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How does leadership support the activity of communities of practice ?

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Summary : the purpose of this paper is to present leadership as an important mechanism underlying the coordination and the cohesion of communities of practice. More precisely, it will be shown that an important factor conditioning the coordination and the cohesion of a community rests on the leaders' capacity to influence individual behaviors. This capacity of influence is grounded on the high degrees of reputation and trust they enjoy within the community. However, coordination of individual behaviors is not ensured by the mere existence of leadership. A simulation model points out the conditions under which leadership forms an efficient coordinating device.

Résumé : le but de cette contribution est de présenter le leadership comme un mécanisme fondant la coordination et la cohésion des communautés de pratique. Plus précisément, il est montré qu'un important facteur sous-tendant cette coordination repose sur la capacité des leaders à influencer les comportements individuels. Cette influence est basée sur les hauts niveau de réputation et de confiance dont jouissent les leaders au sein de la communauté. Notre argument est néanmoins tempéré par le fait que la simple existence de leaders ne garantit pas à elle seule la coordination des individus. Un modèle de simulation permet de mettre en avant les conditions sous lesquelles le leadership permet de coordonner de manière efficace les comportements individuels.

Keywords : communities of practice, leadership, reputation, exit, loyalty, coordination, social simulation.

Mots-clé : communautés de pratique, leadership, réputation, sortie, loyauté, coordination, simulation sociale.

JEL : L23, D23.

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Introduction.

Numerous recent contributions (Adler, 2001, Amin and Cohendet, 2000) pointed out the importance of so-called communities of practice in a knowledge economy. The prominence of those communities has been perceived in several fields of enquiry such as the knowledge-based theory of the firm (Cohendet and Llerena, 2003, Brown and Duguid, 1991 and 2001), open source software development (Kogut and Metiu, 2001) or industrial clusters (Dahl and Pedersen, 2005). The argument frequently put forward is that communities of practice lie at the core of collective learning and collective invention processes (see, e.g. Cowan and Jonard, 2003) since they rely on a constant exchange of knowledge and information related to the considered practice. Those communities, which are characterized by the absence of any contractual scheme aiming at regulating their members' individual behaviors, prove to be particularly efficient in treating the issue of knowledge within the firm. Indeed, many authors (e.g. Hodgson, 1998, Witt, 1998) have pointed out the shortcomings of contractual approaches to coordination such as Transaction Costs Economics (Williamson, 1975) when dealing with knowledge.

However, very little has been written about the functioning of communities of practice. Indeed, since they consist in groups of people engaged in a common activity, numerous questions might be raised, among these, the coordination of their members. The issue of coordination is of importance since it determines the efficacy of individual activities for the development of the common practice. This, in turn, conditions their interest in contributing to the community and, therefore, the community's cohesion. The coordination problem has been analysed in several contributions (e.g. Muller, 2004, Muller, 2006). The argument put forward was that the coordination of individual behaviors was ensured through the existence of social norms and the emergence of community leaders. It was argued in those contributions that leaders differ from other members of the community of practice by being characterised by higher degrees of reputation and trust[1] than their peers.

[1] Reputation is here defined as a set of information shared by the whole community and dealing with an individual's competences and behavior. It corresponds to a device aiming at enhancing the possibility of binding new relationships with other members of the community. Reputation builds on the accumulation of information about an individual's past behavior, those information being subject to a consensus among members. Similarly, trust represents, in a bilateral interaction, a psychological state that incites an individual, in a given situation, to take the risk to suppose that another individual will adopt a behavior *a priori* in conformity with expectations (Fukuyama, 1995). Hence, trust corresponds to an expectation or belief that the other party will act benevolently.

The aim of this paper is to concentrate more precisely on the impact of leadership on the coordination and the cohesion of communities of practice. It will be argued that leaders, due to the high levels of reputation and trustworthiness they enjoy within the community, are able to influence individual behaviors, thus contributing significantly to the coordination and the cohesion of communities of practice.

This paper is organized as follows. Section I will present the concept of community of practice. Section II will treat the problem of the cohesion of communities of practice. It will be argued that one of the major threats for their cohesion lies in the lack of coordination of its members. Section III will argue that leaders, through the influence they exert on individual behaviors, play an important role in the coordination and the success of the communitarian activity. Sections IV and V will present a simulation model studying the conditions under which coordination through leadership is likely to be beneficial for the community.

I. Communities of practice: a short overview.

Communities of practice form a particular instance of knowing communities. Those latter communities can be broadly defined as structures of social interactions aiming at the creation and the diffusion of knowledge. As pointed out by Bowles and Gintis (1998), those communities are notably characterized by frequent interaction among the same agents, non-anonymous information flows and an increased access to information about other community members.

Communities of practice represent groups of people engaged in common practices and interacting constantly in order to develop their competences (Brown and Duguid, 1991, Lave and Wenger, 1991, Wenger, 1998). These interactions, which may occur on a direct, face to face basis or through indirect contacts (in particular in the case of open source software communities) consist in the disclosure and the evaluation of "best practices" as well as any piece of information or of knowledge related to the relevant practice. Through those social habits of knowledge disclosure, community members are able to engage in collective learning processes. Wenger (2001) points out three main characteristics shared by communities of practice: 1) a common domain of expertise (corresponding, in the case of open source software, to some degree of mastery in computer science) ; 2) the existence of interactions

It is a situation where the other part cannot be forced to fulfil this expectation, i.e. there is a risk of betrayal. Trust builds on the accumulation of interpersonal interactions.

among members ; 3) the development of a shared repertoire of resources (corresponding to the development of the source code of the software in the case of open source software, or to publications in academia).

Another distinctive characteristic of communities of practice lies in the absence of any contractual schemes aiming at organizing its activity (Cohendet and Diani, 2003, Amin and Cohendet, 2003). Thus, communities enjoy the capacity to self-organize, this capacity being grounded in the same time on the identity and the autonomy of their members (Wenger, 1998). The first pillar of self-organization corresponds to the capacity of an individual to define his own "identity" in relation to the community. Identity is influenced by the members' comprehension of the position they occupy within the community[2].

Wenger (1998) defines identity along three factors: engagement, imagination and alignment. Engagement corresponds to the capacity of the individual to contribute to the community's cognitive work and depends on the existing gap between the individual's objectives and the communitarian goals. The role played by imagination is to allow to draw a parallel between individual experience and the general models prevailing within the community. It enables the individual to position himself in relation to the dominant practice of the community. Alignment allows to undertake common actions by linking and directing the necessary resources for their accomplishment. Alignment implies that members tend to operate trade-offs between their own objectives and the communitarian goals. Thus, alignment constitutes a mechanism regulating contestation behaviors by enabling a convergence between the individual objectives and the communitarian goals.

Autonomy constitutes the second pillar of a community's self-organizing capacity. Autonomy enables the agent to freely define the nature as well as the level of his commitment to the community. Indeed, since members are endowed with a personal background (which is dealing with his communitarian experience or not), they tend to specialize in particular fields

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of inquiry. In this manner, one of the distinctive traits of communities of practice lies in the specialization of their members (Amin and Cohendet, 2003).

A consequence of specialization lies in the fact that each member is endowed with different objectives and motivations (Leibenstein, 1987). Such specialization effects were notably emphasised in a study of the Freenet project[3] (von Krogh, Spaeth and Lakhani, 2003). It was shown that each member of the project tends to specialize in the development of very specific functionalities of the software (for instance, some may specialize in the user interface, some other specialize in the cryptography modules). This specialization in specific functionalities implies that each member develops particular knowledge related to his field of enquiry while ignoring other parts of the project.

