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Coordination des communautés de pratique : les rôles différenciés de la Réputation et de la Confiance.

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Reputation, trust and the coordination of communities of practice.

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Résumé.

Coordination des communautés de pratique : les rôles différenciés de la Réputation et de la Confiance.

Dans le cadre d'une économie basée sur la connaissance, une part croissante des processus de production et de diffusion des connaissances est assurée par les communautés de pratique. Ces dernières, en fournissant des espaces intangibles propices à la circulation d'informations et de connaissances, jouent un rôle important dans les processus d'apprentissage collectifs. De telles communautés peuvent être définies de manière générales comme des structures d'interactions sociale ayant pour but la génération et la diffusion de connaissances. Plus précisément, de telles communautés représentent des groupes d'individus engagés dans une pratique commune et interagissant fréquemment en vue de développer leurs compétences dans le domaine considéré.

Du fait de l'absence de tout schéma contractuel en leur sein, un des traits fondamentaux des communautés correspond à la liberté laissée à leurs membres dans la détermination de leur trajectoire de spécialisation. En d'autres termes, il leur est possible de déterminer de manière décentralisée tant le volume que la nature de leur contribution à l'entreprise de développement d'une pratique commune. Une telle liberté laissée aux membres va néanmoins de pair avec certaines interrogations concernant l'efficacité du système. Plus précisément, se font jour deux catégories de problèmes. Sur le plan des incitations, l'absence de schémas contractuels peut donner la possibilité aux membres de s'engager dans des comportements

opportunistes du type passager clandestin. Sur le plan de la coordination, se pose un problème d'efficacité des activités des membres. En effet, en l'absence d'une division claire et imposée des tâches au sein de la communauté, les individus peuvent s'engager soit dans des activités disparates, donnant ainsi lieu à un problème de cohérence, soit dans des activités redondantes, conduisant à une sous-utilisation des capacités cognitives des agents.

Le but de ce travail de thèse est d'étudier certains des mécanismes présidant à la coordination et aux incitations des agents au sein des communautés de pratique. Il est proposé que celle-ci est soutenue par la présence d'effets de réputation et de confiance couplée à l'émergence d'individus jouissant d'un statut particulier au sein des communautés : les leaders communautaires.

Le but du chapitre I est de fournir le cadre théorique sous-tendant le travail de thèse. Ce chapitre débute par une proposition de définition de la notion de communauté de pratique. Les communautés de pratique forment un cas particulièrement étudié de communautés intensives en connaissances. Ces dernières sont définies comme des structures d'interactions sociales ayant pour but l'apprentissage, la création, la diffusion et l'accumulation de connaissances. Plus particulièrement, les communautés de pratique représentent des groupes d'individus engagés dans une pratique commune et qui interagissent dans le but de développer leurs compétences personnelles. De telles interactions consistent notamment en la divulgation et l'évaluation de leurs « meilleures pratiques » personnelles ainsi que de toute connaissance ou information relevant de la pratique commune. Une communauté de pratique se distingue suivant trois attributs : 1) l'existence d'un domaine de définition (les membres se concentrent sur une pratique particulière et sont dotés d'un niveau minimum de connaissances dans ce domaine) ; 2) l'existence d'interactions entre les membres ; 3) le développement d'un répertoire de ressources communes (notamment constitué des connaissances développées et partagées au sein de la communauté).

Le problème de la coordination des agents au sein des communautés de pratique part de l'observation que les approches néoclassiques des organisations présupposent généralement l'existence d'une divergence entre les objectifs personnels et les buts du groupe dans son ensemble. Cependant, si de telles approches parviennent à expliquer la coordination des

tâches spécialisées dans un processus productif, elles n'arrivent pas à rendre compte de la convergence et de la coordination des motivations individuelles.

Par opposition, il est soutenu que la gouvernance des communautés de pratique repose sur le lien étroit existant entre normes sociales et leadership. Les normes sociales permettent de diriger l'activité de la communauté en précisant les objectifs ainsi que les moyens à mettre en œuvre pour les atteindre. Elles offrent dès lors un premier mécanisme de coordination en permettant une anticipation des comportements potentiels des individus formant la communauté. Cependant, la coordination par les normes induit certaines limites avec, notamment, des difficultés dans leur mise en place ainsi que dans leur évolution. De telles limites peuvent être surmontées par la mise en œuvre d'un leadership. Ce dernier permet d'accroître la vitesse de mise en œuvre et d'évolution des normes en appliquant une action sur les flux d'informations et de connaissances se produisant au sein de la communauté.

Le leadership se fonde sur l'étroite complémentarité présentée par la réputation et la confiance qui constituent de puissants dispositifs d'incitation à la production et à la diffusion de connaissances. De ce fait, il est soumis à une constante réévaluation. Dans ce chapitre, nous est proposé un modèle visant à rendre compte de l'évolution de ce statut. Dans ce modèle, les relations de leadership se construisent principalement au travers des contributions opérées par les membres à l'activité de la communauté (ces contributions consistant en la diffusion de connaissances ou d'informations proposant une avancée dans l'activité de la communauté). Ces contributions sont évaluées suivant deux dimensions. La première dimension, quantitative, incorpore les niveaux de contribution. La seconde dimension tient compte de la qualité des contributions, cette dernière étant évaluée suivant les normes en vigueur au sein de la communauté. Cependant, les interactions entre leadership et normes sociales, loin d'être unidirectionnelles, sont faites de rapports d'influences réciproques. En effet, si les normes tendent à déterminer la qualité d'une contribution, les leaders peuvent favoriser l'évolution des normes sociales.

Il est néanmoins nécessaire de noter que le chapitre I, en étudiant l'émergence de leaders, suppose de manière implicite que la communauté est établie. Dans cette lignée, le chapitre II traite de la dynamique d'émergence des communautés de pratique. De plus, ce chapitre est motivé par l'observation que la dynamique d'émergence et de morphogenèse des communautés de pratique reste un sujet peu exploré dans la littérature. Certains travaux ont tenté d'aborder ce problème mais leurs tentatives se trouvaient limitées dans leur portée étant

donné qu'elles supposaient que les communautés se formaient dans un cadre établi (comme une firme ou toute autre institution non-marchande). Ainsi, de nombreuses communautés, parmi lesquelles les communautés du logiciel libre, se trouvaient écartées de leur analyse.

Le chapitre II tente de donner une réponse à la question des conditions d'émergence des communautés de pratique. De manière plus précise, ce chapitre propose un modèle rendant compte de l'émergence des communautés de pratiques, qu'elles émergent au sein d'un cadre institutionnel établi (firme ou association) ou en l'absence de tout cadre de référence (comme c'est le cas pour de nombreuses communautés du logiciel libre).

Il est supposé au départ l'existence d'un individu (désigné par la suite sous le terme d'entrepreneur) désirant mener à bien un projet cognitif pouvant donner lieu à des échanges de connaissances (ce projet peut, par exemple, avoir pour but l'écriture et la parution d'un logiciel libre). Le modèle peut être décomposé en deux étapes principales. La première étape est rattachée au degré d'incertitude lié au projet auquel l'entrepreneur doit faire face. Il est opéré une distinction entre différents degrés d'incertitude. Néanmoins, nous nous concentrons sur deux cas polaires. Le premier cas correspond à un niveau d'incertitude faible : l'entrepreneur a une connaissance précise du projet (de l'état final du projet ainsi que des actions à entreprendre pour le mener à bien) et est en mesure de conclure des contrats quasi-complets et de fonder une firme (au sens néoclassique du terme). Dans ce cas, l'entrepreneur désire avant tout profiter des avantages procurés par le regroupement des activités au sein d'une structure unique (afin, par exemple, de réaliser des économies d'échelle). Dans le cas opposé, le degré d'incertitude lié au projet est élevé : l'entrepreneur a une faible connaissance de l'état final du projet et des actions à mener pour son accomplissement. Il lui est donc nécessaire d'avoir accès à des connaissances complémentaires dans le but de mener son projet à bien et il ne sera en mesure que de proposer des contrats incomplets. A partir d'un certain niveau d'incertitude, les avantages procurés par l'écriture de contrats incomplets (notamment en termes de régulation des comportements) sont surpassés par les coûts y étant liés (comme, par exemple, le temps lié à leur négociation). Il devient dès lors rationnel pour l'entrepreneur d'adopter un mode de fonctionnement communautaire, caractérisé par l'absence de contrats liant les membres à la communauté.

La seconde étape du modèle est liée au degré de correspondance entre les objectifs établis par l'entrepreneur et les préférences des individus de la structure de coopération (firme ou communauté). Le degré de correspondance entre préférences individuelles et objectifs communs est directement lié à la nature des contrats signés. Des contrats quasi-complets, en décrivant précisément les tâches dévolues, sont susceptibles de donner lieu à un faible degré de correspondance entre les objectifs communs et les préférences individuelles. En revanche, l'entrepreneur possède une capacité importante de coordonner et d'inciter les individus à contribuer à l'entreprise commune. *A contrario,* des degrés d'incertitudes élevés, en allouant aux individus une grande liberté dans la détermination de la nature de leur contribution au projet commun, peuvent donner lieu à un haut degré de correspondance entre les préférences individuelles et les objectifs commun. La nature de la relation entre l'individu et la structure de coopération, en étant régie par l'existence de contrats quasi-complets ou fortement incomplets (voire l'absence de tout schéma contractuel) implique un certain nombre de conséquences. Ces conséquences portent sur les régimes d'appropriation et d'incitation et les relations de pouvoir existant entre les individus, sur la loyauté des individus à la structure et les liens de confiance existant entre ces derniers.

Le but du chapitre III est d'introduire l'outil d'analyse utilisé dans la suite de la thèse : la simulation numérique. Le choix de cet outil est notamment motivé par sa capacité à modéliser les systèmes sociaux complexes. Outre leur capacité d'auto-organisation, les systèmes sociaux complexes comportent certaines propriétés les rendant difficiles à modéliser par le biais d'autres méthodes analytiques. Premièrement, de tels systèmes sont constitués d'un nombre important de composants hétérogènes. Deuxièmement, ces systèmes sont caractérisés par l'existence d'interactions non triviales entre les composants. Ainsi, chaque partie du système ne peut interagir qu'avec un faible nombre d'autres composants. En conséquence, chaque composant du système peut faire l'objet d'une évolution particulière, donnant lieu à des divergences dans les trajectoires d'évolution entre ces derniers.

Les caractéristiques des systèmes complexes (multitude de composants, relations non triviales entre ces derniers et trajectoires d'évolutions divergentes) contribuent à mettre en relief certains des avantages de la simulation informatique sur les méthodes de modélisation traditionnelles. Plusieurs des propriétés de la simulation informatique peuvent ainsi être mis en exergue. Premièrement, la simulation permet de rendre compte de systèmes pourvus de

multiples composants hétérogènes. Plus précisément, par contraste avec les approches analytiques, la simulation permet de traiter des problèmes complexes constitués de plusieurs milliers de variables. Deuxièmement, la simulation informatique permet de rendre compte de manière précise de la dynamique d'évolution d'un système complexe.

Cependant, en étant encore un champ d'investigation relativement nouveau, la simulation informatique souffre encore de certaines lacunes par rapport aux autres méthodologies de modélisation. Le premier type de problèmes provient de la mise en application même de la méthodologie avec la programmation du modèle. Les difficultés liées à la programmation sont de deux ordres. Premièrement, dans le domaine des sciences sociales, seul un nombre restreint de scientifique maîtrise les langages de programmation les plus communs (C++ ou java). Ceci a pour effet de restreindre le succès de la méthodologie à cette catégorie de chercheurs. Ensuite, étant donné que la simulation numérique consiste à traduire un modèle théorique dans un langage informatique, le recours à cette méthode d'analyse peut fournir certains résultats ne correspondant pas nécessairement au modèle théorique. Cette première ligne de problèmes motive le développement de plateformes de simulation spécifiques (telles LSD ou Swarm) ayant pour but de simplifier la tâche de programmation.

Un second type de problème est lié à l'analyse des résultats obtenus à la suite de la simulation. En effet, si elle permet de rendre compte de dynamiques complexes, les résultats d'un modèle de simulation peuvent être rendus difficiles à interpréter du fait de l'introduction possible de multiples effets annexes à la dynamique principalement étudiée. Dans le but de conserver un lien clair entre les résultats obtenus et leur causes, il est donc nécessaire de construire au début un modèle très simple. Ce modèle peut ensuite être complexifié au fur et à mesure des évolutions de l'analyse.

Les chapitres IV, V et VI constituent un approfondissement du cadre théorique élaboré dans le chapitre I tout en fournissant une série de modèles destinés à simuler les dynamiques d'émergence de leadership et de coordination au sein des communautés de pratique.

Le but du chapitre IV est de poursuivre l'analyse de la réputation au sein des communautés de pratique esquissée dans le chapitre I. Les visées de ce chapitre sont doubles.

Premièrement, il y est proposé une définition de la réputation appliquée au contexte des communautés de pratique. Deuxièmement, est mis en lumière le rôle de la réputation dans les dynamiques communautaires. Une redéfinition du concept de réputation appliquée au contexte des communautés de pratique est rendue nécessaire pas l'observation que les approches classiques de cette dernière (notamment, dans le cadre de l'Economie de l'Information) ne peuvent y être appliquées. Une raison avancée provient du fait que la réputation, ainsi comprise, adopte principalement un raisonnement en termes de jeux. Plus précisément, la réputation résulte d'un calcul économique : les individus choisissent un comportement coopératif (leur permettant d'acquérir une bonne réputation) car un tel comportement donne lieu à des gains potentiels plus élevés. Une telle approche de la réputation ne peut être appliquée au domaine des communautés de pratique étant donné que ces dernières se basent sur les asymétries de connaissances existant entre leurs membres. Par opposition l'Economie de l'Information ne postule que l'existence d'asymétries d'information.

Ce chapitre propose une définition de la réputation « basée sur la connaissance ». Plus précisément, il est fait état de la réputation comme d'un concept comprenant deux niveaux. Le premier niveau de réputation se situe au niveau de la communauté dans son ensemble. Une réputation communautaire est liée à la représentation externe des connaissances et compétences développées et possédées au sein de la communauté ainsi que des normes sociales fondant son activité. La réputation communautaire, en fournissant aux membres de la communauté un point focal (au sens de Schelling), contribue à fournir un mécanisme de coordination de première instance.

