure introduces some coherence in the development of learning, by implementing a process of routine selection (see Figs. 8a,b, 9a,b). In this case, learning and profitability are improved (Figs. 8e,f, 9e,f). However this result maintains its robustness only in the presence of conflict (for a similar result, see Foss, 2003). Clearly then, it does not lead to the conclusion that hierarchical pressure is always viable, but, more modestly, to the idea that some leadership can be useful to limit a fall in profitability produced by a misalignment between political and social forces.

4 Conclusion

This article starts from an evolutionary view of the firm in order to tackle the problem of latent conflicts first introduced by Cyert and March and later redeveloped by Nelson and Winter. The importance of this issue has been recently stressed in the literature (see e.g. Dosi, Levinthal and Marengo, 2003), showing the need for the evolutionary theory of the firm to develop some operational tools in order to

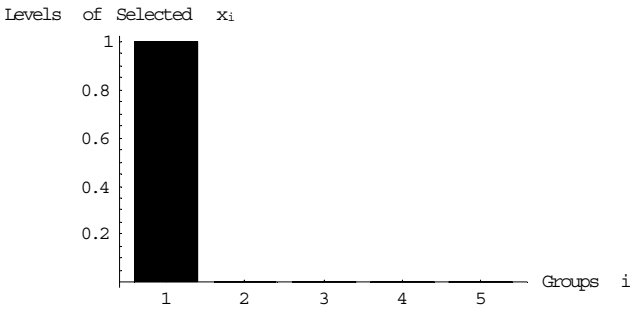

Fig. 9b. Structure of selected practices, $t = 2 \cdot 10^6$

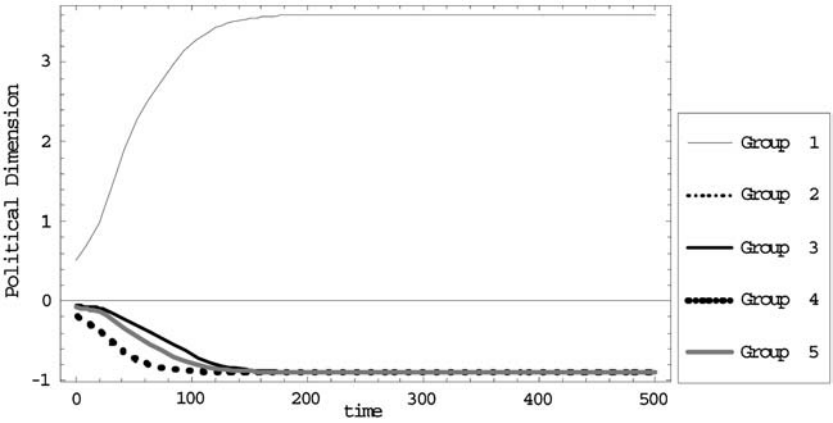

Fig. 9c. Political dimension

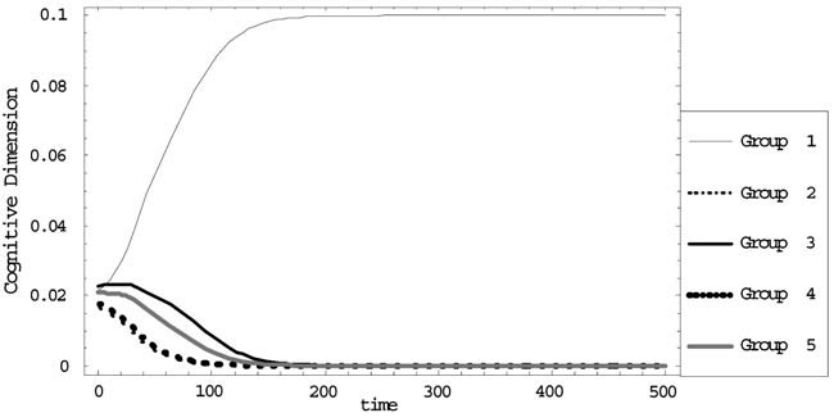

Fig. 9d. Cognitive dimension

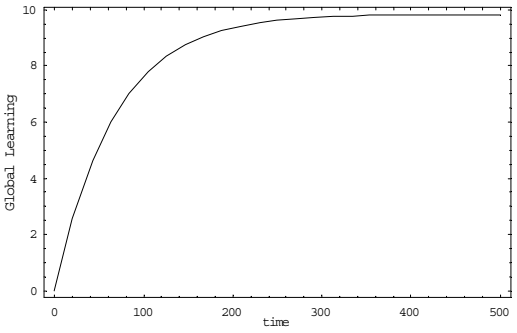

Fig. 9e. Global learning

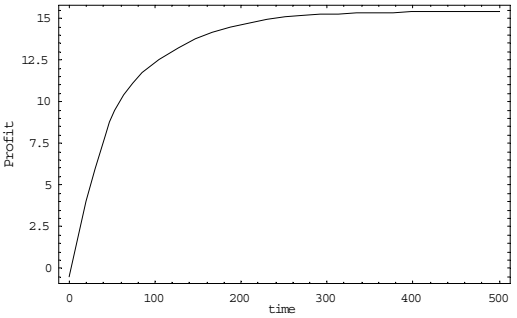

Fig. 9f. Profit

understand this puzzle. From this standpoint, we proposed a model of internal selection of routines based on the interplay of the cognitive and political dimensions. Two political configurations, truce and conflict, were considered in set-ups displaying different degrees of hierarchical pressure on knowledge creation and learning. Numerical simulations show how the strictness of the hierarchy is decisive in the selection of routines in these two opposed political configurations.

Selection is crucial in the presence of conflict, since it has a counterbalancing effect in a chaotic context. In the case of conflict, hierarchy attempts to impose order and re-establish coherence, a fact that restores the level of profitability. This result does not of course mean that hierarchy and leadership are generally essential to knowledge creation, but simply that some conflicts may discourage motivation and learning (Foss, 2003). In the presence of a truce, the co-evolution of practices goes hand in hand with a high level of profitability. Low hierarchical pressure combined with a truce leads to a situation in which creativity and learning are preserved. In such circumstances, high hierarchical pressure tends to undermine a firm's viability by hindering learning.

Finally, our model shows that the Nelson and Winter conjecture is quite robust, in the sense that profits fall in the presence of conflict and some form of leadership is required in order to restore profitability. Consequently, the model contends that

networking designs are more profitable organizational configurations because of their dynamics of learning, but that they are also very sensitive to the truce problem.

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