Such heterogeneity in individual knowledge and behavior implies some shortcomings in terms of task coordination and of work coherence. However, these limitations can be hardly addressed by the classical approaches to organizations. Several reasons can be put forward. First, one of the basic characteristics of communities of practice lies in the fact that they do not rely on any contractual scheme. This implies that contributions of their members are the product of their free will: they are able to decide whether or not they contribute to the community and the type of their contribution. In this manner, agents enjoy the freedom to set the amount as well as the nature of their contributions without expecting any equivalent feedbacks from the community. Second, communities are relying on the existence of trust relationships among members since the environment of communities is constantly evolving. Members have to adapt their behavior to those evolutions. Trust constitutes an efficient coordinating device by allowing a certain degree of flexibility in the behaviors.

Leibenstein (1987) pointed out that hierarchy coordinated specialized tasks notably by a close intertwining between incentives and sanction mechanisms. However, to be effective and credible, those mechanisms require the implementation of monitoring systems aiming at assessing the level of effort of each member. Such monitoring systems can, in turn, be interpreted as an evidence of a lack of confidence of the hierarchy in the members of the organization. As a consequence, an atmosphere of distrust tends to flourish within the organisation.

[3] The Freenet software corresponds to a peer-to-peer software allowing for the dissemination of information over the internet. This software fulfils the same tasks as other peer-to-peer software such as Napster.

II. How to insure the cohesion of communities of practice?

A major characteristic of communities of practice lies in the absence of any contractual scheme. This implies that individual behaviors can hardly be guided by the use of the incentive mechanisms traditionally put forward in classical theories. As notably argued in Muller (2004), this coordination problem is partly overcome by the existence of social norms[4]. Social norms fulfil two tasks necessary for the durability of communities of practice. First, along with the common domain of focus, they contribute to filter the access to the community. Second, they contribute to the coordination of community members by providing a focal point (in the sense of Kreps (1990)) on which they can rely. Still, social norms only partly achieve to raise loyalty since, due to their high degree of generality, they can give rise to ambiguities in their perception and interpretation (Muller, 2004). This yields different and even conflicting perspectives among members of the community as well as between the community (as a whole) and its members. Coordination is achieved through the complementary action of community leaders.

Community leaders, due to their capacity to coordinate the behavior of heterogeneous agents, allow to enhance the implementation and the evolution of the social norms prevailing within the community. Leadership is here defined as the capacity to influence individual behaviors through an influence exerted on information and knowledge flows (see Aghion and Tirole, 1997, Hermalin, 1998, Foss, 2001). Community leaders play important roles in maintaining the cohesion of the community by speeding up the construction of commonalities among members. Moreover, they can reinforce members' interest in the community's common enterprise by influencing evolution in social norms.

This capacity to maintain the cohesion of communities follows their privileged position within the communication network of the community. Leaders are likely to be more connected to each other and, in this way, to propose a more coherent vision of the community. Indeed, under some circumstances, it is reaTheir higher communication capability is due to the high degree of reputation they enjoy within the community of practice (Muller, 2006). The

[4] Social norms are here understood as a set of general rules of voluntary behavior (Kreps, 1997) which fulfils several conditions: 1) it is shared by the members of the community; 2) it is maintained by the existence of sanction (which, in communities, take particularly a moral form) imposed to the individual having betrayed it; 3) members of the community believe in its relevance (Elster, 1995) (see Muller, 2005 for further developments on this point).

main function of reputation is to mitigate the uncertainty associated with other individuals' competences and behaviors. Hence, reputation constitutes an important factor determining the choice of potential partners: leaders endowed with a higher reputation are more likely to be solicited for a new relationship than other individuals.

This section aimed at explaining the contribution of community leaders to the coordination of members, thus conditioning the cohesion of the whole community. However, as we shall see in latter sections, the cohesion of the community may not be ensured by the sole recourse to leadership. Next sections will present a model discussing the condition under which leadership affects members' behaviors in a way that the cohesion of the community is ensured.

III. A model of behavior coordination.

Community leaders, who are characterized by higher levels of reputation, enhance the coordination of individual behaviors through an influence put on their behavior and knowledge. This, in turn, affects the coherence and the loyalty to the community. The formal model we present in this section constitutes an implementation of our previous discussion on the influence of leaders on the building of cognitive commonalities among members. The building of commonalities, in turn, influences their loyalty to the community of practice. In order to show this, we make use of a model of continuous choice among heterogeneous agents[5].

Our model takes on as a starting point that individuals may adopt behaviors which may be viewed in a continuous manner. More precisely, it is here assumed that individuals have the ability to adopt any behavior ranging between two extremes[6]. This type of modelling, which has previously been introduced by physicists (Weisbuch et al., 2002, Deffuant et al., 2002) allows to study the evolution dynamics of individual behaviors. Unlike models of

[5] Models of choice among heterogeneous agents have been the object of a wide focus among economists. Those models range from game theoretic (Young, 1993), to evolutionary, focusing on recruitment (Arthur, 1989, Kirman, 1993) or on herd (Banerjee, 1992, Orléan, 1995) behaviors. However, this class of models faces some shortcomings in accounting for the actual dynamics occurring in communities of practice for several reasons. First, those models are mainly related to binary or discrete choices. This situation doesn't suit well the case of communities of practice which are characterised by a wide variety in individual choices and perspectives. Moreover, by proposing binary choices, this class of models fails to monitor evolutions in individual behaviors as the outcome of multiple external influences.

[6] In the frame of communities, they may, for instance, range from purely opportunistic, free-riding behaviors in which individuals disclose no information and knowledge, to purely altruistic behaviors.

binary behaviors in which the evolution in one's behavior results from economic calculus or from the reaching of a critical mass, one can undertake a more realistic study of behavior evolution. Moreover, choice is the outcome of the circulation of information within the group. It follows that, during interactions, individuals try to influence their peers in order to bring the latters' behavior closer to the formers'. The model proposed in this paper focuses on the relationship between social characteristics and group dynamics by evaluating the impact of the influence of communitarian leaders on the evolution of individual behaviors.

1. Description of the model.

At time 0, let us consider a population S of N agents *i*, each having a behavior $x_{i,0}$. Initial behaviors are distributed in an interval [0;1] in such a way that $\forall i = 1,\ldots,N, x_{i,0} \in X = [0;1]$ where X corresponds to the set of behaviors which are considered as acceptable in the community. Therefore, behaviors considered as extreme are characterized in our typology as $x_i = 0$ and $x_i = 1$. Different behaviors might, in open source communities, correspond to different approaches to the architecture or even the philosophy of the project (Bezroukov, 1999).

Agents are only likely to be influenced by individuals having behaviors which are not too far from their own. This effect is grasped by two phenomena. First, community members tend to become less and less likely to influence their peers as divergences in behaviors increase. This effect mimics social stratification phenomena in which individuals tend to interact only with persons sharing the same behavior or some common traits. Individuals only interact with agents whose behavior remains below a given threshold. If the gap goes beyond this threshold, the former is not influenced by the latter (Hegselmann and Krause, 2002). This threshold might be interpreted as an individual's ability to understand others' behaviors and is therefore relying on the community's ability to build up a common knowledge base. This behavioural assumption is therefore closely linked to the issue of task specialization which constitutes a distinctive characteristic of open source communities[7].