Cependant, étant donné que tous les membres de la communauté bénéficient de la réputation communautaire, peuvent surgir des problèmes de contribution à ce bien public. Ceci motive l'existence d'un deuxième type de réputation qui est fondé, pour sa part, sur les comportements passés des individus. Cette réputation individuelle est principalement interne à la communauté. Elle permet à chaque membre de construire sa propre représentation des connaissances et des intentions d'un de ses pairs sans toutefois avoir interagit avec ce dernier. La réputation individuelle se construit au travers de l'accumulation d'indications sur l'activité passée de l'individu en question. De ce fait, la réputation individuelle remplit deux rôles distincts. Premièrement, en réduisant l'incertitude liée aux compétences et au comportement d'un individu, elle permet d'améliorer la coordination des agents au sein de la communauté. Deuxièmement, en facilitant la production d'une première interaction entre deux individus,

les individus bénéficiant d'une forte réputation sont susceptibles de jouir d'un avantage informationnel sur les autres membres. Ceci se traduit par un accroissement de leur influence sur ces derniers. Ainsi, hormis sont rôle de coordination, la réputation, en contribuant à l'émergence de leaders, constitue un mécanisme de motivation pour prendre part aux activités de la communauté.

Le chapitre V se propose d'étudier le rôle de la confiance au sein des communautés de pratique. De plus, partant de l'observation que le concept de confiance, tel qu'il a été traité dans le cadre de l'Economie de l'Information, s'avère peu satisfaisant dans le contexte des communautés de pratique, il est proposé une définition renouvelée de ce concept. En effet, à l'instar de la réputation, la confiance, telle que traitée dans l'Economie de l'Information est principalement caractérisée par le fait qu'il est possible de recourir à des mécanismes d'incitation et de dissuasion en vue de faire respecter les engagements pris entre deux individus. De ce fait, la confiance comporte une forte dimension calculatoire : la décision de faire confiance à un individu dépend d'une évaluation des gains et des pertes encourus suivant le comportement adopté. De plus, la confiance repose sur la capacité à se prémunir contre tout comportement opportuniste.

Il est soutenu que la confiance au sein des communautés de pratique est d'une nature bien différente de cette approche calculatoire. Elle correspond à la capacité de faire un pari sur le comportement potentiel d'un individu sans toutefois être en mesure de forcer ce dernier à adopter le comportement anticipé. De ce fait, l'acte de confiance implique un certain degré de vulnérabilité par rapport à la possibilité de comportements opportunistes. Néanmoins, contrairement à l'argument de Williamson (1993), le concept de confiance développé ici n'implique pas qu'elle soit aveugle mais implique l'acquisition d'informations concernant les compétences et le comportement du partenaire, ces informations étant collectées au fil des interactions avec ce dernier. De manière plus précise, les interactions entre individus donnent lieu à une émission de signaux de la part de chaque partenaire, ces signaux fournissant des indices concernant les compétences et les intentions de chacun.

Ainsi, la confiance, en étant issue de cette activité de signalement, remplit deux rôles distincts. La première fonction correspond à la coordination locale en contribuant à la construction d'un référentiel commun entre les partenaires. De manière plus précise, la

construction d'un référentiel commun entre les partenaires passe par la routinisation des comportements et la construction d'une base de connaissances communes. Deuxièmement, la confiance constitue un mécanisme d'incitation à la participation à l'activité communautaire en permettant de légitimer ses leaders. Etant donné que la confiance repose sur la capacité des agents à produire des signaux, des niveaux plus élevés de confiance sont associés à des fréquences de signalement plus élevées. De plus, des degrés de confiance plus élevés entraînent une plus grande capacité d'influence des individus bénéficiant de cette confiance. Ceci a pour effet de contribuer à l'efficacité du leadership dans son rôle de coordination.

Le but du chapitre VI est d'étudier le rôle du leadership dans la coordination globale des communautés de pratique. Le chapitre V a soutenu que la confiance constitue un mécanisme de coordination. Cependant, la coordination opérée par le biais de la confiance est seulement locale car elle ne se manifeste que par la création d'un référentiel commun entre partenaires. La coordination des agents au niveau des communautés (prises dans leur globalité) peut par conséquent ne pas être garantie.

Ce chapitre se propose d'aborder le problème de la coordination globale des communautés de pratique. La discussion sur la coordination globale est étroitement liée à celle sur la cohésion des communautés de pratique. En effet, la cohésion de telles communautés est pour partie déterminée par leur capacité à dissuader l'adoption par leurs membres de comportements de sortie (au sens de Hirschman) et ce, en dehors de tout cadre contractuel. Un facteur important conditionnant les comportements de sortie se situe dans la perception par les individus du rôle qu'ils tiennent au sein de la communauté : les agents seront tentés d'adopter des comportements de sortie si ils sont persuadés que leurs actions on un impact marginal sur l'activité de la communauté. Une telle perception peut être influencée par plusieurs facteurs. Ces facteurs correspondent à l'adoption par les membres d'une position périphérique au sein de la communauté où à un manque de référentiel commun aux individus, induisant que les effets de leur activité seront peu compris et exploités par leurs pairs. De ce fait, un mécanisme de base permettant de remédier aux comportements de sortie (ou, de manière similaire, de susciter la loyauté des individus envers la communauté) consiste en la construction d'un référentiel commun entre les membres. Ce référentiel commun permet notamment d'établir une compréhension commune des objectifs fixés au niveau communautaire ainsi que des moyens et ressources mis en œuvre pour les atteindre.

Les leaders communautaires prennent une part importante dans la mise en place d'un référentiel commun. En bénéficiant d'un haut degré de réputation et de confiance, ces derniers sont en mesure d'exercer une influence sur les connaissances détenues ainsi que sur les comportements individuels. Ceci permet d'accroître le degré de cohérence de la base de connaissances communes de la communauté. Cependant, les résultats des simulations montrent que cette cohésion n'est obtenue que sous certaines conditions. Premièrement, les leaders ne sont en mesure de susciter la loyauté que si ces derniers sont capables d'influencer tous les membres de la communauté. Deuxièmement, un facteur important déterminant la cohésion de la communauté se situe dans la cohésion de leurs membres : l'existence de désaccords profonds entre les leaders peuvent conduire à une scission de la communauté.

Table of Content.

Introduction.

I. Why is the concept of community of practice important ? the issue of knowledge in Economics.

This work develops a theoretical framework aiming at introducing the dimensions of incentives and coordination in communities of practice. The main argument of this dissertation is that the motivation and the coordination linked to the tasks of production, diffusion and storage of knowledge have to refer to the development and the dynamics of trust and reputation and leadership among members of communities of practice. This introductory section aims at justifying the importance of communities in the evolutionary literature by starting from the very definition of knowledge used in this theory.

The concept of community of practice and, more generally, of knowing (or knowledge intensive) community is the subject of an increasing interest among scholars. An increasing number of scientific contributions (Brown and Duguid, 1991, Gensollen, 2001) have pointed out the key role of communities in the production, circulation and storage of knowledge. The literature on communities of practice is in line with evolutionary and knowledge based theories since, contrary to the classical literature, which mainly focuses on the problems of

allocation of existing resources, those approaches put the emphasis on the issues of creation of resources and of knowledge (*cf*. Nelson and Winter, 1982). This emphasis put on knowledge has also implied a radical departure from the classical approach to knowledge. This first approach relies on a rationalist approach to knowledge by notably assimilating it to information. According to this perspective, knowledge can be defined as a "justified true belief" (see Ancori *et al*., 2000). This Cartesian vision is characterized by the fact that knowledge are characterized by their absolute truth and remain valid in any circumstances. It follows that knowledge are a stock building on the accumulation of information. Moreover, the prevailing vision of knowledge is centred on the individual (Simon, 1991a). Although most of economic theories, are grounded on the classical approach to knowledge, a rising number of scholars have criticized this view they perceive as to simplistic (Boulding, 1953, Machlup, 1983).

The view of knowledge in the evolutionary and knowledge based litteratures articulates around two dimensions (Nonaka, 1994, Spender, 1996) with, on the one hand, an ontological dimension concentrating on its collective/individual nature on the other and an epistemological dimension focusing the tacit/ explicit form of knowledge[1]. Even though it constitutes a significant evolution in comparison to classical approaches, this vision still suffers from presenting knowledge as a stock which is static by essence and cannot insofar account for the issues of learning and knowledge creation. In order to overcome this limitation, Nonaka and Takeuchi (1995) proposed that the processes of learning and of knowledge creation were the outcome of a cycle based on the transformation of knowledge in each form (as accounted for by the distinction between the epistemological and the ontological dimensions). This cycle of knowledge involves four mechanisms: socialization (corresponding to a transformation of individual tacit knowledge into collective tacit knowledge), externalization (transforming collective tacit knowledge into collective explicit knowledge), combination (consisting in recombining the piece of explicit knowledge with other pieces of knowledge) and internalization (the knowledge produced during the combination phase are internalized by individuals and become tacit). However, the representation of the knowledge cycle, as exposed by Nonaka and Takeuchi, only partly

[1] The reader can refer to Hatchuel (1999), Machlup (1980) and Starbuck (1983) for further discussions on the ontological dimension of knowledge and to Ancori, Bureth, Cohendet (2000), Cowan and Foray (1997), Cowan, David and Foray (2000) Polanyi (1958, 1966) for developments on the epistemological dimension.

succeeds in providing a dynamic account of knowledge since their description is characterized by the fact that it can hardly be operationalized.

In order to tackle this problem, Cook and Brown (1999) introduced a distinction between *knowledge* (understood as a stock) and *knowing* (understood as a process). According to those authors, the distinction between knowledge and knowing is of importance since knowledge refers to the epistemology of possession (i.e. having knowledge of physics) while knowing refers to the epistemology of action (i.e. acquiring knowledge through the practice of physics). In this way, a parallel can be drawn between the interaction between knowledge and knowing and the interaction pointed out by Nooteboom (2000) between knowledge and action: while knowledge guide the way the individual or the group interacts with the environment, the environment conditions individuals' acts (and, therefore, their *knowing*), thus influencing the dynamics of accumulation of knowledge. This perpetual feedback relationship between knowledge and *knowing* was expressed by Cook and Brown as a "generative dance". For instance, after an experiment (which results from an action, the design of the protocol being shaped by the existing stock of knowledge accumulated with past experiences), the physicist mobilizes his knowing in order to interpret and to give a sense to the results he has obtained. In turn, those results influence his knowledge.

Knowing, which determines the dynamics of accumulation of knowledge is, in turn, shaped by an individual's interactions with his environment. In this way, if it has been previously argued that knowing coevolves with action, it is influenced by social interactions too. Brown and Duguid (1991) identified several vectors through which this process of learning by interacting can take place: narration (corresponding to the telling of past experiences, the problems previously encountered and their resolution), collaboration (several individuals endowed with complementary knowledge and competences jointly contribute to the achievement of a given task) and a social construction (consisting in the construction of a shared understanding and common representation and the construction of a common identity).

Since the dynamics associated with *knowing* depends on the accumulation of interactions with the environment and with other individuals, this dissertation is based on the hypothesis that communities of practice constitute a central aspect of learning and of knowledge production. Those communities represent groups of people engaged in common practices and interacting constantly in order to develop their competences. These interactions

consist in the disclosure and the evaluation of “best practices” as well as any piece of information or piece of knowledge related to the relevant practice. The three defining characteristics of communities pointed out by Wenger (2001) all contribute to evolutions in knowledge and in knowing. These characteristics are:

⇒ **A domain of definition**. Members have, at least, to share a minimum level of knowledge and competences related to the goals of the community. This minimum level of expertise allows to distinguish members of the community of practice from other people and acts as the basis for the building of a common identity. For instance, the belonging to an open source community requires some minimum level of knowledge in a computer language.

⇒ **Interactions among members** giving rise to learning by interacting through narration, collaboration and social construction.

⇒ **The development of a shared repertoire of resources**. This shared repertoire of resources is a repository containing experiences, stories, routines and ways of solving recurring problems. The repertoire of resource notably contains the common knowledge base of the community. Together with the domain of definition, it contributes to influence knowing, thus determining the direction for further learning and knowledge production.

Thus, communities of practice appear as active units of competences and knowledge allowing the production, diffusion, accumulation and validation of new knowledge.

II. The issues raised by the literature on communities of practice and the basic argument.

Although communities of practice are the object of a rising interest in the knowledge based and evolutionary literatures (see Cohendet *et al*., 2004, Brown and Duguid, 1991), some of their aspects appear to remain rather ill-explored since most contributions have focused either at the individual level by being concerned with the description of the evolution of individual behaviors (e.g. Lave and Wenger, 1991, Wenger, 1998) or at the community level by putting the emphasis on the dynamics of learning (Amin and Cohendet, 2000). Our works departs from those two lines of enquiry by adopting a "meso" approach. The emphasis is put on the important issues of coordination and motivation which have been, to our knowledge, rather overlooked. By doing this, our discussion of the specific case of communities of practice may indirectly provide some useful insight for more general discussions on organizational issues in evolutionary economics.

The first issue is dealing with the coordination of agents. This issue has already been at the centre of discussions in organization theories (classical and evolutionist). In classical organizations the coordination task is ensured by the recourse of the hierarchy to authority. In this way coordination is the outcome of a centralization of the decision process, few members of the organization enjoying the right to select actions affecting the organization (Simon, 1951, Aghion and Tirole, 1997). In the evolutionary literature, Becker (2003a) identifies several factors contributing to the coordination of economic agents. Coordination may notably be ensured through the integration of dispersed parcels of knowledge (e.g. through the recourse to authority or to routines). However, a basic limitation of such approaches to coordination in the frame of communities lies in the fact that they assume the existence of contractual schemes contributing in the first place to the coordination of members of organization. Due to the absence of such schemes, coordination within communities of practice may not be ensured *prima facie*.