[7] In their study of the Freenet community, von Krogh et al. (2003) provide evidence of very strong tasks specialization effects: most of the contributors to the project only contribute to one or very few modules of the software. Their knowledge is limited to the sub-community they are belonging to. Thus, their ability to communicate with and to influence other members of the community might be restricted to their module. Von Krogh et al. also found that each file belonging to a module and coding for the functionalities of the module are, on average, written by only one or two contributors. This provides an evidence of further specialization, members of OSS projects usually sharing their expertise with, at most, one of their peers. This observation

Each member of the community is assumed to be endowed with reputation R_i. Reputation approximates the leadership status an individual enjoys since the former forms a prerequisite to the latter (cf. Muller, 2006). Indeed, since reputation allows an individual to bind numerous relationships with other members of the community, he has the ability to influence a significant proportion of community members. Reputation acts in the opposite way to differences in the behaviors as it provides the individual with a higher visibility within the sub-community he is belonging to, thus increasing his ability to influence other members. In the model, a distinction is drawn between individuals endowed with high reputation levels R^{Max} and individuals endowed with low reputation levels R^{Min}. Individuals endowed with high reputation levels are contained in the set S^{Max} while individuals endowed with a low reputation belong to the set S^{Min}.

The dynamics of the system decomposes into two steps. The first step is related to partnership binding and the second step is dealing with the actual behavior dynamics. At each time step an individual *i* characterized by behavior x_i is randomly drawn. This individual interacts with an other member *j*. *j* is chosen with a probability depending on his reputation R_j weighted by his behavior x_j. Formally, the probability for *j* to interact with *i* (similarly, to form a pair $\{ij\}$) is given by:

$$P\left[\{ij\}\right] = \begin{cases} \dfrac{R_j^{1-\left|x_{i,t}-x_{j,t}\right|}}{\sum\limits_{k<N/\left|x_{i,t}-x_{k,t}\right|<\varphi} R_k^{1-\left|x_{i,t}-x_{k,t}\right|}} & if\ \left|x_{i,t}-x_{k,t}\right| < \varphi \\ 0 & else \end{cases}$$

Where φ corresponds to the threshold value under which interaction can take place. From our previous discussion, it follows that this threshold is negatively related to the degree of specialization in the community: the higher the value of the confidence threshold, the lower the degree of specialization in the community. One may observe that the index of *j* has not been restricted such as $j \neq i$. The possibility that agent *i* doesn't interact with anyone else is kept.

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therefore supports our hypothesis of individuals' declining influence as behaviors become more different. Linking specialization and influence ability, we may therefore conjecture the negative relationship between both: the higher the degree of specialization within the community, the lower the ability to directly communicate and, therefore, to influence other members. This conjecture is in line with Leibenstein (1987) who argued for the positive relationship between the degree of specialization and the dispersion in individual motivation: higher degree of specialization lead individuals to ignore individuals engaged in other tasks, thus limiting their capacity to communicate with each other.

The second step of the process consists in the actual behavior dynamics. It is assumed that the interactions are only unidirectional, implying that only individual *i* is influenced by agent *j*. An instance of such a relationship corresponds to feedbacks that a programmer of the community gets from his peers once he has disclosed a piece of code. A similar process is to be found in academia, a researcher getting comments from peers during a conference or after having submitted a paper for publication. Those comments made on the contribution influence, in turn, the individual's behavior. Formally *i*'s behavior after having been under the influence of *j* is given by :

$$x_{i,t+1} = x_{i,t} + \delta\left(x_{j,t} - x_{i,t}\right)$$

where δ is a convergence rate which is interpreted as agent *j*'s ability to efficiently influence *i*'s behavior.

2. Numerical analysis.

Due to the existence of the threshold φ, the dynamics of the model are non linear, thus making the model particularly hard to solve in an analytical way (Hegselmann and Krause, 2002). This difficulty motivates the use of numerical simulation for the analysis of the model. Basically, our interest lies in the influence of the structure of leadership in the evolution of individuals' behavior. Moreover, our interest lies in the analysis of the conditions underlying the ensuring the cohesion of the community or, at the opposite, the conditions under which members adopt exit behaviors and communities fork into several communities. The first effect of interest corresponds to the ability of community leaders to direct members' behaviors. This effect is grasped by the analysis of the evolution of community members' average opinion. Those statistics are computed for both individuals endowed with high reputation levels and individuals endowed with low reputation levels:

$$\overline{x}_t^{Max} = \sum_{i/R_i=R^{Max}} x_{i,t} \text{ and } \overline{x}_t^{Min} = \sum_{i/R_i=R^{Min}} x_{i,t}$$

The differentiation of the members of the community according to their reputation proves to be of great interest since it allows us, first, to monitor the evolution in the individuals' behaviors according to their characteristics. Second, it informs about the more particular behavior dynamics occurring among highly reputed individuals. Third, it provides us with first evidences of the possible influence of highly reputed members on behaviors. Still, this measure only shows the evolution of the average opinion among both individuals enjoying high and low reputation levels. It doesn't address the other theoretical question underlying the present analysis: under which conditions do community members manage to reach a consensus or diverge in their behaviors ? This question might be tackled by making use of the behavior standard deviation for individuals endowed both with low and high reputation:

$$\frac{\sigma^{Max}}{\sqrt{\# S^{Max}}} = \frac{1}{\# S^{Max}} \sqrt{\sum_{i \in S^{Max}} \left(x_{i,t} - \overline{x}_t^{Max} \right)^2} \text{ and } \frac{\sigma^{Min}}{\sqrt{\# S^{Min}}} = \frac{1}{\# S^{Min}} \sqrt{\sum_{i \in S^{Min}} \left(x_{i,t} - \overline{x}_t^{Min} \right)^2}$$

Standard deviation constitutes a simple though rather reliable measure of the dispersion in the individual behaviors. Indeed, the emergence of a consensus corresponds to the adoption of the same behavior by all members of the community. This corresponds to the case that, $\forall i, j \in S, i \neq j, x_i \simeq x_j$, leading to $\frac{\sigma^{Max}}{\sqrt{\# S^{Max}}} \to 0$ and $\frac{\sigma^{Min}}{\sqrt{\# S^{Min}}} \to 0$. At the opposite, community forking corresponds to the case that several distinct behaviors remain. In this case, $\frac{\sigma^{Max}}{\sqrt{\# S^{Max}}} = \varepsilon_1 >> 0$ and $\frac{\sigma^{Min}}{\sqrt{\# S^{Min}}} = \varepsilon_2 >> 0$.

Still, standard deviation constitutes an imperfect measure of dispersion. In fact, it only informs about the existence of diverse behaviors within the community. A second measure, complementary to behavior standard deviation is provided by a measure of the number of behavior clusters. This measure is inspired by the measure of dispersion proposed by Derrida and Flyvberg (1986). Basically, it builds as follows. The spectrum of acceptable behaviors X is divided in κ intervals where κ is the sensitivity of the measure (in this model, κ is set to 20). The following dummy variable is then constructed:

$$Y_j = \begin{cases} 1 \ \ if \ \ \exists x_i, i = 1 \ldots N / x_i \in \left[\frac{j-1}{\kappa}; \frac{j}{\kappa} \right[, \ j \in [\![1; \kappa]\!] \\ 0 \ else \end{cases}$$

The measure of the number of clusters is then given by : $Y = \sum_{j=0}^{\kappa} Y_j$

The simulation settings are given in table 1.

IV. Results.

The major concerns of this model are about the influence of the leadership structure on community members' behavior and the condition of their convergence. In order to better asses the condition ensuring the coherence of the community, simulation runs controlled for the position of community leaders in the interval of acceptable behaviors X. The first results presented in this section discuss the influence of community leaders on the behavior dynamics. The second part of the discussion focuses on the dynamics the community in the case of disagreements among leaders.

1. Leadership and behavior dynamics.

The results presented in this section are dealing with the long term convergence of individual behaviors. The emphasis is put on the evolution of the average behavior as well as of its dispersion for both community leaders and individuals endowed with lower reputation values in the basic case of no disagreements among community leaders.

[Insert figure 1a about here]

[insert figure 1b about here]

Figures 1a and 1b display the evolution of average behavior for both individuals endowed with low and high reputation respectively[8]. In traditional models of continuous opinion dynamics with no reputation effects (e.g. Weisbuch, 2004), average behavior sticks in the long term to the value of 0.5. As shown in Figure 1a, the introduction of reputation effects has a consequence on the long run behavior of the community. The impact of the introduction of reputation effects on the average behavior of R^{min} individuals depends on 2 factors: the initial dispersion in leaders' behaviors and the share of community leaders. The first factor to be considered is the initial dispersion in the leaders' behaviors. As shown in Figure 1a, by

[8] Each figure is composed of 8 panels. The right panels show the evolution of average behavior in the case of a centralized leadership (i.e. few individuals are endowed with high reputation values) whereas left panels show the evolution of average behavior in the case of a distributed leadership. Moreover, panels display the cases in which community leaders' behaviors have been restricted to X_{Max} = [0;0.7], [0;0.8], [0;0.9] and [0;1] (from the top to the bottom). Finally, each panel displays the evolution of average behavior in the cases of high specialization ($\varphi = 0.3$), average specialization ($\varphi = 0.325$) and low specialization levels ($\varphi = 0.35$).

comparing different degrees of dispersion in leaders behaviors, the more concentrated community leaders in their initial behaviors, the more radical the evolution in the community's behaviors. In fact, decreases in the initial dispersion in leaders' behaviors implies higher degrees of coherence in the replication of their behaviors, thus making for leaders the "voice" option (Hirschmann, 1971) (corresponding to the capacity of influencing behaviors through protest) more effective. The second effect is related to the governance structure (either centralized, with a few leaders, or distributed). By comparing right and left panels in Figure 1a, evolutions in the behaviors become more spectacular as the proportion of individuals enjoying high reputation degrees is increasing.

Figure 1b displays the evolution of community leaders' average behavior. While they may influence the behavior of members enjoying low reputation, their own behavior is, in turn, evolving towards more central values. This implies that leaders are subject to the reciprocal influence of other members of the community. The extent of the evolution in the average behavior is determined by two factors: the initial dispersion in the leaders' behavior and the share of leaders in the community. Lower values in the initial dispersion in leaders' behaviors implies more striking evolutions in their behavior. At the same time, higher shares of leaders in the community imply fewer evolutions.

The previous discussion on the evolution of average behavior for both leaders and other members of the community does however not inform us under which circumstance they adopt, in the long run, similar behaviors. This question might be solved by the study of the evolution of behavior dispersion for R^{Max} individuals and R^{Min} individuals.

[Insert figure 2a about here]

Figure 2a and 2b display the evolution of behavior dispersion for R^{Max} and R^{Min} individuals respectively. In all panels, the decreasing shape of the curves representing standard deviation and the number of clusters indicates a reduction in behavior discrepancies among community leaders. This is done through the accumulation of influence relationships involving every members of the community (R^{Max} individuals as well as R^{Min} individuals). The coordination among community leaders is nevertheless conditioned by their position in the behavior spectrum.

As evidenced in Figure 2a, consensus is reached in the cases that $X_{Max} = [0;0.7]$ and $X_{Max} = [0;0.8]$. The emergence of consensus in the cases in which $X_{Max} = [0;0.9]$ and $X_{Max} = [0;0.1]$ is conditioned by the degree of specialization and the structure of governance (either centralized in which π = 0.1 or distributed in which π = 0.3). Low degrees of specialization (φ = 0.35), by enhancing the ability to communicate and to influence other members of the community, facilitate the emergence of consensus. In contrast, high degrees of specialization (φ = 0.3) lead community leaders to stick to different behaviors.

The second factor underlying the emergence of consensus among leaders is given by the structure of governance. A distributed leadership (corresponding to the case in which π = 0.3) increases the ability to achieve consensus among community leaders. Finally, one should note the effect of the dispersion in leaders' behavior and of the leadership structure in the speed of convergence. Distributed leadership combined with a lower dispersion in the leaders' initial behaviors tend to speed up the process of behavior convergence.

[insert figure 2b about here]

Interestingly, convergence in R^{Min} individuals' behaviors is favoured by a centralized structure of leadership. One may therefore observe that all conditions favouring the emergence of consensus among leaders tend to prevent other members from converging. An answer to this apparent paradox lies in the speed of convergence in leaders' behaviors. Distributed leadership combined with a lower dispersion in the leaders' initial behaviors speed up the emergence of consensus among leaders. But, due the barriers imposed by specialization, increases in the leaders' speed of convergence decrease their ability to communicate and to influence other members of the community (especially those endowed with extreme behaviors). This prevents those latter individuals to reach an average behavior, and they may possibly be thrown out of the community (as in the case in which X_{Max} = [0;0.7] and π = 0.3).

Summing up, while, as in the case of leaders, decreases in the level of specialization enhance the convergence of behaviors among community members, distributed leadership combined with a lower dispersion in the leaders' initial behaviors prevent the convergence. Linking it with real cases of open source communities, whereas Apache-type of communities, which are characterized by distributed leadership, better perform in directing members behaviors, they are more likely to run the threat to marginalize the members who do not agree with leaders' behaviors. In the Linux community, remarkably, leaders have a lower ability to direct the behavior of the members but this type of community appears to be less likely to marginalize the members who do not agree with leaders' behaviors.

2. What if leaders disagree?

The purpose of this section is to study the consequences of disagreements among community leaders. It is notably shown that those disagreements may, under certain circumstances, lead the community to fork. Forking may be described as follows. At the start, community members are endowed with different behaviors. When those differences become too strong, they may diverge and form several major "streams" within the community. If members are not able to reconcile those streams, the community is likely to fork into several distinct communities. Forking is often seen as a major threat for open source projects since it leads to split up communitarian resources (cognitive and material) between those communities and may, eventually, cause the death of the project (Bezroukov, 1999).

In our model, community forking is evidenced by the existence of high values for behavior standard deviation in the long term coupled by a low number of behavior clusters (for both R^{Min} and R^{Max} individuals) evidencing the emergence of a few significant competing sub-communities. Results displayed in the preceding section did not seem to display cases of forking since, most of the time, there is only one remaining behavior cluster in the long run.

Figures 3a and 3b show the evolution of behavior dispersion for community leaders and R^{Min} individuals in the case of disagreements between leaders at the start of the simulation[9].

[insert figure 3a about here]

[insert figure 3b about here]

[9] The shape of X_{Max} allows to control for the deepness of the disagreement between community leaders. For instance, X_{Max} = $[0;0.35]\cup[0.65;1]$ corresponds to the case of a strong disagreement existing between leaders whereas X_{Max} = $[0;0.45]\cup[0.55;1]$ corresponds to the case of slight disagreements.