The second issue is dealing with the motivations for contributing. In organization theories, the problem of motivation has mainly been tackled in the frame of the New

Institutional Economics (and, notably, in the frame of Transaction Costs Economics) (Williamson, 2000). According to this stream of literature, the hierarchy induces cooperative behaviors through the recourse to incentives and sanction. Other explanations have pinpointed the role of reputation[2] (or, similarly, trust) in inducing cooperative behaviors: agents, by operating an economic calculus, conclude to the optimality of the adoption of a cooperative behavior. The evolutionary literature, by mainly focusing on the problems of coordination, pushed for long time the issue of motivation into the background of the analysis[3]. This problem has been reconsidered with the introduction of the concept of communities in the evolutionary theory (see Cohendet and Llerena, 2003). Factors affecting the adoption of cooperative behaviors have been identified as the intrinsic motivation of members of a community for contributing to the common enterprise (Kreps, 1997) or by career concerns (Lerner and Tirole, 2000).

However, this treatment of incentives in the literature on communities remains rather unsatisfying since it appears to be rather limited in its scope. If we acknowledge the powerful effect of intrinsic motivation in inducing the adoption of cooperative behaviors, the argument of career concerns looks more problematic since it only tackles the issue of the relationship between members of the community and its external environment. Furthermore, by contrast with classical theories in which coordination and motivation are ensured through an unique mechanism (the recourse to hierarchy), this direct relationship between coordination and motivation seems to be rather hidden in the evolutionary literature.

The object of this dissertation is precisely to present a theoretical framework arguing for the existence of an unique mechanism contributing to coordination and motivation in communities of practice. It is developed the idea that a basic mechanism underlying the activity of communities of practice rests on the emergence of community leaders in relationship with reputation and trust. Leadership is here defined as the ability to direct behaviors through an influence exercised on information and knowledge flows. Leaders, due to their capacity to influence individual behaviors contribute to the coordination of community members.

[2] As we shall argue latter, this vision of reputation and trust, which is calculative by essence, does not fit in the context of communities.
[3] It was considered that routines, by their very nature, encapsulated a mechanism of "truce" aiming at taming the conflicts between members of the organization. This hypothesis raised several questions notably dealing with their emergence (see Coriat and Weinstein, 1995).

Moreover, the acquisition of a leadership status, by allowing members to influence individual behaviors, provides extrinsic incentives for contributing to the community's activity. Indeed, leadership builds through the accumulation of reputation and trust. While reputation consists in a set of information aiming at reducing the uncertainty associated with an individual's competences and behavior in the perspective of a first interaction, trust corresponds to an expectation about an individual's behavior which based on the accumulation of past interactions. Furthermore, high levels of trust and reputation contribute to increase one's influence over his partners while the building of trust and reputation rests on the emission of signals (knowledge or information) contributing to the activity of the community. Hence the acquisition of a leadership status, through the combination of reputation and trust, constitutes a powerful device motivating individuals to contribute to the community.

III. Structure of the document.

Chapter I aims at presenting a theoretical model of the coordination in communities of practice. It is argued that coordination is ensured through the combined action of social norms and leadership. Social norms allow to direct the community's activity by specifying its goals as well as the ways used by members to reach them. In this respect, social norms offer a first coordinating device by allowing to forecast the behaviours adopted by community members. However, coordination through norms implies some shortcomings mostly related to their implementation and their evolution. A way to avoid those limitations lies in the existence of community leaders. The existence of community leaders allows to increase the speed of social norms implementation and evolution through an influence exerted on information and knowledge flows occurring within the community. Since leadership is grounded on the strong

complementarities between reputation and trust, it is constantly evolving along with the levels of trust and reputation individuals enjoy.

Chapter II stresses some elements differentiating communities from other types of organization such as firms. By doing so, this chapter aspires to describe the conditions favouring the emergence of communities of practice rather than firms. The starting point of the argument lies in the existence of an individual wanting to fulfil a cognitive project (and who is designated under the term “entrepreneur”). The entrepreneur faces different degrees of uncertainty which determine is capacity to write contracts and, therefore to settle a firm. In this manner, whereas low levels of uncertainty enable the entrepreneur to ground a firm (in the neoclassical sense) by allowing him to write (almost) complete contracts, higher degrees of uncertainty imply the writing of incomplete contracts. From one point, a comparison between the costs and the benefits of contracting leads the entrepreneur to ground a community.

Subsequent chapters of the dissertation aim at developing the argument put forward in chapter I. To this end, each aspect of leadership are discussed and formalized by making use of the methodology provided by numerical simulation. This methodology, which is increasingly perceived as a powerful analytical tool, is the object of a growing interest among scholars in social sciences. Hence, the aim of chapter III is to offer a justification of the resort to numerical simulation in the modelling of the dynamics of communities of practice. In this way, it is argued that computer simulation is a particularly powerful tool for analysing complex social systems since it can handle numerous heterogeneous agents and to monitor their evolution through time. However, due to its relative novelty, computer simulation still suffers from some methodological weaknesses (Axelrod, 1997a). This observation constitutes a second motivation underlying chapter III in which are discussed some propositions aiming at tackling the weaknesses of computer simulation.

Chapter IV considers the relationship between reputation and the emergence of leadership. The goals of this chapter are twofold. First, it discusses the notion of reputation in communities of practice. By contrast with the calculative view to reputation proposed by classical theories, it advocates a form of reputation grounded on the accumulation of information and corresponding to community members’ shared representation of an individual’s knowledge and behavior. This representation forms according to his past activity

within the community. In a second part, we discuss the relationship between reputation and leadership. A simulation model shows the emergence of community leaders as the outcome of differentials in the degrees of reputation of individuals.

Chapter V offers an examination of the nature and function of trust in communities of practice. It is argued that the notion of trust in the frame of communities of practice departs from traditional, calculative, views as expressed in the famous article by Gambetta (1988). Rather, it proposes a definition of trust consisting in taking a bet on a partner's potential behavior. This bet is grounded on the knowledge related to an individual's competences and behavior, those knowledge being collected through the accumulation of interactions and, more precisely, through the accumulation of signals of the partners' competences and goodwill. By taking part to the building of commonalities among partners, trust contributes to the coordination among them. Moreover, since it favours an individual's capacity to influence his partner (thus legitimizing the leadership status of the former) and builds on the emission of signals about an individual's goodwill and competences, trust furnishes incentives for contributing to the community.

Chapter VI discusses the capacity of community leaders to contribute to the coordination and the cohesion of communities of practice. The problem of cohesion and coordination are closely related. A lack of global coordination in members' behaviors, by leading to reductions in the efficiency of the community's activity, decreases their interest in the community, thus providing a factor triggering their exit from the community. Hence, community leaders, by contributing to the global coordination in communities of practice, constitute, under certain circumstances that are discussed in this chapter, a factor for their cohesion.

Chapter I. Theoretical framework: the governance of communities of practice.

Introduction[♦].

The goal of this chapter is to present the basic theoretical framework underlying the present doctoral dissertation. It is pointed out some of the coordination mechanisms underlying the activity of communities of practice. More specifically, this chapter aims at highlighting the role played by community leaders in the coordination of members.

The concept of Community of practice benefits from a growing literature in numerous fields of enquiry, as evidenced in the literature on open source software development (e.g. Kogut and Metiu, 2001), the knowledge base theory of the firm (Brown and Duguid, 2001) or

♦ This chapter largely results from Muller, Paul. 2004. Autorité et gouvernance des communautés intensives en connaissance: une application au développement du logiciel libre. Revue d'Economie Industrielle. N°106. 2nd Trimester. pp. 49-68.

industrial clusters (Dibiaggio and Ferrary, 2003). However, as argued in the general introduction of this dissertation, the past literature has put very few emphasis on the internal organization of the community and stuck to micro-level descriptions of the individual activity of each member (as in the case of Wenger, 1998) or to descriptions of their general properties (see Bogenrieder and Nooteboom, 2004). In this manner, some other aspects have been completely overlooked. An aspect motivating this dissertation lies in the dynamics of the internal organization of those communities.

This work starts from the observation that the traditional theories of the firm (notably the transactional approaches such as the agency theory and the transaction costs economics), by mostly focusing on the allocation of productive resources, fall short in handling immaterial resources in general and knowledge in particular. At the opposite, a primary concern of communities of practice lies in the creation, the disclosure and the preservation of knowledge in innovative environments. In this manner, transactional theories are of little use in explaining the coordination of agents within communities.

The basic argument developed in this chapter is that the coordination of community members is affected by two important mechanisms: social norms and personal leadership. Social norms, by delimiting the range of acceptable behaviors, allows to make forecasts about community members' behavior, hence providing a first coordination mechanism. Leadership supports the action of social norms in their coordinating task. Moreover, the effectiveness of leadership is ensured by the close intertwining between reputation and trust.

This chapter is organized as follows. Section I aims at providing a description of the concept of community of practice. Basic characteristics of communities, such as the absence of any contractual device or their self-organization, prevents the use of traditional approaches to organizations to explain the internal dynamics of communities. Section II offers a description of social norms. More precisely, it will be shown that, by contributing to delimit the set of acceptable behaviors within the community, they offer a first coordination device. Section III details leadership as a complementary coordination device. In this section, it will notably be established that community leaders allow to fill the problems raised by the coordination through social norms by contributing to the implementation of common knowledge among community members. Section IV offers a dynamic model of community

dynamics. In this way, it will notably establish the relationship between trust, reputation, leadership and social norms.

I. Communities of practice.

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:

⇒ **The domain**. The fact that a community of practice focuses on a shared practice implies that members share a common level of knowledge of the domain. A community does not therefore merely consist in a network of acquaintances or a

group of friends. In the case of OSS software, members of the community have to enjoy some degree of mastery in computer science in order to contribute to the project (as Lakhani and von Hippel (2003) point out in their case study of the Apache[1] project, members of the Apache community have, at the very least, to be sufficiently skilled in computer sciences in order to precisely point out a bug or a problem in the software, contributing thus to its improvement).

⇒ **Interactions**. Members, bound together by a common interest, freely devote to joint activities, try to help each other, exchange advice and share information. The existence of interactions among members is central since it differentiates communities of practice from other types of communities (in the sociological sense) such as people having the same job or the same title or people belonging to the same social class.

⇒ **The development of a shared repertoire of resources**. Members of a community of practice develop a shared repertoire of resources which is made up of experiences or tools. In OSS communities, this repertoire of resources is generally provided in two ways: the source code of the project and a discussion forum. The source code constitutes the outcome of most important and valuable contributions to the project. Thus, the source code constitutes a synthesis of the communitarian progress in the assigned task and fulfils the same task as publications in the scientific community. However, it only constitutes the tip of the iceberg. The everyday life of the community is best accounted for by the discussion forum which constitutes the most complete repository of resources since it stores all communications made by members to the community. Those communications may consist in problem reports and solutions related to those problems. But, they may also be the scene of disputes and disagreements related to a given point of the project. As a repository of resources, the internal organization of discussion forums proves to be of great interest by exhibiting a hierarchical structure. The starting page of the discussion forum stores messages outlining problems related to the project. Each of the messages of the forum starting page opens a new thread of messages (corresponding to a sub-forum) aiming at solving the problem at stake. In comparison with a book,

[1] Lakhani and von Hippel (2003) describe Apache as 'a web server software used on web server computers connected to the Internet. […] A typical server waits for clients requests, locates the requested resource, applies the requested method to the resource, and sends the response back to the client.' (p.924).

the starting message corresponds to the title of a chapter while the thread it has generated corresponds to its content. Such a hierarchical organization provides members of the community with a better access to the knowledge stored in the discussion forum.

Apart from the features enumerated above (a domain, interactions and a shared repertoire of resources), a distinctive characteristic of communities of practice lies in their self-organizing capacity. This capacity is grounded in the same time on the identity and the autonomy of their members (Cohendet and Diani, 2003). 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. 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. It depends on the existing gap between the individual's objectives and the communitarian goals. In this manner, higher degrees of matching between the overall objectives of the community and the individual goals may yield higher degrees of intrinsic motivation for contributing to the community.

The role played by imagination is to allow to draw a parallel between individual experience and the general models prevailing within the community. In this way, it allows the individual to position himself in relation to the dominant practice of the community. More precisely, imagination, by linking individual objectives and communitarian goals, enables each member to monitor the evolution of the community. If the gap between the communitarian objectives and his personal goals exceeds a given threshold, the individual would consider himself as being marginalized from prevailing practice. This, by reducing his level of loyalty to the community, may give rise to a movement of protest (Boroff and Lewin, 1997). In extreme cases, the individual may also exclude himself from the community.

Alignment allows to undertake common actions by linking and directing the necessary resources for their accomplishment. Alignment constitutes a particularly important dimension of the building of identity. Indeed, it implies that members tend to operate trade-offs between their own objectives and the communitarian goals. Moreover, alignment constitutes a mechanism regulating contestation behaviors by enabling a convergence between the individual objectives and the communitarian goals. Lastly, alignment, by supplying the

members of the community with a common framework, provides them with a sense of common identity (Anderson, 1996).

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 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[2] (von Krogh, Spaeth and Lakhani, 2003). It is 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.

Along with their type of expertise, members are defined by the deepness of their communitarian experience. This corresponds to the time spent by the individual in the community and conditions his/her level of understanding of the social norms and customs of the community as well as his level of knowledge of the practice. In a study of the Apache helpdesk, Lakhani and von Hippel (2003) observe that a significant share of the contributions are sent by a hard-core of Apache developers and users: 50% of the contributions were actually sent by only 10% of the contributors. By contrast, most of the members adopt a relatively passive attitude and only send a few contributions.

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

[2] 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.

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 (due to their autonomy) without necessarily expecting any equivalent feedbacks from the community.

Second, communities are relying on the existence of trust relationships among members (Cohendet and Diani, 2003). This is due to the fact that the environment of communities is commonly evolving. Members have to adapt their behavior to those evolutions. In this manner, trust constitutes an efficient coordinating device by allowing a certain degree of flexibility in the behaviors. As underlined by Adler (2001, p. 218):

> "While trust is a complex, multifaceted phenomenon, the complementarities between the components of each of its four key dimensions enable trust to function as a highly effective coordinating mechanism. Groups whose cohesion is based primarily on mutual trust are capable of extraordinary feats. Trust is therefore usefully seen as a third coordination mechanism […]."

By opposition, Leibenstein (1987) pointed out the fact 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.

Accounting for all the limitation of the classical modes of coordination, it is argued that the coordination of communities of practice is grounded on the complementarities between social norms and communities leaders.