The comparison between Figures 3a and 3b shows that R^{Max} and R^{Min} individuals adopt similar patterns of evolution in their behavior. This provides an evidence of the strong influence of the initial position of community leaders on behaviors observed within the community. In both Figures 3a and 3b, the comparison of the dynamics for different X_{Max} settings show the strong influence of the deepness of leaders' disagreements on the dispersion of behaviors.

The existence of strong disagreements lead to community forking (as evidenced by high values for standard deviation combined by low values for the number of remaining clusters for both R^{Max} and R^{Min} individuals). This finding is consistent with the observation that unresolved disputes among community members constitutes a primary ground for forking (Lerner and Tirole, 2000). However, as evidenced by the comparison between the results presented in the current and the former sections, for community forking to happen, contestation has to be initiated by community leaders. Indeed, thanks to the higher degree of visibility and of legitimacy they enjoy, they seem to be the most appropriate members to initiate a long-lasting and successful contestation movement within the community.

As in the case of no disagreement among leaders, the structure of leadership plays an important role in the internal cohesion of the community. As shown in Figures 3a and 3b, more distributed structures of leadership increase the community forking likelihood. In fact, the basic process at stake is the same as in the case of no disagreement among leaders. In the previous section, it has been argued that the existence of a distributed leadership (characterized by high values for π) implies that community leaders, by influencing each other, converge quickly to the final values for behavior. If a strong disagreement is already existing, it might be strengthened by the existence of numerous leaders. Leaders of each group, by influencing each other, converge in their behaviors and, eventually, form "movements" within the community. Furthermore, other members of the community, by being influenced by the leaders whose behaviors are the closest to their own, are led to join one of the movements of the community. In the long run, those streams of behaviors are not likely to influence each other any more. At this point, the community forks into several communities.

One may conclude that communities characterized by a distributed leadership (as in the case of Apache) are more likely to incur forking than communities characterized by a centralized leadership (as in the case of Linux). However, such threat might be tamed by the degree of specialization prevailing within the community, lower degrees of specialization supporting the cohesion of the community. In this manner, Linux-types of communities, due to their centralized structure, can afford to promote specialization. Conversely, a central factor underlying the cohesion of Apache-types of communities lies in maintaining lower degrees of specialization of their members.

However, those results have to consider that the structure of leadership was assumed to be fixed. Thus, community leaders were assumed to be legitimate *de facto*. If we consider a more dynamic context involving, in the same time, the emergence of community leaders and the problems of coordination of individual behaviors, the conclusion of the relative weakness of distributed leadership in ensuring the coherence of the community might be not clear cut any more. Indeed, in the case of a distributed leadership, it takes less time for members to be legitimized as community leaders (Muller, 2004). Hence, one may conjecture they may influence individual behaviors more efficiently than in the case of centralized leadership and contribute more efficiently to the cohesion of the community.

Conclusion.

The aim of this paper has been to study the role of leadership as a mechanism addressing the issue of the coordination and cohesion of communities of practice. It has been concerned with the description of the issues of coordination and the cohesion of communities of practice. It has been shown that those two problems are closely related. In fact, the cohesion of communities of practice is determined by their capacity to avoid the adoption by members of exit behaviors. An important factor conditioning exit lies in the individual's perception of his role within the community: the individual is more likely to choose an exit behavior if his activity is perceived as having little impact on the community's work. Several reasons for this have been identified. They correspond to the adoption by the individual of a peripheral position within the community or to a lack of commonalities among members. To this end, a basic mechanism contributing to avoid exit behavior (or, similarly, to raise loyalty to the community) lies in the building of commonalities among members. The building up of commonalities reinforces loyalty to the community since it allows members to develop a common understanding of its basic aims and objectives. The emphasis has been particularly put on the role played by community leaders. It has been argued that leaders, due to their high degrees of reputation and trustworthiness, are able to increase the degree of coherence of the members' knowledge base and basic objectives thanks to the influence they exert over individual behaviors through the influence of information and knowledge flows.

Finally, this paper has proposed a simulation model aiming at discussing the conditions under which leaders can contribute to the coherence and the cohesion of a community of practice. Simulations have given rise to several findings. First, exit behaviors are prevented if leaders are able to influence all members of the community. Second, an important factor conditioning the cohesion of the community lies in the degree of cohesion among leaders: communities of practice are more likely to fork into two distinct communities if leaders are characterized by several conflicting approaches to the communitarian activity. However, by focusing on the role of leaders, this model has left aside some aspects of our previous description of the mechanisms underlying the coordination of agents within communities. In this way, further attempts to model the coordination of community members shall embed the influence of social norms on behaviors.

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Parameter	Definition	Value
Model parameters		
	Number of periods	80 000
	Number of agents	250
δ	Rate of behaviors' convergence	5%
Individual characteristics		
φ	Level of specialization	0.3 – 0.325 – 0.35
π	Proportion of leaders (with high reputation levels)	0.1 – 0.3
R^{Max}	Reputation level of leaders	5
R^{Min}	Reputation level of other members	2
Distribution of leaders in the behavior interval		
	Distribution in the case of no disagreement	[0;0.7] – [0;0.8] – [0;0.9] – [0;1]
	Distribution in the case of disagreement	[0;0.35]∪[0.65;1] – [0;0.4]∪[0.6;1] – [0;0.45]∪ [0.55;1]

Table 1: Description of parameters and simulation settings.

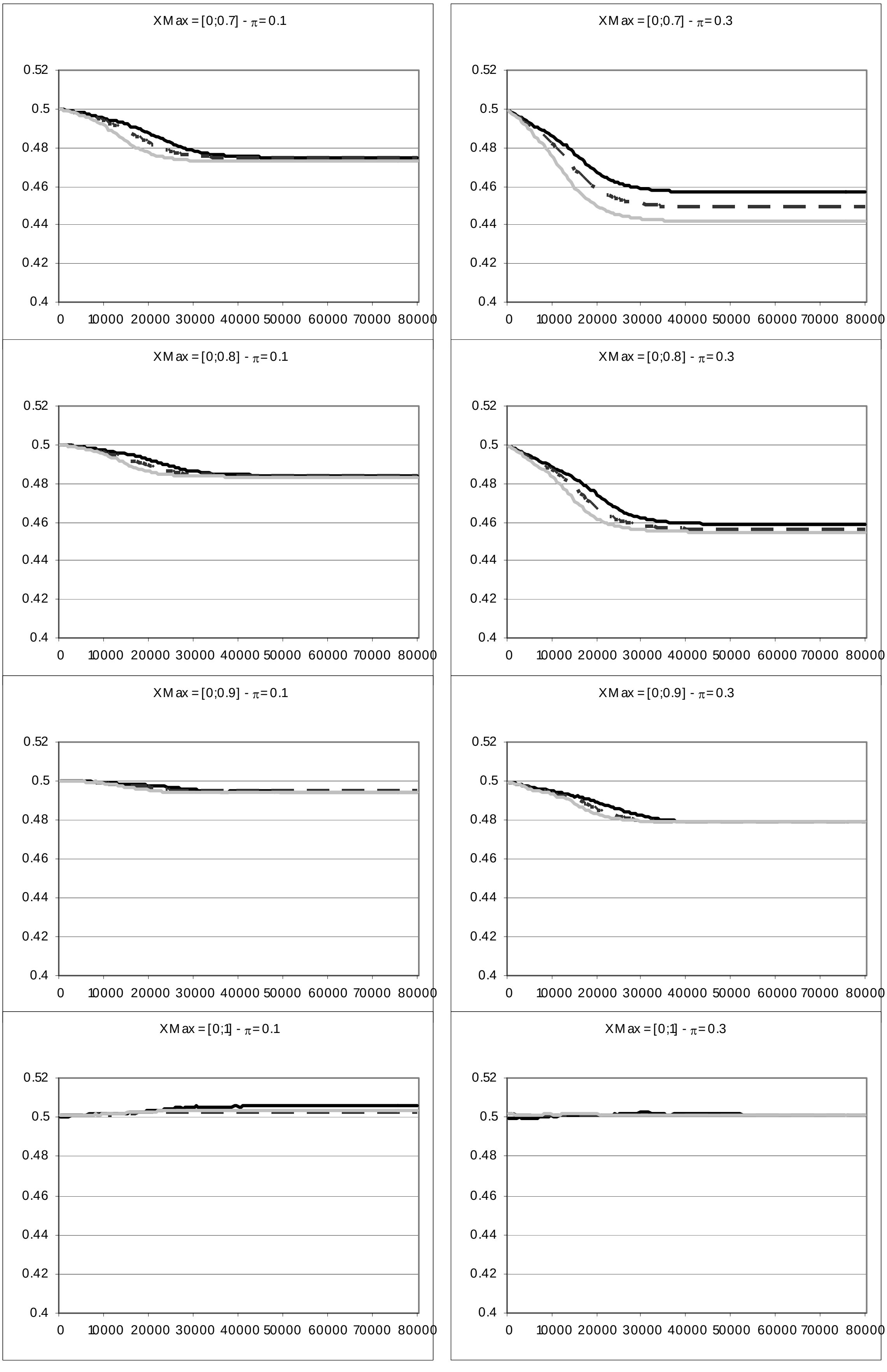

Figure 1a : Average behavior for R_{Min} individuals: $\varphi = 0.3$, black solid curve; $\varphi = 0.325$, black dotted curve; $\varphi = 0.35$, light grey curve

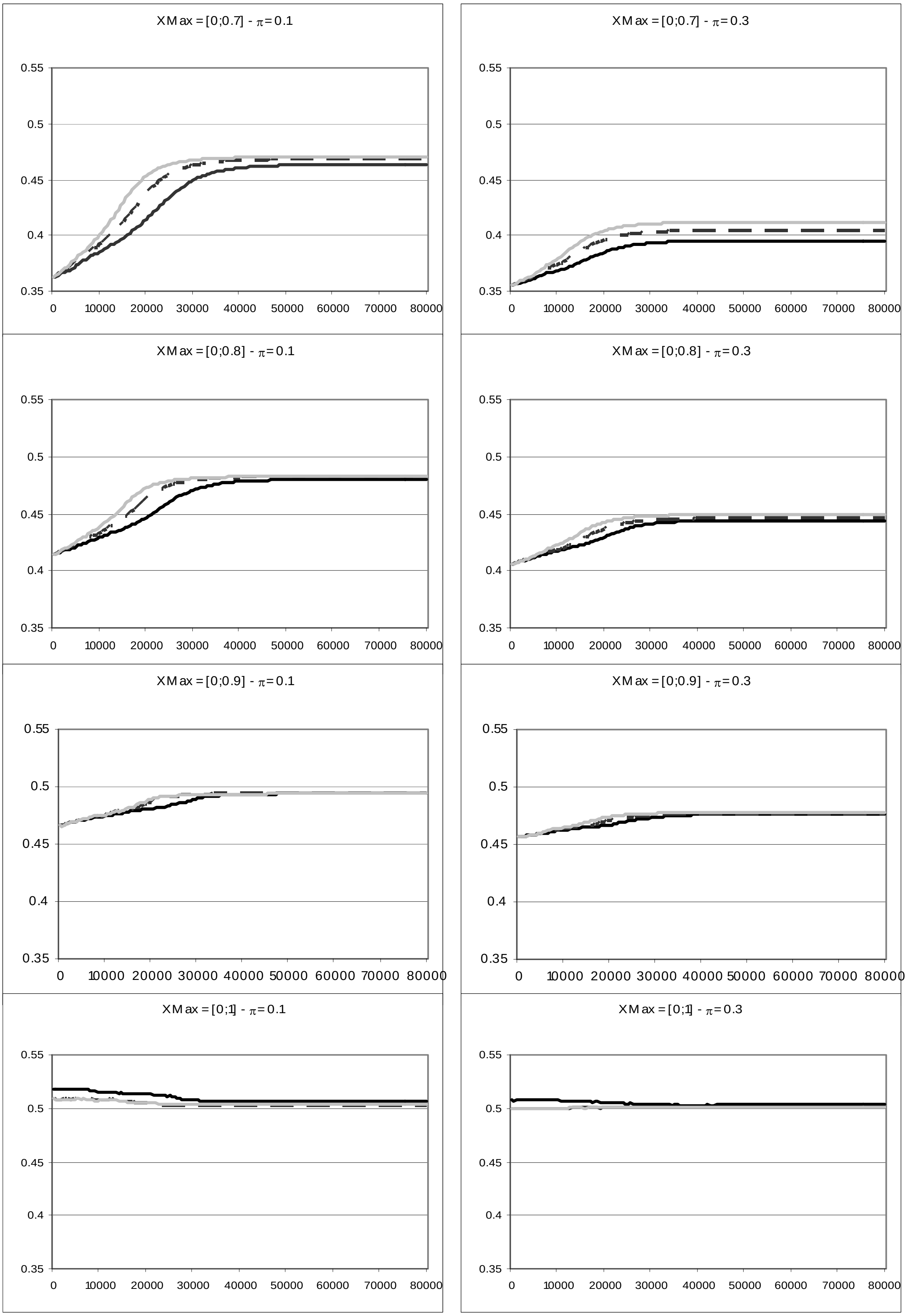

Figure 1b : Average behavior for R_{Max} individuals: φ = 0.3, black solid curve; φ = 0.325, black dotted curve; φ = 0.35, light grey curve.