II. Social norms and the coordination of communities of practice.

Transaction Costs Theory emphasises that the convergence in individual behaviors is mainly due to the implementation of incentive devices. By contrast, the aim of authority, as developed in this dissertation, is to coordinate individual behaviors through their influence and without the help of any coercive action. It differentiates from the notion of power found in Buckley (1998), which is characterized by the capacity to control behaviors through the implementation of explicit incentive and sanction devices. One could note that the notion of power developed by Buckley is very close to the notion of authority, as developed in Transaction Costs Economics.

Our perception of authority embeds two dimensions: social norms and leadership. Those two dimensions exert a direct (in the case of social norms) or indirect (in the case of leadership) influence on individual behaviors through the capacity to prescribe appropriate behaviors or to regulate information and knowledge flows.

The first dimension of authority corresponds to the existence of social norms as a reification of an impersonal form of authority (in the sense of Arrow (1974)). A social norm is defined 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).

Social norms constitute a basic condition for the existence of communities of practice by 1) limiting its access to the members complying with the criteria formulated in the frame of the norms; 2) by providing a first coordination mechanism. More precisely, the basic aim of social norms is to provide a general description of the basic goals of the community as well as the ways to reach them. For instance, open source communities are characterized by various norms of behavior and one of the most common norms is dealing with the property right regimes. Various regimes of property rights, which, in general, take the form of licenses,

coexist. In this manner, one of the first types of licenses was the GNU license which was introduced by the Free Software Foundation in the early 80's. the GNU license notably stipulates that any software using a part of the code written in software under GNU license has to propose a free and unlimited access to its source code. A second type of license, the Debian license, was introduced in 1995 in order to relax this constrain. In this way, software under Debian license do not have to propose a free and unlimited access to their source code.

Drawing the analogy with the contribution of Herbert Simon (1951) dealing with the employment market, social norms allow to delimit the set of individual objectives and goals which are considered as acceptable within a community of practice. On their side, each agent is endowed with an "area of acceptance" (or, in other terms, a set of objectives and behaviors which he considers as acceptable). In this manner, the problem of the selection of the individuals to be integrated to the community corresponds to a problem of matching between the set of individual objectives and of communitarian goals. Higher levels of matching between individual objectives and communitarian goals increase the probability of integrating the individual to the community. From a dynamic point of view, social norms provide a first coordination mechanism due to the influence they exert on individual areas of acceptance. Because of the influence they exert on individual preferences, they contribute to their convergence. This, in turn, by producing an homogenization of individual behaviors, beliefs and objectives, allows to save on communication costs and contributes to the cohesion of the community (see Chapter VI).

Before being considered as full members, newcomers have to learn the social norms prevailing within the community. This learning process, which is similar to the process of "legitimate peripheral participation" developed by Lave and Wenger in their 1991 book, enables the individual to better grasp the basic aims of the community as well as the ways to reach them. This phenomenon has been widely discussed in the literature on open source software development. In their study of Freenet, von Krogh *et al.* (2003) argue that any newcomer follows what they called a "joining script". A joining script refers to the process by which a newcomer becomes a full member of the community. A fundamental aspect of a joining script corresponds to the time dedicated to the acquisition of the social norms and the basic habits prevailing within the community. This activity is "silent" in the sense that the individual doesn't actively contribute to the activity of the community. After having completed the joining script, the agent can consider himself as a full member of the

community. At this time, he becomes an active member and contributes to the community by disclosing information and knowledge.

Due to their moral dimension, compliance to social norms involves in a significant way the notion of emotion (Elster, 1995). The use of emotions proves to be central to the permanence of social norms since individual behaviors can, in most cases, be only assessed through an evaluation of their results. In this perspective, the concept of pro-social emotion, which was developed by Bowles and Gintis (2001), enables to draw a relationships between emotions and the compliance to norms. The aim of pro-social emotions is to provoke the adoption of altruistic behaviors in the sense that, aside from their own preferences, each agent takes into account other agents' preferences. The pressure exerted by social norms on individual behaviors through pro-social emotions can be expressed in different ways:

⇒ The first effect notably highlighted by Granovetter (1985), relies on the social structure. Complementing the interpretation of altruistic behavior based on recurring interactions, Bowles (2001) shows the influence of the social structure in the behaviors. Individuals are more disposed to adopt altruistic behaviors in the case of a strong social segmentation of the group they belong to.

⇒ The second effect reflects the "social learning" of the individual. This social learning, reified through social feelings[3], give the individual the ability to prevent any action which may imply some ex post costs. Those costs take the form of a limitation to the access to some community resources, a weakening of his personal reputation or even the exclusion from the community.

A basic condition underlying the compliance to social norms lies in the fact that they have to be common knowledge (or, at least, common belief). Indeed, as soon as this norm becomes common knowledge, its support provides a direct benefit to members by enhancing their coordination within the community. Indeed, the existence of this common framework allows to save on the time and the costs related to the negotiation and the alignment of personal objectives and preferences.

[3] 7 social feelings were identified by Plutchik (1980): shame, love, guilt, embarrassment, pride, desire, jealously.

However, coordination through norms may face some limitations expressed through a lack of efficiency or, in extreme cases, the disappearing of the community. One of the main limitations the norms encounter lies in the implementation of the common belief feature. Indeed, in the absence of any centralized authority, agents may be confronted to coordination issues in the implementation of social norms as a result of a lack of beliefs coordination. A second limitation lies in the great inertia of social norms. Actually, their evolution implies not only, for each member of the community, an evolution of his personal approach to the norms (they have to distinguish the gains of the new norm relative to the former one) but this evolution has to include the common belief feature too. Like conventions, such an evolution may be a very slow process (cf. Young (1993) for further discussions). Therefore, coordination through norms must be considered together with community leaders.

III. Leadership.

III.1. The role played by leadership in support of social norms.

Even though the existence and attributes of leadership in communities have been extensively emphasised in the literature on open source software development (Bezroukov, 1999, Kogut and Metiu, 2001) the issue of its building and its dynamics have been the object of little focus. 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 (Aghion and Tirole, 1997, Hermalin, 1998, Foss, 2001). Such an influence exerted on information and knowledge flows is the outcome of two complementary effects: the ability to constrain communication flows and a preferential access to information and knowledge.

The ability to constrain communication flows is the outcome of the leaders' capacity to take on the roles of mediators (in the sense of Schelling (1960)). Such a capacity of mediation, by offering leaders the opportunity to filter communication flows, allows them to direct members' behaviors in a given direction. In fact, as Schelling pointed out (p. 144):

> "A mediator can do more than simply constrain communications –putting limits on the order of offers, counter-offer, and so forth- since he can invent contextual material of his own and make potent suggestions. That is, he can influence the other's players expectations on his own initiative, in a manner that both parties cannot help mutually recognizing. When there is no apparent agreement, he can create one by his own power to make a dramatic suggestion."

Thus, by filtering communication flows, leaders increase the coherence of the community's common knowledge base. In the case of Linux, any contribution provided to the source code has to be filtered by the members of the community designated by Linus Torvalds, the maintainer of the project. Such appointments are based on the quantity and the quality of individual contributions (Bezroukov, 1999).

Apart from their capacity to take on the role of mediators, community leaders enjoy a preferential access to information and knowledge. This special access to information and knowledge is due to the multiplication of relationships with other members of the community. knowing that, community members assume that leaders face lower degrees of uncertainty and are therefore likely to take more appropriate decisions. In this manner, leaders may be subject to informational mimesis behaviors. Informational mimesis was defined by Orléan (2001, p.109) as:

> "this particular mimesis which consists in copying other individuals because one believes a better knowledge about the situation. Put in another way, we mimic other people because we believe that they are better informed"[4].

One can draw a parallel between informational mimesis and the concept of "leading-by-example" which was introduced by Hermalin (1998). In experimenting the influence of leadership behaviors on the contribution to the provision of public good, Meidinger and Villeval (2002 p.4) gave the following description:

> "In "leading-by-example", the leader is allowed to choose her effort publicly before the other agent chooses his own. When the leader is working hard, the follower can infer that a high return of effort prevails, whereas whenever the leader shows little effort, he should believe that a low return is likely. By such a commitment, the leader is able to convincingly transmit her information to the follower."

At this point, some questions may arise out of our discussion. First, the issue of the leaders' legitimacy has not been addressed. It has insofar been assumed that the only goal of community leaders has been to act for the good of the community. This is not necessarily the case since leaders may exploit their informational advantage in order to direct the community's work towards their own personal interests. This implies a need for regulating mechanisms dedicated to control leaders' behaviors. Secondly, leaders have been so far considered as a fixed entity, this coming in contradiction with the fickleness of such informal community. It implies several questions : on what foundations such authority is based? Is this construction fixed (like in the case of the Williamsonnian hierarchy) or is it constantly evolving ? Which legitimization mechanism the authority is based on ? Finally, authority has been only considered from the coordination standpoint. However, like more classical coordination mechanisms such as market and hierarchy, the cognitive work as well as the exercise of authority may involve extrinsic incentives such as the need for reputation and the acknowledgement of a specific expertise (Dalle and Jullien, 2003). The answer to those three issues lies in the intertwining between reputation and trust in leadership building.

[4] The translation is in the charge of the author.

III.2. Reputation, trust and leadership.

Leadership building is primarily based on the reputation of community leaders, those agents being perceived as the only individuals able to adequately direct the community's cognitive work. However, by facilitating the first interaction, reputation only constitutes a short term mechanism necessary for the construction of leadership. By contrast, a leader's legitimacy can only build in the long run, through the accumulation of interactions with other community members. In this way, trust allows the permanence of the relationship between the leaders and other members of the community. Thus, there is a strong link between reputation and trust: while the former allows to build a leadership status by facilitating the occurrence of first interactions, the latter allows to legitimate this status by allowing individuals to engage in long-lasting relationships.

The concept of reputation is here understood as a set of information dealing with constant and recurring elements of an individual's behavior, those information being the object of a perpetual assessment. Those information may have different origins and come from persons having already interacted with the agent. However, to be accounted as elements of reputation, they have to fulfil several conditions. First, they have to be verifiable by other members of the community. In this way, agents must be able to track the sources of those information and to point out who produced it. Second, they have to be objective and to be freed from any interpersonal content (like past disputes or any interpersonal feelings). Finally, they have to be shared by the whole community. Those three conditions differentiate reputation from other effects such as rumours or any other phenomenon aiming at generating a biased picture of the individual. For instance, a main factor influencing reputation in open source software development corresponds to the contributions to the project. Those contributions feed reputation since they are codified. The codification of the contribution allows to fulfil the two condition imposed on reputation: they can be accessed by all members of the community and, since they incorporate the identity of the contributor, and anyone can trace back to the sources of the contribution.

A positive reputation provides numerous advantages such as a reduction of the costs related to a first interaction. Those costs notably correspond to the time spent in searching the relevant person and in defining the aims of the interaction. In the frame of academic research, reputation allows to know *a priori* that an individual is specialized in econometrics or that his

current field of inquiry is dealing with labour economics. Moreover, his reputation can embed elements about his behavior such as his degree of cooperativeness or of honesty. However, when the costs of maintaining a reputation are higher than the advantages, it may not prevent opportunistic behaviors. This leads to the implementation of devices aiming at punishing any deviation from it. Such devices may consist in a loss of reputation leading to a decrease in future opportunities. Such punishing mechanisms assume however that the behavior is not subject to ambiguity and the consequences are observable and verifiable in order to legitimate at the level of the community the reassessment of the reputation.

As Kreps (1990) pointed out, the notion of reputation may be useful in situations characterized by uncertainty, where expectations about behavior are otherwise impossible. In such situations, the notion of reputation refers to concept of focal point developed by Schelling (1960) and described by Kreps (1990, p.121) as "*some principle or rule individuals use naturally to select a mode of behavior in a situation with many possible equilibrium behaviors*". This definition implies some remarks. Firstly, in the case in which the outcome resulting from different actions is known, the behavior corresponding to the focal point may be locally sub-optimal. Such behavior may however be rational in a global perspective, for example, by providing further opportunities. Second, the choice of a focal point results from a process of trial and error and of selection based on past experiences. In this manner, this type of behavior may imply better results in uncertain environments (Kreps, 1990).

However, if reputation provides a device reducing the uncertainty associated with a first interaction, it is of little help in the case of recurrent interactions. In this case, trust replaces reputation. Trust is here understood in a cognitive sense. Cognitive trust refers both to a judgement of competence (based upon verifying the quality of the behavior) and of reliability about the partner (referring to the congruence between words and actions) (Rocco et *al*., 2001). In this manner cognitive trust refers to the belief that 1) the partner holds competences which may benefit to the individual 2) since the relationship is perceived by both partners as mutually beneficial, the partner is inclined to act benevolently and not to betray the relationship. It differs from classical views of trust which refer to an individual's ability to rely on his partner because the former believe that it is not in the interest of the latter to misbehave and to adopt an opportunistic behavior (Gambetta, 1988).

Cognitive trust differs from the classical, calculative views of trust in that the former do not necessarily rely on the binding of contracts. Indeed, incomplete contracts and calculative trust are both highly complementary: a contract, by describing the most salient features of a relationship, delimits the set of mutually acceptable behaviors as well as the possible sanctions in the case of any contravention (Brousseau, 2000b). Conversely, calculative trust, by corresponding to an expectation in the partner's behavior, allows to save on contracting costs. In this way, calculative trust correspond to the adoption of a strategic behavior characterized by a "weighted" risk-taking: individuals expose themselves in the limits set by the degree of uncertainty characterizing the relationship and by their degree of risk aversion.

While cognitive trust corresponds to a behavior expectation based on private information which have been accumulated through past interactions, the building of reputation relies on the accumulation of public information coming from different sources. However, although they are different in their construction, reputation and trust are actually closely related. Reputation constitutes a necessary condition for a first interaction to take place by reducing the uncertainty and the costs associated with it while trust constitutes a factor enabling the permanence of the relationships by allowing a certain degree of flexibility in the behaviors. In this manner, whereas reputation determines the decision of an agent to trust another individual (Granovetter, 1985), trust can also influence the evolution of reputation (Coriat and Guennif, 1998).

However, trust relationships are not stable in time. Individuals have to continuously exchange signals about their intention to cooperate in a non opportunistic manner. Such signals may reinforce trust relationships in two ways. First, signals, by their very nature, embed a strong informative content. In the frame of open source project, signals consist in disclosing advices and pieces of codes. In this way, they can inform the partner about the knowledge and the degree of programming skills of the individual. Second, the costs entailed by signalling show the truthfulness of the intentions (Brousseau, 2000b). For instance, those costs consist in the time and the resources spent in codifying the piece of knowledge incorporated to the signal or to the resources mobilized in disclosing it. Moreover, as soon as those signals are observable and verifiable, it becomes easy to disclose them to the entire community, thus reinforcing the reputation of the concerned individual.

In the frame of communities, what may those signals correspond to? the three main tasks completed by communities of practice being the production, the disclosure and the storage of knowledge, reputation and trust are therefore mainly built around the objectives of such communities. Thus, reputation and trust building may rely on the ability of each community member to contribute to the pursue of the objectives defined at the community level, those contributions being reified through the production and diffusion of knowledge or any other activities related to the tasks under consideration.

However, one should notice that reputation and trust rely not only on the volume of contribution but on their quality too. In fact, the quality of signals must be assessed in relationship with the social norms prevailing within the community. In the case of too strong discrepancies between the content of the signal and the standards of quality (as enacted by social norms), the quality of the signals disclosed by the individuals is poor. This may affect the individual's trustworthiness and reputation which may, in turn, influence his social position within the community. In the case of the Linux community, a ranking of the hackers is established, this ranking being based on criteria such as the amount of code disclosed as well as their popularity (which may constitute an assessment of the quality of the code). This ranking, in turn, determines the social position within the Linux community: high ranked programmers become leaders of the community while low ranked programmer are rejected to the periphery of the community.

Given that reputation may give rise to new personal relationships, her reinforcement increases an individual's notoriety within the community. If the agent meets his reputation, a virtuous circle would form where the increase in the number of successful interactions would reinforce the reputation which would lead to an increase in the number of interactions. From the social networks standpoint, this might translate in a higher density in his personal network which may eventually lead to a polarization of the social network within the community[5]. Such a polarization implies two main advantages: on the one hand, the individual enjoys a

[5] From a social networks standpoint, appears a fundamental difference between hierarchical groups and "more informal" knowledge intensive communities. When hierarchical groups are often characterized by a tree shaped network featuring properties such as transitivity (if A>B and B>C then A>C) and antisymetry (if A>B then B is not superior to A) as well as the existence of a unique root of the tree (Radner, 1992). At the opposite, in the frame of the social network describing the relationships within knowledge intensive communities, the informal hierarchy is made of denser subgraphs. Thus, the individuals forming the upper part of this informal hierarchy are at the middle of higher density subgraphs than the other members of the community. We may thus find an analogy with the concept of centrality developed in social networks theory(cf. Borgatti and Everett, 1999 ; Mizruchi and Potts, 1998).

central position in the community's communication network, thus inducing a belief among members that he may possess first hand information. On the other hand, this central position within the communication network enables him to become a mediator (in the sense of Schelling). This, in turn, increases the influence exerted by the agent on the community members. However, such a central position may imply some drawbacks linked to this central position within the social network. Thus the preserving of reputation may become a central concern given that any information about unsuccessful relationships would diffuse much quicker than in a sparsely connected social network.

IV. A dynamic model of authority evolution.

The aim of this section is to present a model accounting for the evolution of the relationship between social norms and leadership. In the definition of communities of practice, it has been argued that one of the distinctive traits of such communities lies in its self-organizing capacity resulting from the identity and the autonomy of their members.

Identity is grounded on three factors: engagement, alignment and imagination. The engagement of an individual within the community is related to the richness of his experience as a member and may therefore be strongly related to the participation of the member to the cognitive work of the community. Of course, engagement is constantly evolving. This was described by Wenger (1998) as taking the form of trajectories. In this respect, this author drew a distinction between three types of evolution:

⇒ A **peripheral trajectory** occurs when a member of the community chooses to commit himself slightly. To put it in an other way, the individual chooses never to actively participate to the community.

⇒ An **inbound trajectory** occurs when, starting from a low level of commitment, the agent commits himself deeper to the community's cognitive work. The more the individual chooses to commit himself, the more central becomes his position within the community.

⇒ An **outbound trajectory** occurs when, starting from a high level of commitment, the individual chooses to step back from the community. Such trajectory may lead the individual to the community's periphery. In some extreme instances, it may also lead the individual out of the community by a process of marginalization.

One should note that the concept of trajectory refers to the level of implication of the individual *relative* to the other members of the community. Indeed, given that other members' commitment levels are also constantly evolving, an inbound trajectory tends to describe a greater evolution of the contribution level relative to other members. Moreover, participation to the working of the community is essentially a social process. Thus, an individual following an inbound trajectory actually increases the frequency of social interactions with other members of the community. This eventually leads to an increase in the influence he exerts within the community.

Trajectories of engagement within the community describe the dynamics of leadership of a given individual within the community. Since an individual adopting an inbound trajectory multiplies the frequency of his interactions with other members of the community at a higher pace than the overall community, he acquires the ability to become a mediator in the sense of Schelling, leading him to gain influence over the community. Conversely, an individual adopting an outbound trajectory tends to decrease the frequency of interactions with other community members leading him to loose the influence he used to have on other members.

Alignment is related to the quality of the individual experience within the community. In fact, each contribution is subject to procedures of control and of selection focusing on the

relevance and the quality of the signal. Such procedures rely on a comparison of the contribution with the criteria decreed by the social norms prevailing within the community. Compliance with social norms, which forms the basis of alignment, acquires a paramount importance in determining the quality of communitarian experiences. Indeed, one of the main effects of social norms lies in the fact that it contributes in reducing the uncertainty related to individual behaviors. In this way, individuals aiming at acquiring high degrees of reputation and trustworthiness (and, therefore, a leadership position) have not only to sustain high contribution rates but a high degree of compliance with norms too.

However, since the community is submitted to frequent evolutions in its environment, its cohesion and efficiency might be threatened by sticking to a sub-optimal norm. This threat is of paramount importance since social norms direct individual behaviors, thus influencing learning and knowledge creation processes. It follows that the capacity of social norms to evolve along with the community's environment is critical.

The capacity for norms to evolve entails several competences of community members. The first type of competences corresponds to the capacity to figure out the community's environment and to anticipate its further evolutions. Those competences can, in a general way, be gathered under the term "imagination". Imagination has been previously described as the capacity to link personal experience to the general models of behavior prevailing within the community. Imagination, by allowing the individual to represent himself the current state of the social norms, allows to detect their strengths and weaknesses. Hence, imagination provides the necessary condition for the evolution of social norms.

The actual evolution of social norms relies on the autonomy of agents. Autonomy allows community members to challenge (corresponding to a process of "voice" in the sense of Hirschman (1970)) the current norms as soon as they detect that it may threaten the cohesion and the cognitive progress of the community. In the extreme case that the process of "voice" doesn't provide satisfying results, some members can decide to exit the community.

To be effective and credible, the processes of voice and of exit have to be strictly controlled and regulated. At this point, the degree of compliance to current social norms plays (referring to the concept of loyalty developed notably by Hirschman (1970) and Simon (1991b)) a critical part by postponing the point at which individuals enter into voice and exit

processes. In this perspective, a high degree of compliance to social norms implies that individuals postpone as much as possible the point at which they start to challenge the current social norms. But, once this point reached, the impact of the protest is larger since it really means that “something is going wrong”. Conversely, a low degree of compliance to social norms, by inducing a low degree of loyalty, may jeopardize the credibility of the protest.

The levels and the motivations inducing protest may vary according to the individuals. This is due to the fact that communities gather individuals possessing different knowledge and information which may, in turn, induce different perceptions of the environment. The role of community leaders consists in collecting, selecting and collating those heterogeneous perceptions and protests in order to propose to the community a viable evolution for the social norms. The exploitation of protest by community leaders is made possible since, apart from the expression of a discrepancy between the individual objectives and the social norms, protest embeds a strong informative content about possible evolutions of social norms by proposing alternative solutions (*cf*. Hirschman, 1970). Figure I-1 provides a summary of the model of authority evolution.

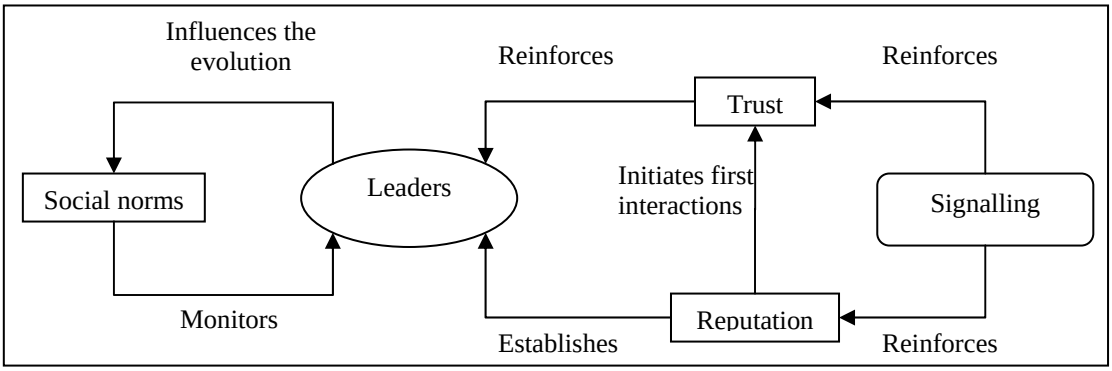

Figure I-1: dynamics of authority in communities of practice.

The capacity to protest against the current social norms and against individual decisions has been widely discussed in the literature on open source software. Numerous scholars (Bezroukov, 1999, Kogut and Metiu, 2001) emphasised the existence of numerous disputes among developers. For instance, those disputes are dealing with the architecture of the program or the type of license (GNU or Debian). However, Lerner and Tirole (2000) pointed out the interesting fact that rather few open source communities were facing forking problems

(corresponding to the case that numerous members step back from the community and build their own competing community). This, in our model, can be explained as the outcome of several factors.

The first factor corresponds to the capacity of leaders to propose viable evolutions for the social norms. This effect might be found in the case of the Sendmail[6] community. Eric Allman, the initiator of the Sendmail project, managed to build up a community dedicated to the development of Sendmail in which he became a legitimate leader. However, after some years spent in the community, he decided to step back from it because of professional duties. After Allman having stepped back, disputes arose about the architecture of the program in such a way that the project forked in several competing version. When Allman took control of the project by a drastic rewriting of the source code and the adoption of a new software architecture (thus imposing an evolution in the current norms of the community), he managed to raise such a consensus that the competing versions were abandoned in favour of Allman's version. In conclusion, Allman managed to recover the cohesion of the community.

The second effect limiting forking corresponds to the community members' high levels of social norms compliance. It has been previously argued that a basic condition for newcomers to become full-members of the community lies in the silent learning of social norms. In this manner, a distinctive trait of community members corresponds to their high degree of compliance to those norms. This, in turn, contributes to postpone the exit of community members. Finally, the third factor, which will be developed in Chapter VI, corresponds to the capacity of community leaders to coordinate individual behaviors by influencing their personal knowledge.

The aim of this section was to present a dynamic model accounting for the close and complex relationships existing between social norms and leadership. Leadership is based on trust and reputation and enables to enhances the adoption and evolution of social norms. In turn, social norms exert a permanent pressure on community leaders by directing the criteria relevant for the dynamics of reputation and trust for each member of the community.

[6] Sendmail is an email router which has been developed by Eric Allman. It main advantage lies in its interoperatability: Sendmail incorporates a function allowing to routes emails in networks using different communication protocols (Lerner and Tirole, 2000).

Conclusion.

This chapter aimed a presenting the theoretical framework underlying this doctoral dissertation by highlighting some elements dealing with the governance of communities of practice. Traditional approaches have usually dealt with hierarchy either as a costs reducing device or as a device aimed at regulating strategic behaviors (Dosi and Marengo, 1999). If traditional contractual approaches to organizations succeed in explaining the coordination of specialized tasks in an industrial perspective, they fall short in accounting for the convergence and the coordination of individual motivations (Leibenstein, 1987), those concern being central in communities of practice.

In the perspective of communities of practice, we contend that their governance relies on the close relationship existing between social norms and leadership. Social norms allow to direct the community's activity by specifying its goals as well as the ways used by members to reach them. In this respect, social norms offer a first coordinating device by allowing to forecast the behaviors adopted by community members. However, coordination through norms implies some shortcomings mostly related to their implementation and their evolution. A way to avoid those limitations lies in the existence of community leaders.

The existence of community leaders allows to increase the speed of social norms implementation and evolution through an influence exerted on information and knowledge flows occurring within the community. Leadership is grounded on the strong complementarities between reputation and trust which constitute important incentive device for the production and disclosure of knowledge. In this way, a leadership status is constantly evolving along with the levels of trust and reputation individuals enjoy.

Chapters IV and V will constitute an implementation of the preceding discussion on the relationship between reputation, trust and leadership. In this way, chapter IV will discuss in more depth the relationship between reputation and leadership. It will propose a model of leadership dynamics as the outcome of differences in levels of commitment to the community. Chapter V will constitute a further development by discussing the notion of trust and by proposing a simulation model linking reputation, trust and leadership. Chapter VI on his side,

will discuss the role of leadership as an important factor ensuring the cohesion of a community.

This chapter, although having shed some light on the important issues of the coordination and the motivation of agents within communities of practice, leaves several issues unexplored. One of the most important and basic issues is dealing with the emergence of communities of practice. Chapter II will precisely tackle this important issue of the morphogenesis of communities of practice by inserting the discussion into a wider framework, that is, the social dynamics of groups and the creation of social entities. These entities are either formal (as in the case of firms) or informal (as in the case of communities).

Chapter II. Why do communities emerge ? a Model of Group Dynamics.

Introduction.

The goal of this chapter is to explore in more depth the genesis of communities of practice by studying the conditions under which communities emerge. More precisely, its objective is propose a theoretical model accounting for the structuring of groups of individuals and the conditions under which, out of those groups of people, do communities or, conversely, firms emerge.