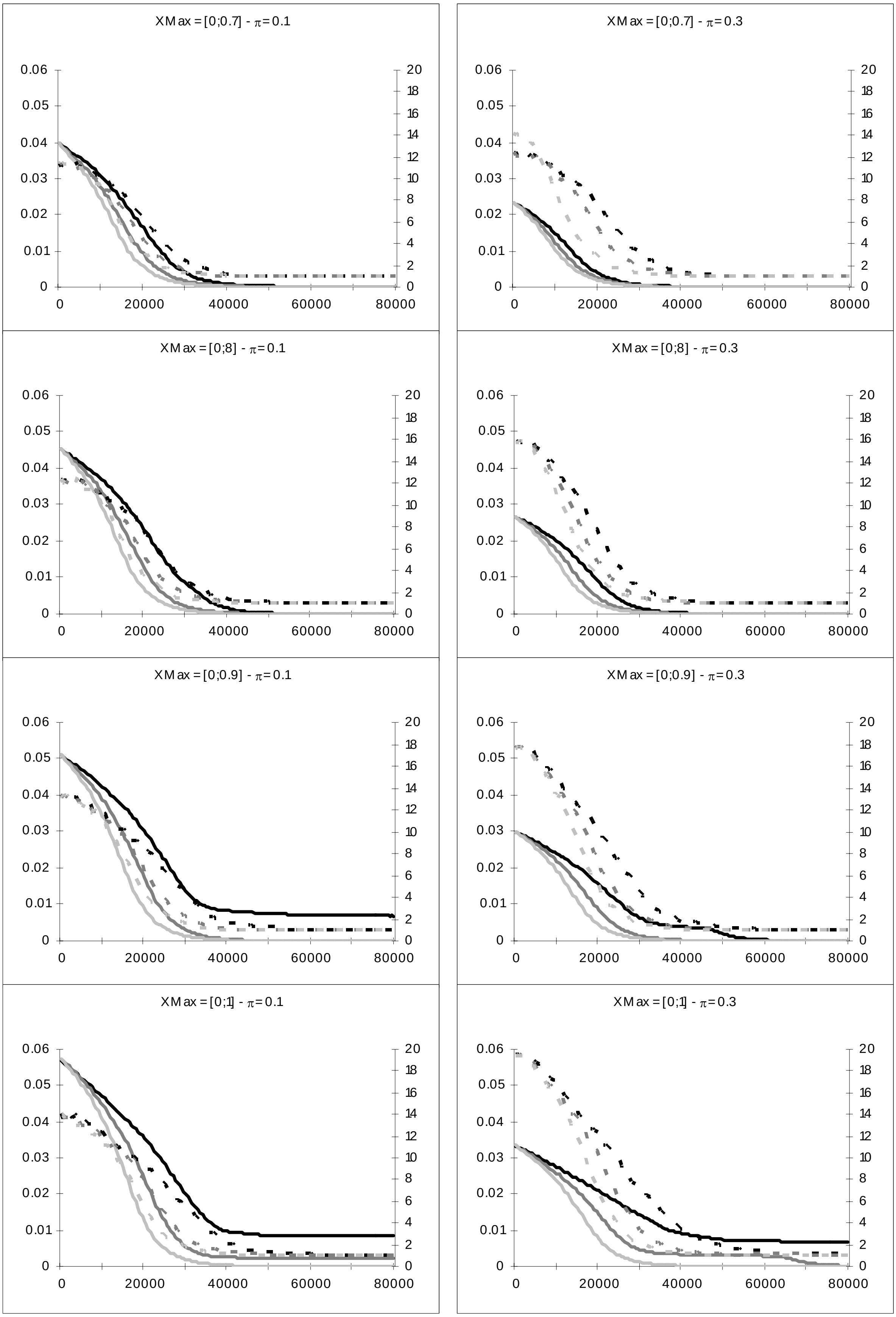

Figure 2a : behavior standard deviation (solid lines, left axis) and number of clusters (dotted lines, right axis) for R_{Max} individuals with no disagreement among leaders: φ = 0.3, black curve; φ = 0.325, dark grey curve; φ = 0.35, light grey curve.

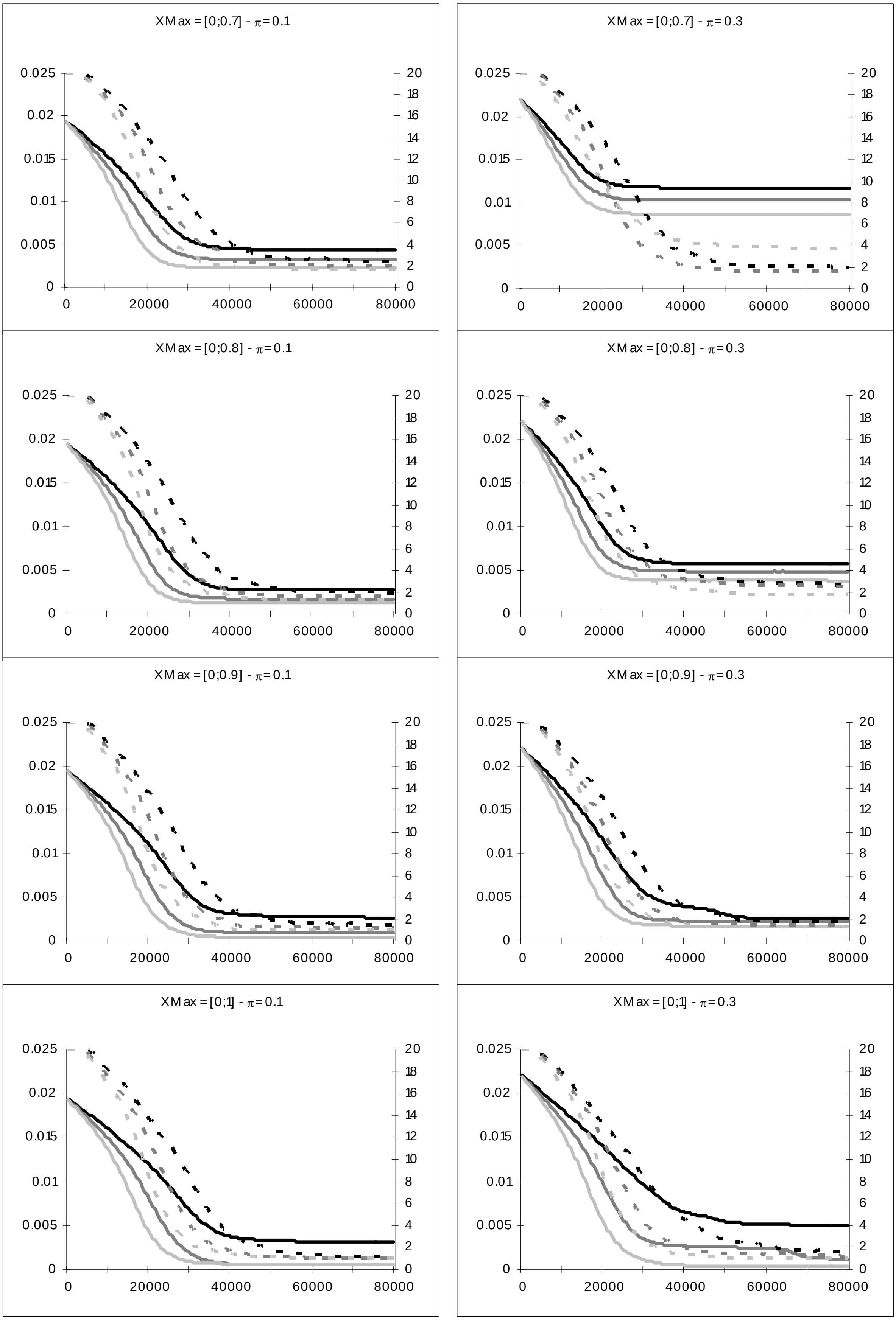

Figure 2b : behavior standard deviation (solid lines, left axis) and number of clusters (dotted lines, right axis) for R_{Min} individuals with no disagreement among leaders: φ = 0.3, black curve; φ = 0.325, dark grey curve; φ = 0.35, light grey curve.