This chapter is motivated by a double observation. First, the literature on communities of practice commonly deals with already existing communities. It is therefore mainly focusing on describing the properties of communities and their internal functioning as well as their application (cf. Brown and Duguid, 1991, Wenger, 1998). To our knowledge, only very few

contributions try to explain its emergence (Dupouët *et al.*, 2003, Dupouët, 2003). Still, if those contributions are interested in the morphogenesis of communities of practice, they nevertheless assume that they only form in a well established institutional framework (e.g. an insurance company) and that their members have already cultivated some basic commonalities: they are bound by common objectives (e.g. they have to assess insurance contracts or loans evaluation) and they share a common knowledge base that has been established through past experiences. They fall short in explaining the emergence of communities in less established environments. For instance, open source communities often emerge in the absence of well established institutional settings such as firms or any other type of organization.

The second observation motivating this chapter lies in the relative lack of any unified explanation for the emergence of firms. In fact, numerous theoretical streams have stressed different causes for the emergence of firms, each differing from the other. In this manner, whereas neoclassical orthodoxy has grounded the existence of firms in the existence of technological interdependencies among employees (Alchian and Demsetz, 1972), or on the market failure induced by the public character of knowledge (Atkinson and Stiglitz, 1980), the evolutionary theory has notably emphasized the gathering of complementary competences and knowledge (Loasby, 1998).

In order to address this stream of observations, this chapter will show that, although the causes underlying the existence of firms appear to be rather diverse or even divergent, they are actually all underlain by the degrees of uncertainty individuals have to face. It ranges from a low level of uncertainty, principally corresponding to the absence of an objective probability distribution associated with known outcomes (Savage, 1954) to pervasive forms of uncertainty in which the structure of the problem is so ill defined that it is impossible to forecast possible outcomes (March and Simon, 1958).

A consequence of the degree of uncertainty is the ability to bind contractual relationships. More precisely, whereas low levels of uncertainty, by enabling to foresee future contingences, make possible the writing of rather complete contracts, higher levels of uncertainty give rise to more incomplete contracts. From a theoretical point of view, whereas, low levels of uncertainty would give rise to the building of classical firms, increases in the degrees of uncertainty imply a progressive switch from the neoclassical view to an

evolutionary approach to the firm. At the extreme, contracts become so incomplete that it turns out to be more rational to switch to a communitarian regime in which individual relationships are not regulated by contracts.

The main argument of the chapter can be decomposed into two main steps. The first step is related to the degree of uncertainty individuals have to face. This degree of uncertainty affects the entrepreneur's choice of the most suited type of organization: whereas low levels of uncertainty give rise to the building of classical firms, high degrees of uncertainty lead the entrepreneur to adopt a communitarian regime. The second step of the argument is dealing with the community's work. In the frame of the classical firm, contracts are characterized by high degrees of completeness enabling the entrepreneur to set powerful incentive mechanisms. At the opposite, due to the absence of any contractual scheme, the success of communities heavily depends on the entrepreneur's ability to arouse the voluntary adhesion of the members to the common enterprise. From this, several implications can be highlighted. These are dealing with incentives and property rights regimes, the evolution of knowledge specialization and the nature of the relationship between the individual and the rest of the organization.

This chapter will address the previous observations by notably focusing on the two polar cases: the classical firm and communities. In this manner, this chapter is organized as follows. Section I gives an overview of the classical firm by notably describing its internal organization and the repartition of property rights. Section II provides a description of a model of group structuring and wishes to account for the reasons underlying the choice between a community- versus a firm-type of organization. Section III is dealing with the consequences of the adoption of a firm vs. a communitarian regime. More precisely, it inspects the consequence in terms of incentives and property rights regimes, the evolution of specialization and the nature of the relationships binding each individual to the rest of the group.

I. The classical firm: an overview.

The classical firm (or team) has been notably discussed by Alchian and Demsetz in their famous article "Production, Information Costs and Economic Organization" (1972) and has received important developments since then (see e.g. Jensen and Meckling (1976) and Fama and Jensen (1983)). The primary aim of this article was to rehabilitate the analysis of the firm (which had hitherto been considered as an individual agent) in neoclassical orthodoxy. This paper constitutes a reaction to the developments of Coase (1937, 1960) and Knight (1921). On the one hand, according to Coase, the existence of firms is motivated by the existence of a market failure arising from difficulties in discovering the relevant prices or the costs of negotiating and concluding a separate contract for each transaction taking place on the market. On the other hand, Knight's explanation of the existence of firms lies in the fact that economic agents are facing risk while taking decisions and the grouping of those individuals into a firm allows to reduce risk at the individual level.

In a very basic way, a team can be defined as "a group of persons each of whom takes a decision about something different but who receive a common reward as the joint outcome of all those decisions" (Marschak, 1955, p. 128). Moreover, Alchian and Demsetz' argument starts from the observation that the main rationale of organizations rests on the existence of technological interdependencies among agents. Their point is therefore that, under the assumption of interdependencies among production factors, the coordination of production in a team better performs than through market mechanisms. Let's consider the production of a good or service Z_{Team} involving two inputs i and j in quantities X_i and X_j such as $Z_{Team} = f\left(X_i, X_j\right)$. It is furthermore assumed technological interdependencies among production factors: $\partial^2 f / \partial X_i \partial X_j \neq 0$. Under certain circumstances, the organization of production in a team will be preferred to the organization through market mechanisms when $Z_{Team} > Z_{Market} = f_i\left(X_i\right) + f_j\left(X_j\right)$.

While taking advantage of inputs interdependencies, the main challenge facing team production lies in organizing and disciplining team members. According to Alchian and Demsetz, in team production, marginal products of cooperative team members are only indirectly and costly observable. This is due, on the one hand, to interdependencies in the

productive resources and, on the other hand, to the fact that those productive inputs are not all owned by the same person. Difficulties in observing the individual contribution to the team production provides each individual the opportunity to act according to his own preferences. This might end up in shirking and free-riding behaviors. The accumulation of such behaviors by team members may decrease and, *in fine*, withdraw the comparative advantage of teams over markets.

In order to solve the free-riding problem, Alchian and Demsetz introduce an agent who specializes in monitoring the input performance of team members. The monitor's main tasks consist in measuring output performance, apportioning rewards, observing the individual input behaviors in order to estimate their marginal productivity and giving instructions to the team members. The status of the monitor within the team is therefore special since he doesn't directly take part to team's production. Moreover, another question remains: why does he not shirk ? Or, to put it in another way, which mechanisms control the monitor and ensure that he fulfils his task in an effective way ? In order to answer this further theoretical challenge, Alchian and Demsetz endow the monitor with property rights over the team resources. Those rights decompose in two distinctive attributes: residual control and residual claim.

The first attribute corresponds to the right of residual control over the inputs of the team. Residual control consists in the right to take decisions concerning the use of any inputs in the limits set by the legal system or assigned to another by contract (Milgrom and Roberts, 1992). This attribute, by providing the ownership over the productive resources of the firm, enables the monitor to perform his supervisory task.

The second attribute corresponds to the right to residual claim. Residual claim corresponds to the right to appropriate the benefits resulting from the production of the firm. Thus, residual claim contributes to provide the monitor with incentives to efficiently hold his task since his income increases as the level of shirking in the team decreases.

Another aspect grounding the existence of residual claim and control, lies in the existence of incomplete contracts (Hart, 1991). Contractual incompleteness arises out of several factors among which (Milgrom and Roberts, 1992): 1) the existence of unforeseen contingencies. Especially in long term contracts, contingencies may arise that have not been accounted for because they haven't been imagined at contracting time. The existence of

unforeseen contingencies has to be linked with uncertainty which, in this case, corresponds to an absence of an objective probability distribution associated with outcomes (Savage, 1954). 2) the existence of contracting costs. Even when contingencies are foreseen, they may appear so unlikely that it is not worthwhile to describe them in detail and to agree about what to do if they should arise. This is most likely the case when the contingencies seem very improbable, when the opportunity costs and the time spent writing the contract rather than doing the productive work are high or when the contingencies seem unlikely to cause large disputes if they should occur. 3) the imprecision of language. The natural languages in which contracts are written are inherently imprecise, meaning that statements describing any reasonably complex situation must be somewhat ambiguous.

Residual control and claim are both consequences of contract incompleteness. Residual control aims at filling the gaps left open by incomplete contracts by allowing to adapt the agreement to unexpected contingencies (Hart, 1991). For instance, a capitalist entrepreneur (who merges with the team's monitor in the theory of Alchian and Demsetz) as the ability to adapt the firm's capital in reaction to the evolution of the demand. Moreover, as the owner of the firm's resources, the monitor has the right to renegotiate the contracts binding the team with its members. This renegotiation might be motivated by the emergence of ex-post contingencies.

Residual claim constitutes another consequence of contract incompleteness. In fact, under complete contracting, the division of the wealth in each eventuality would be specified contractually, and there would be no return that could usefully be thought of as residual (Milgrom and Roberts, 1992). In the classical firm, the monitor and team members agree on the fact that, whereas the latter earn a fixed income, the former's income depends on the team performance which is, by essence, unknown during the period of contract negotiation.

Two observations might be addressed to the theory of Alchian and Demsetz. First, organizations are grounded on the ability to conclude incomplete contracts. This type of contracts is motivated by the existence of a kind of uncertainty *à la* Savage (1954). It assumes that both contracting parties are, at least, endowed with limited foresight. However, several scholars have advocated the existence of a much stronger, pervasive form of uncertainty (see Knight, 1921, Keynes, 1973, March and Simon, 1958). In this case, situations are so ill structured that the possible outcomes will remain unknown despite any attempt to increase the

amount of available information. It shall be argued that the existence of this pervasive form of uncertainty might prevents from the binding of any contractual relationship due to the agents' inability to appropriately set the terms of the contract. Secondly, the existence of a monitor is principally motivated by the shirking risk stemming from the existence of strong preference divergences among the members of the team. In this perspective, it shall be next argued that a lack of strong divergences among the members' preferences forms the basis of communities which are characterized by the absence of any central monitoring authority in the sense of Alchian and Demsetz (Muller, 2004a).

II. From groups to teams and communities: a model of collective dynamics.

The purpose of this section is to offer a simple model of group dynamics. By so doing, it aims at identifying some conditions under which a group structures either as a firm or as a community. Interestingly, the issue of group structuring, although being, in our opinion, at the root of any economic and social activity, has been, to our knowledge, largely overlooked. In order to tackle this issue, the argument exposed in this section decomposes into two steps which exploit two basic attributes of any economic activity: the agents' ability to conclude contracts and the effect of heterogeneities in individual preferences on the evolution of the group.

II.1. The determination of the type of structure: team or community.

Our discussion starts with a population of agents forming a group. This group might be viewed as a mob in the sense of Argyris and Schön (1978) in the sense that it has no actual common identity and its limits are ill-defined. However, one agent of this group departs from his peers by the fact that he assigns himself a particular cognitive task. The term "task" is here used in a very broad sense and may encompass all activities related to knowledge creation. Instances of this task may be found in the software industry with the dichotomy between proprietary/open source software (such as, for example, the competition between the Microsoft Windows operating system and Linux) even though a growing number of businesses propose services linked to open source software (e.g. Red Hat).

Due to physical and/or cognitive constraints, the entrepreneur is not able to fulfil the task on his own and tries to bind relationships with other members of the group. Instances of such processes of project initiation lie at the root of open source software (OSS) development. Basically, OSS projects proceed as follows. The starting point of a project stems either from a need in a given application (as in the case of Fetchmail, developed by Eric S. Raymond (2000)) or from a dissatisfaction with current solutions, as proposed by other softwares or operating systems (proprietary or not, as in the case of Linux), by an individual programmer. Then, this programmer tries to write and publish a first version of the software (the application and the program associated with it). Programmers interested in the project download the software and can contribute to its development by identifying problems or by implementing needed features.

The motivation of the individual to gather a group of individuals in order to achieve his cognitive project instead of turning to market mechanisms might be motivated by several factors[1]. First, the recourse to a group of individuals may enable him to achieve higher productivity rates due to the existence of technological interdependencies among agents (Alchian and Demsetz, 1972). Second, the recourse to a group instead of market mechanisms might come from the specificities of the project, which involves intensive knowledge creation. The specificity of knowledge lies in the fact that it has been commonly viewed as a public good (see Arrow, 1962; Nelson, 1959). The property of knowledge as a public good

[1] Other types of factors might also be considered such as the entrepreneur's altruistic character or his desire to market or not the final outcome of his project.

leads to a market failure due to the adoption by agents of free riding behaviors (Atkinson and Stiglitz, 1980). Contributions to the fulfilment of the task might therefore be more efficiently undertaken in the frame of group production than through market mechanisms. A third and related rationale lies in the search of bargaining power. In fact, patenting is traditionally viewed as an efficient incentives device for the production of knowledge for two reasons. Firstly, it provides an answer to the market failure problem induced by the public character of knowledge (this is done by excluding other competitors from the use of the patented knowledge). Second, it provides the inventor a temporary monopolist rent over the produced knowledge (Bloch and Markowitz, 1996).

The three types of motivations (profiting from technological interdependencies, solving the free-riding problem related to the achievement of the project, gaining bargaining power) already partly condition the decision of this entrepreneur[2] to constitutes a team or a community. However, apart from his personal motivations, the entrepreneur's actual strategy might be of different orders depending on his level of knowledge and on the nature of the task at hand. More precisely, in the case that he possesses full knowledge of the task, his strategy may be driven by the realization of economies of scale through a classical process of division of tasks and of specialization. Conversely, if his knowledge of the task is very incomplete, his strategy is driven by the gathering of complementary capabilities.

With this spectrum of strategies is associated the level of uncertainty related to the task. The former case, characterized by the possession of full knowledge of the task, is very close to the levels of uncertainty handled in the neoclassical perspective. The problem is well defined, the outcomes are known and only the probability distribution of those outcomes is initially unknown. In this case, the main challenge facing the entrepreneur consists in attributing subjective probabilities to each of the outcomes. This is done by increasing the amount of information in order to improve the basis for estimation of subjective probabilities and their accuracy (Becker and Knudsen, 2004). At the other end of the spectrum, the strategy of the entrepreneur mainly consists in gathering complementary knowledge. This case is characterized by pervasive uncertainty. Pervasive uncertainty corresponds to an absence of measurable probabilistic knowledge. In this case, situations are so ill structured that the possible outcomes will remain unknown despite any attempt to remedy the situation by

[2] The notion of entrepreneur is here understood in a very broad sense encompassing both orthodox views *à la* Alchian and Demsetz (as a monitor) and more evolutionary views rooted on the Schumpeterian perspective of entrepreneurship as linked to the creation of novelty.

increasing the amount of available information (Becker and Knudsen, 2004). As argued by Minkler (1993a), the dispersion of knowledge constitutes a cause of this strong form of uncertainty. Consequently, a way for the entrepreneur to reduce it consists in gathering complementary capabilities and knowledge (Loasby, 1998).

Differences in the entrepreneur's strategy, which are closely tied to his motivations as well as the level of uncertainty associated with his project, may induce different recruitment behaviors. By definition, low levels of uncertainty imply that the entrepreneur concentrates most of the knowledge related to his project and his recruitment behavior might be motivated by the achievement of economies of scale. It comes out that the entrepreneur enjoys an important advantage over other individuals since he is the only person having full knowledge of the project. In this way, he is in a position to foresee its most salient features implying that: 1) he is able to set an efficient division of work by assigning project members the tasks to be fulfilled. 2) He is able to forecast the most important contingencies associated with their achievement. The conjunction of those two effects enables the entrepreneur to enter into contractual relationships with other members of the group. One should however note that contracts are incomplete by nature, due, for instance, to the existence of contracting costs or imperfections in the language. The entrepreneur builds up a firm in the neoclassical sense. At this point, since members of the group enjoy the freedom to contract or not with the entrepreneur, we agree with Alchian and Demsetz (1972) with the fact that the relationships between the entrepreneur and the members of the group are not hierarchical. However, as we shall see latter and contrary to the argument of those authors, once the contract concluded, those relationships acquire an hierarchical nature.

As the level of uncertainty increases and reaches the state of pervasive uncertainty, the motivations of the entrepreneur switch from achieving economies of scale in the development of the project to reducing this uncertainty through the gathering and the organization of complementary capabilities and knowledge. With pervasive uncertainty, the entrepreneur is subject to more constraints than in the former case. Due to his limits in the knowledge of the project, his vision of the steps and tasks required to reach its completion is blurred. Consequently, he is unable to set an efficient division of work by assigning project members the tasks to be fulfilled. Moreover, since he is evolving in an environment characterized by pervasive uncertainty, the entrepreneur can, at most, only imperfectly foresee the contingencies associated with the tasks' achievement. The conjunction of those effects limit

his ability to enter into contractual relationships with the members of the group. Indeed, limits in his ability to define the basic features of the contract (dealing both with its goals and the ways of reaching them) end up in decreasing its level of completeness and increasing the costs associated with contracting[3]. From a certain point, the costs associated with contracting surpass the advantages it provides in terms of the regulation of individual behaviors. Consequently, it becomes more rational for the entrepreneur to engage in non-contractual relationships with his potential partners and he contents himself with prescribing some guidelines related to the goals of the project and the way to reach them. The withdrawal from a contractual scheme is at the root of the building of a community (Cohendet and Llerena, 2003).

While, in the case of the classical firm, the starting point of the relationship involving the entrepreneur and the agent is univocal (starting from the contract signature) and clearly involves two parties (the entrepreneur and the agent), the case of non contractual schemes is more fuzzy. First, the nature of the relationship is quite different from the classical firm: the individual decides to enter the community and to bind relationships with other community members and not specifically with the entrepreneur. Moreover, since one of the basic features of communities lies in the autonomy of the agents (corresponding to their capacity to freely set the nature as well as the intensity of their relationship to the community) the entrepreneur can more hardly induce any individual to enter or not into the community. Conversely, the decision of entry is, to a great extent, taken by the individual in an unilateral way after having learned the basic principles prevailing within the community (see Von Krogh *et al.* (2003) for further developments on this point). Differences in the recruitment behaviors are, as will be argued in a later section, due to the fact that the entrepreneur doesn't concentrate all the property rights over the communitarian resources. He therefore benefits from a limited ability to control the entry and the subsequent behaviors of the members. While acknowledging those differences in the recruitment procedures, we will use the term "joining" to indifferently designate both the conclusion of a contract binding the entrepreneur and the individual and the entry decision of the individual into the community.

[3] The contracting costs are of two types. The first type of costs are linked to the writing, the negotiation and the conclusion of the contract. The second type of costs corresponds to an opportunity cost linked to the lack of flexibility of the relationship between the contracting parties.

II.2. The evolution of the relationship between the individual and the structure (firm or community).

A direct consequence of the level of uncertainty of the project lies in the degree of specialization prescribed by the entrepreneur at the joining stage. In the case of low levels of uncertainty, the entrepreneur concentrates most of the knowledge relevant to the project. He is therefore able to set a relatively clear division of work. As a matter of fact, the costs of coordinating and organizing the tasks among the members of the team are relatively low in comparison to the comparative advantage provided by the division of work (Becker, 2003a). By contrast, in the case of pervasive uncertainty, the knowledge held by the entrepreneur is very incomplete and is likely to be distributed among the members of the group. Coordination costs stemming from dispersions in the knowledge may prevent any attempt by the entrepreneur to operate a clear division of labor among members of the group. Up to this point we should make clear the fact that we have been insofar only concerned with the level of specialization as *a priori* set by the entrepreneur. As we shall see latter in this section, the actual level of specialization occurring within a given group is very likely to evolve in response to the freedom left to the agents to choose the behaviors they perceive as the most satisfying.

The degree of specialization, as prescribed by the entrepreneur, has significant implications concerning the individuals' behaviors towards the group and the entrepreneur. As individuals are assumed rational, their behavior is primarily driven by their preferences which are supposed to be heterogeneous and might not necessarily match the group's objectives. We have so far only discussed the necessary conditions of the transition from a group of individuals to a team or a community. Specialization and individual preferences form the basis of the second step of our model of collective dynamics.

In order to better grasp the evolution of the relationship binding the entrepreneur and each group members, we make use of the concept of area of acceptance, initially developed by Simon in the frame of employment relationships (1947, 1951). Let's suppose a bipartite relationship binding the entrepreneur (the "boss" in Simon's paper, noted E henceforth) and a member of the group (a "worker" in Simon's typology, noted MG henceforth). Central to the model is the fact that the behaviors of both E and MG are ruled by the satisficing principle: a given action is chosen as soon as its outcome meets or exceeds the level of aspirations set by

the individual. Thus, the area of mutual acceptance corresponds to the set of actions for which the outcome are above the level of aspiration for both E and MG. The existence of an area of mutual acceptance therefore forms a condition for the collaboration of E and MG.

From now, it is assumed that MG has joined the group by having accepted the conditions induced by E. This implies that MG accepts to contribute to the achievement of the project under the eventual supervision of E (depending on whether this relationship is contractual or not). This situation is shown on the left panel of Figure II-1. This figure represents the outcome of MG and E's behaviors in the space of behaviors. A_{MG} (A_E) corresponds to the outcome of MG's behavior (E's behavior). The zone in which $A_{MG} = 0$ corresponds to the case that the outcome of MG's behavior equals his current aspiration level, $A_{MG} > 0$ ($A_{MG} < 0$), the case that the outcome of MG's behavior is above (below) MG's aspiration level. From the entrepreneur's point of view, $A_E=0$ corresponds to the set of MG's behaviors for which E is indifferent with those that both E and MG have agreed on. The $A_E>0$ ($A_E<0$) zone corresponds to the set of behaviors giving rise to higher (lower) levels of satisfaction. The fact that MG has joined the cooperation structure implies that, at this point, MG's current behavior belongs to the area of mutual acceptance.

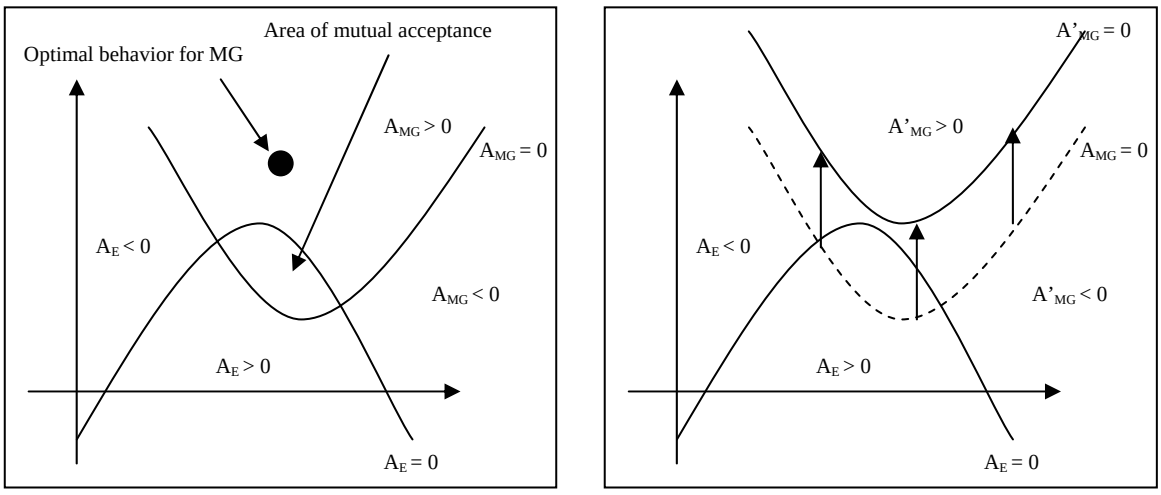

Figure II-1: Representation of the outcome of MG and E's behavior in the space of behaviors.

The fact that MG has joined the cooperation structure and has accepted to contribute to the achievement of the project does however not rule out any free riding behavior (MG is considered to be shirking when his behavior belongs to the $A_E<0$ zone). As depicted in Figure II-1, MG's optimal behavior might not belong to the area of mutual acceptance. Furthermore, MG's current behavior may be constantly revised owing to a process of aspiration level

updating. This process of aspiration level updating is influenced by two effects (Greve, 2002). The first effect corresponds to an historical dimension in which is operated a comparison of previous aspiration levels with the outcome of past and current behaviors. Rules of this type match the cognitive heuristic of anchoring (on the previous aspiration level) and adjustment (by the realized performance) (Tversky and Kahneman 1974). The second effect causing aspiration levels updating corresponds to social comparison. MG, while interacting with other members of the group, discovers other behaviors which may be more satisfying, leading to adjustments in his own behavior and aspiration level. As depicted in the right panel of Figure II-1, such a process of aspiration levels updating leads to the reduction and to the possible disappearance of the area of mutual acceptance which was at the root of the joining of MG. It follows that, MG's behavior, by diverging too strongly from the behavior expected by E, leads to lower outcomes from E's point of view.

E has the choice between different types of strategies for inducing MG to actively contribute to the joint output. The application of those strategies depends on whether E has built a community or a firm. The main aspect differentiating firms from communities is dealing with the ability, in the former case, to write and conclude contracts involving the entrepreneur and the members of the group. This, gives rise to different types of configurations, as shown in Figure II-2.

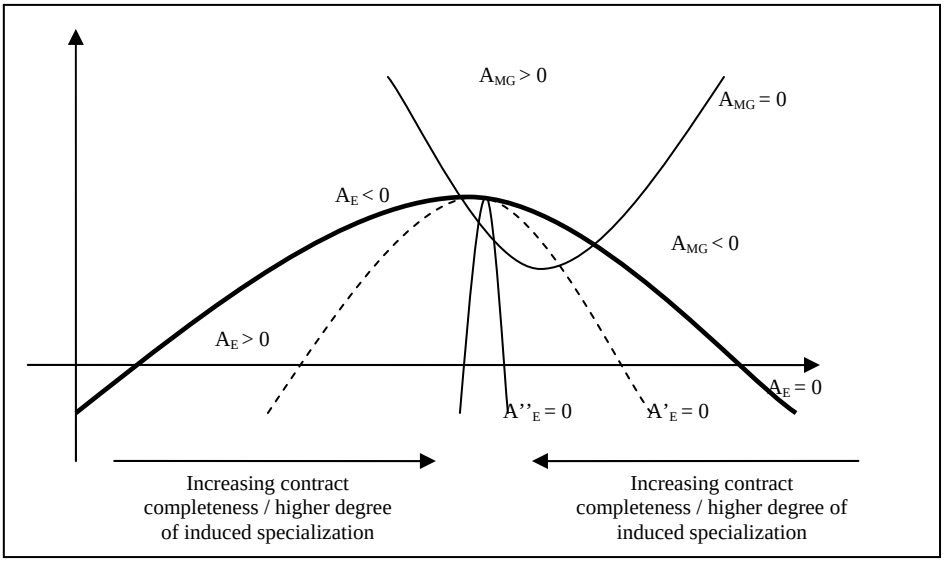

Figure II-2: Configurations of the relationship between E and MG as a result of contract completeness.

Contracts involving E and MG aim at defining the adequate behaviors for MG, as decreed by E. However, since they are incomplete by nature, the set of behaviors perceived as

acceptable (or even more satisfying) by E may vary in its size. Almost complete contracts (represented by the $A"_E=0$ curve –thin solid line) are more constraining for MG since they describe more precisely the set of tasks to be achieved (corresponding to higher degrees of induced specialization). Consequently, the set of mutually acceptable behaviors tends to narrow. Conversely, as the degree of contract incompleteness increases, the set of acceptable behaviors tends to widen ($A'_E=0$ curve –thin dotted line). From a certain degree of incompleteness, it becomes not rational to conclude a contract (considered the costs and the advantage that such a type of agreement entail). This case is depicted by the $A_E=0$ curve (thick solid line). In this case, MG enjoys a high degree of freedom without being considered as a shirker in E's eyes.