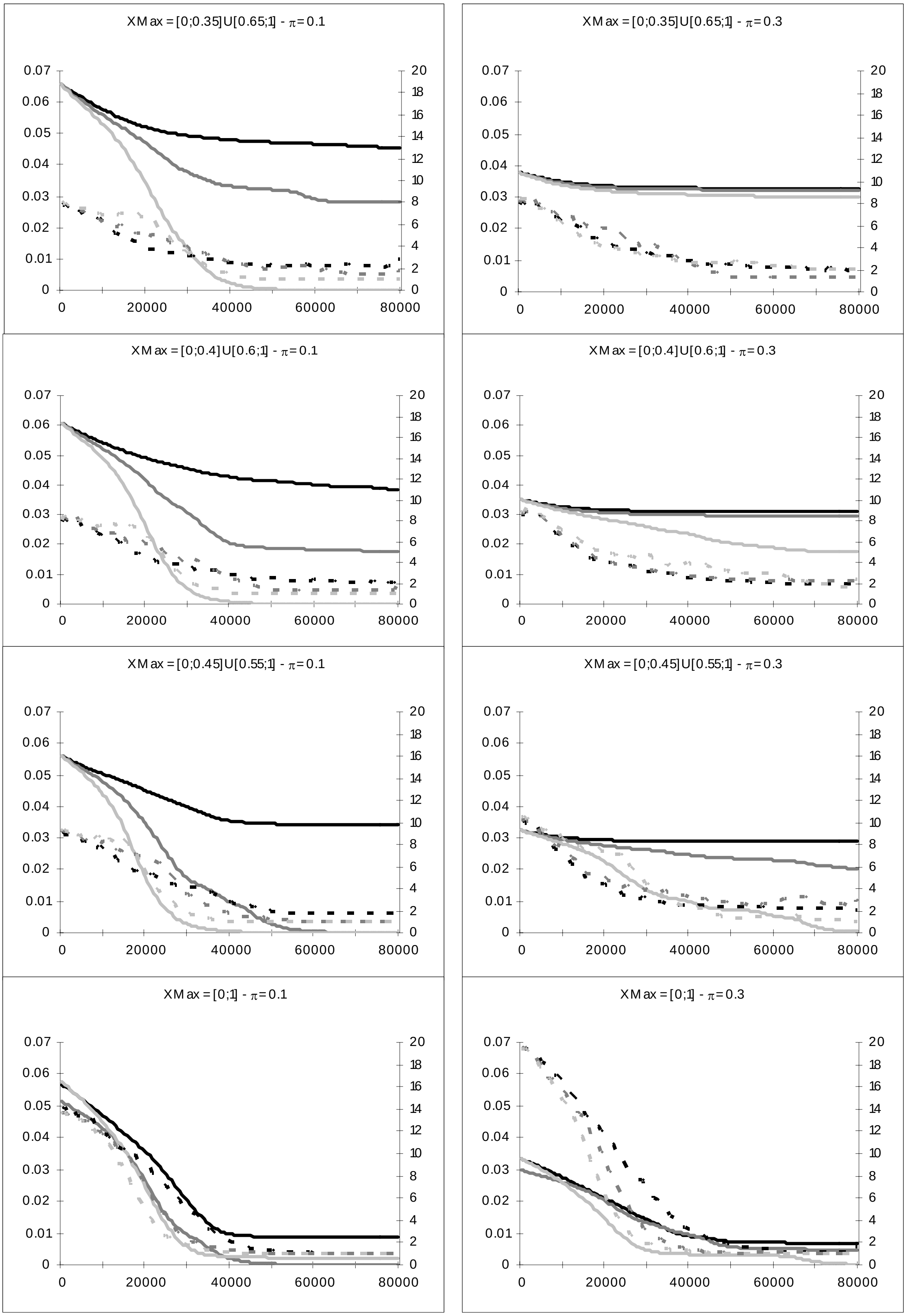

Figure 3a: behavior standard deviation (solid lines, left axis) and number of clusters (dotted lines, right axis) for R_{Max} individuals with disagreement among leaders: φ = 0.3, black curve; φ = 0.325, dark grey curve; φ = 0.35, light grey curve.

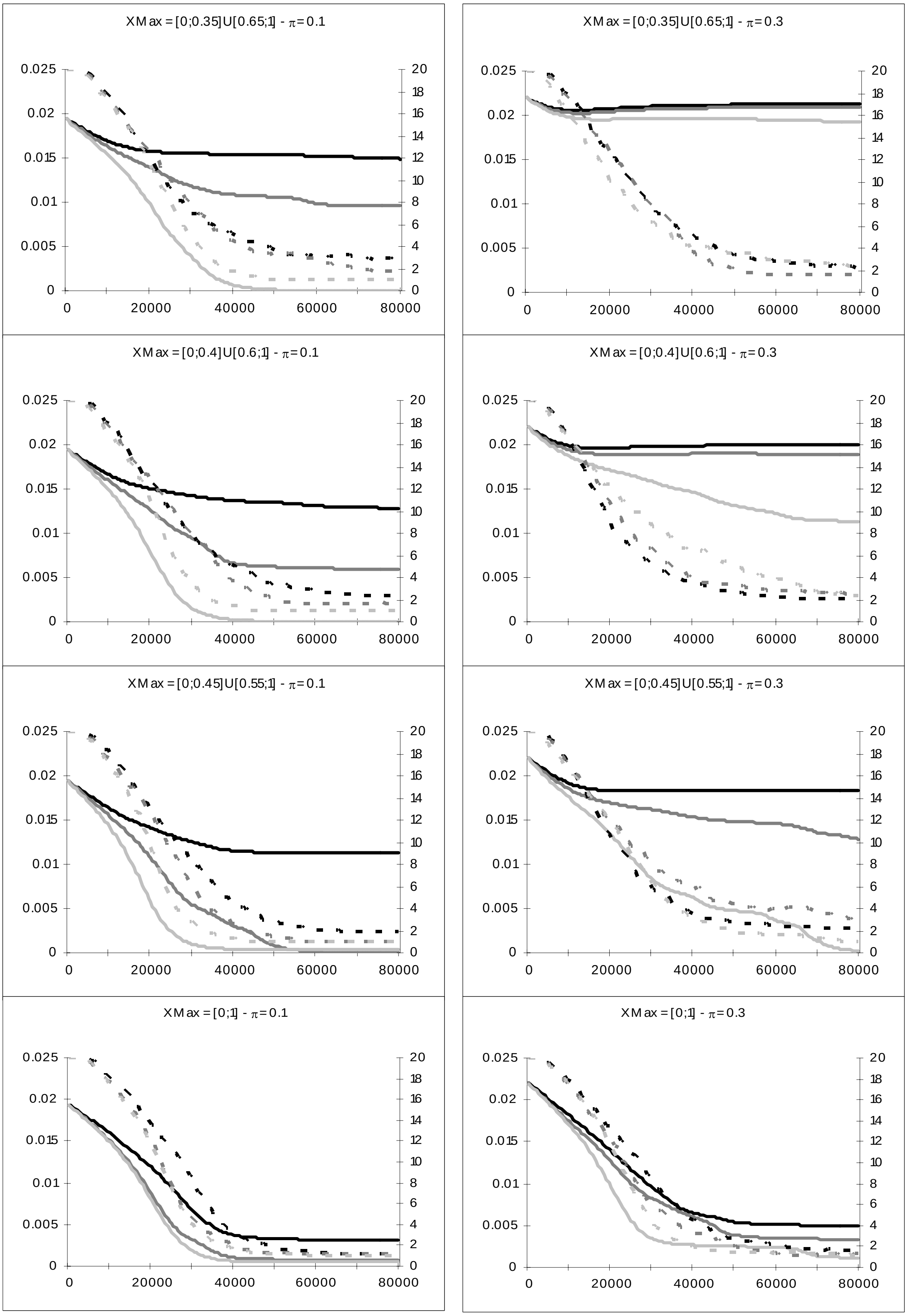

Figure 3b : behavior standard deviation (solid lines, left axis) and number of clusters (dotted lines, right axis) for R_{Min} individuals with disagreement among leaders: $\varphi = 0.3$, black curve; $\varphi = 0.325$, dark grey curve; $\varphi = 0.35$, light grey curve.

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