It seems rather reasonably arguable that the determination of a shirking behavior rests on E's hands. In this manner, E's strategy to prevent free-riding behaviors from MG decomposes in two ways, both of them resulting from features of the project set by E. The first way corresponds to the creation of incentives systems in order to force MG to stick to the position he has adopted during the contracting round. This incentive system results from the degree of completeness of the contract. It comes out that the degree of precision in the description of the tasks and of the appropriate behavior constitutes a first incentive system (Holmstrom and Milgrom, 1994). This is rather straightforward since the tightness in the description of the task and of the appropriate way to achieve them eases the monitoring and rewarding task of E. The second way to prevent shirking works in the opposite direction from the previous mechanism and consists in allowing a high degree of freedom to the individual. In this way, instead of resorting to external incentive mechanisms, the entrepreneur puts the emphasis on intrinsic motivations as a basic mechanism inducing individuals to contribute to the common project. The expected outcome is that MG voluntarily subscribes to the general goals of E's project. This case is particularly exemplified in the frame of open source development in which individual behaviors aren't regulated by any contractual scheme. For instance, in their study of the Freenet community, Von Krogh, Spaeth and Lakhani (2003) found evidence that one way to arouse the adhesion of other hackers to the project is to leave them the choice of the nature and the amount of the contribution to the project. However, one should point out that the efficiency of such a system is rather limited. First, it assumes that the "natural" optimal behavior for MG is close enough from (or even comprised in) the set of behavior considered as adequate by E. Secondly, it has to be coupled with other incentive devices such as the need for reputation and trust (Muller, 2004a).

Summing up, and as shown in Figure II-3, contractual incompleteness determines both the existence of free-riding behaviors and the incentive system designed to prevent them. Firstly, contracts prescribe the set of behaviors considered as acceptable from the entrepreneur's point of view. A high degree of contract completeness, by restricting the set of acceptable behaviors, gives rise to higher natural degrees of shirking from the members of the teams. But it also provides a strong incentive system by easing the controlling and rewarding tasks. In this case, the group moves towards a neoclassical firm way of functioning. A low degree of contract completeness (or, even the inability to write contracts) widens the set of acceptable behaviors. This ends up in increasing the likelihood of individuals to voluntarily adhere to the aims of the project, as established by the entrepreneur. In this case, the group moves towards a communitarian way of functioning.

Finally, an interesting point lies in the intermediate case in which the entrepreneur is able to conclude contracts with the members of the group but the contract are sufficiently incomplete to provide the team members with a wide set of acceptable behaviors. In this case, the high degree of freedom left to the team members is likely to provoke their voluntary adhesion to the objectives established by the entrepreneur. Individuals, bound by common objectives, are likely to form communities within the team. Moreover, interestingly, many communities form without being explicitly initiated by any communitarian entrepreneur[4]. One shall argue that the starting point of those communities lies in the existence of a common environment allowing them to meet and to exchange advices. For instance, such an environment might be provided by a firm since it may provide a shared context in which individuals can interact (by providing a *ba* in the sense of Nonaka and Konno (1998)) and in which they can express common interests. More generally, common non-market institutions[5], by crystallizing the converging interests of individuals, may form the starting point of communities without the explicit need for a communitarian entrepreneur. The case of the emergence of communities within firms has been explored in several contributions (*cf.* Dupouët, 2003, Dupouët *et al.*, 2003).

[4] See, for example, the very instructive case studies of Lave and Wenger and Wenger (1998).
[5] Institutions are here understood as durable systems of established and embedded social rules structuring social interactions (See Hodgson, 1998).

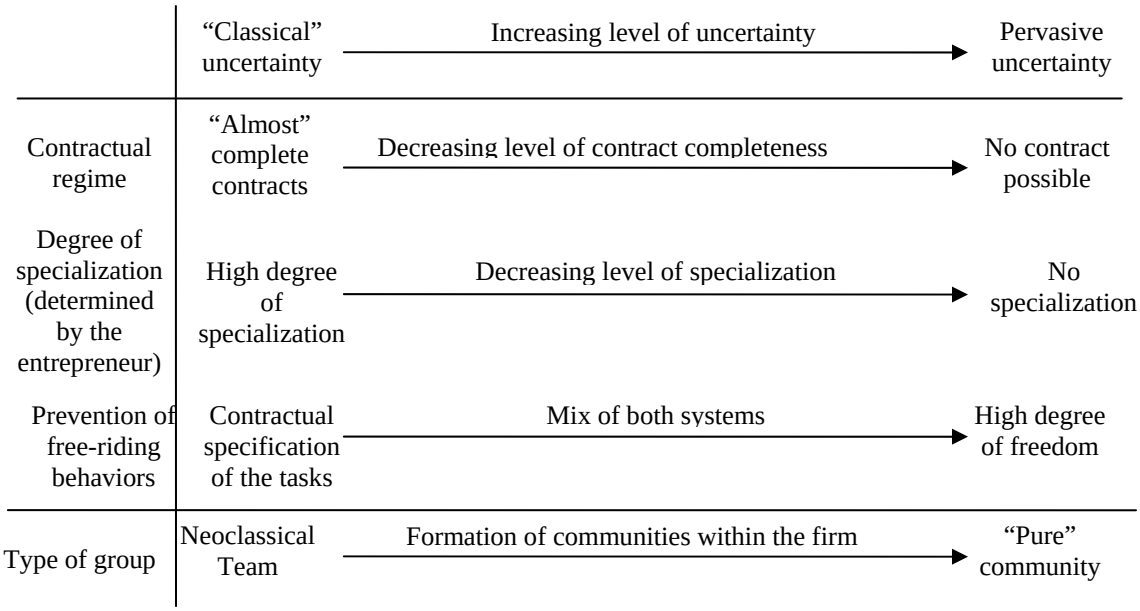

Table II-1 : summary of the features of teams and communities.

III. Implications of the team/community structure of cooperation.

The choice between a classical firm and a communitarian structure of cooperation entails numerous implications for the internal organization of the group as well as for the nature of the relationships between the possible entrepreneur[6] and the group members and among group members. Three types of consequences are stressed in this section. These are dealing with 1) the incentives and property rights regimes (and, consequently, with the status and function of the entrepreneur), 2) the repartition of knowledge and the evolution of

[6] This section considers the case in which an entrepreneur exists and is at the root of the cooperation structure. The case, previously exposed, in which a community may form without the explicit help of an entrepreneur isn't considered here. We should however point out the fact that our discussion may easily transpose to this particular case in which an established institutional setting comes in support of the community.

knowledge specialization and 3) the nature and the deepness of the relationship among members.

III.1. Incentives, property rights regime and the status of the entrepreneur.

The regime of property rights is, to a large extent, determined by the nature of the relationship binding the individual to the entrepreneur. Whereas relationships within teams are mainly of a contractual nature, communities are characterized by the absence of any contractual scheme.

In the frame of teams, the relationship between the entrepreneur and other members is characterized by the existence of an explicit work contract. This type of contract corresponds to an exchange of property rights: the employee accepts to provide his personal resources in exchange of a compensation provided by the employer (which very often takes a monetary form) (Simon, 1951). More precisely, the employee accepts to put his personal resources under the authority of the employer, the latter enjoying the ability to prescribe the set of tasks to be performed as well as the ways to achieve those tasks (under the limits set by the laws). Employment contracts are characterized by their incompleteness that is motivated by the inability of both contractual parties to foresee all the contingences which may emerge during the relationship. Those contracts prescribe the set of objectives to be achieved, a general description of the ways to reach them, the criteria allowing to decide the actions to be undertook in the case of unexpected contingencies and the general dispositions to apply in order to solve possible conflicts (Milgrom and Roberts, 1992).

In order to fulfil his task in a satisfactory way, the entrepreneur enjoys the right of residual control over the inputs of the team. Residual control consists in the right to take decisions concerning the use of any inputs in the limits set by the legal system or assigned to another by contract (Milgrom and Roberts, 1992). Residual control provides the monitor the right to hire and fire employees (in the limits set by the law and the employment contract), to set the quantities to be produced, the prices and the firm’s strategy.

Apart from the rights of residual control, the entrepreneur enjoys several other rights (Alchian and Demsetz, 1972): 1) the right to observe and control the behavior of the team members; 2) the right to be the party common to all contracts of the joint inputs; 3) the right to renegotiate any input's contract independently of contracts with other inputs owners; 4) the right to sell his central contractual status and the rights associated with it. In brief, the concentration of material property rights over the productive resources achieved by the entrepreneur constitutes the basis of his decisional function and of his ability to enforce those decisions through the appropriate incentive regimes. Moreover, due to his central position within the contractual network, the entrepreneur constitutes each employee's most important (if not only) link with the organization. This, by being the principal conveyor of information to organization members, further enhances his ability to control the individual's behavior.

The regime of appropriation prevailing in communities is quite different from that in teams. One of the keys to the communities' development rests on the members' ability to voluntarily disclose the knowledge they hold. This is why communities are commonly viewed as grounded on a logic of gift and counter-gift (see Raymond, 1999). However, such view encounters several limitations. First, a basic condition underlying the sustainability of any community corresponds to the fact that its members share a common set of objectives. This translates into the existence of an area of mutual acceptance which is common to the community and members have a direct, personal interest in contributing to the advance of the common enterprise. This constitutes an intrinsic motivation and translates, for instance, into a satisfaction arising from the resolution of a puzzle (Stephan, 1996). Second, as exemplified in scientific communities, the regime of priority in discovery plays a central role in the cognitive advance of the community (Merton, 1957). This constitutes an (extrinsic) incentive device conferring the intellectual property right of the discovery to the first discover.

The efficiency of such a reward system is made possible by the very particular status of knowledge: due to its public feature, it can spread and be reproduced very easily and at low costs within the community ; due to its immateriality it is not depleted when shared with other members of the community (Stephan, 1996). The intellectual property rights over the communitarian resources are therefore distributed and shared among community members.

An other consequence of this regime of priority is that it allows producers of knowledge to acquire the status of community leaders. The accumulation of knowledge

exchanges tend to shape individual cognitive structures (see Homans, 1950). This, *in fine*, contributes to shape behaviors. In this perspective, community leaders, by enjoying a certain (although limited) influence on members' behaviors, are likely to affect the direction and the extent of the community's cognitive advance (see Muller, 2004a and previous discussions on this issue). As such, and under the assumption that they honour their status, they become leaders and affect the cognitive advance of the community.

This power over the community is particularly striking in open source software development. For instance, Linus Torvalds, due to his specific status in the Linux community, has the final word over the project, having the ability to reject or to accept any contribution (Bezroukov, 1999). However, contrary to the case of the classical firm in which the entrepreneur constitutes the individual's only "social" link to the organization, community members enjoy the ability to bind relationships with other members. This ends up in limiting the influence of the entrepreneur on individuals' behaviors: he only has the power to propose new directions for the community's cognitive advance without being able to impose them.

Summing up, in the frame of a classical firm, the entrepreneur, who concentrates most of the property rights over the firm's resources, exercises his monitoring task through the implementation of explicit incentives devices. By contrast, communities are characterized by the fact that members enjoy intellectual rights over their own production. The influence of the possible community entrepreneur is, in this case, more limited in his scope (Minkler, 1993b). He functions more as a leader who has the power to propose new directions for the community's cognitive advance without being able to impose them (Witt, 1998).

III.2. The evolution of knowledge specialization.

A second issue of interest is dealing with the evolution of knowledge specialization as an outcome of the nature of the agreement binding each individual with the cooperation structure. The evolution of the repartition of knowledge within the structure is, to a large

extent, determined by the existence of a contractual scheme and, more importantly, by the type of contract involved.

The classical firm is characterized by the fact that contracts binding the entrepreneur with other members of the firm reach a high degree of completeness. This implies several remarks. First, it assumes that the entrepreneur has full knowledge of the task assigned to each employee. This state gives him the ability to forecast most of *ex-post* contingencies and to elaborate the most appropriate response to those contingencies. The problem faced by the entrepreneur is therefore that of informational asymmetries: The agent may possess some private information that the principal (i.e. the entrepreneur) doesn't necessarily possess and the task of the latter consists in inducing the most profitable behavior by the former through the appropriate incentive regime. Second, due to the high degree of contractual completeness, the entrepreneur enjoys the ability to operate a high degree of tasks division (in the limits set by coordination costs, see Stigler (1951) on this point). An optimal division of labour corresponds to the classical example of Adam Smith's pin factory: each employee is assigned tasks in such a way that they overlap as little as possible in order to reduce the monitoring and coordination costs.

The consequences of those remarks are twofold. First, due to the high degree of contract completeness, each employee is, from the start, highly specialized both in his task and his knowledge. The ability for further knowledge specialization is therefore very limited. Second, in a dynamic perspective, the design of the production process requires the lowest possible degree of tasks overlap in order to minimize the monitoring costs. In this perspective, at the production level, the knowledge flows are reduced to the strict minimum.

It follows that the classical firm is characterized by 1) the possession of full knowledge of the production process by the entrepreneur. 2) employees are, from the beginning, attributed highly specialized tasks. They are therefore characterized by highly specialized knowledge. Moreover, due to the minimization of tasks overlaps, the knowledge held by employees is highly fragmented. In this case, there is a (almost) perfect matching between the division of labour and the division of knowledge.

As the level of uncertainty increases, knowledge becomes more dispersed and, similarly, contracts become less complete since the entrepreneur doesn't possess all the

necessary knowledge for the project. The motivations underlying recruitment behaviors therefore switch from the realization of economies of scale to reduction of uncertainty by an accumulation of complementary skills and knowledge. Moreover, increasing degrees of contract incompleteness (or, even the absence of any contractual scheme) set a wide range of acceptable behaviors on the side of the agent. This high degree of freedom is exploited by the individual in the following way: as a rational individual, he orders all the mutually acceptable behaviors according to his own preferences. He then selects and adopts the most satisfying ones from his own point of view. It comes out that the set of behaviors he has adopted restricts to a small subset of the area of mutual acceptance. Having chosen this small subset, the individual enters into learning processes, giving rise to higher degrees of specialization and, therefore, of knowledge dispersion.

However, rises in knowledge dispersion contribute to increases in (Becker, 2003a):

⇒ **Difficulties in knowledge transfer**. The pattern of knowledge dispersion within the cooperation structure has an impact on the ease, or difficulty, with which knowledge can be transferred from one agent to another within it. Indeed, in groups made up of generalists, group members are more likely to share conceptualizations of one another's expertise. Conversely, when group members have non-overlapping information and knowledge, group members have difficulty discussing or sharing that knowledge.

⇒ **Coordination costs**. Coordination requires information about the elements to be coordinated as well as about their interdependencies. It is achieved through the gathering and the processing of information. But the costs linked to those tasks increase with the dispersion of knowledge. To be efficient, information acquisition (necessary for the efficiency of the individual or the unit) needs a high degree of specialization. At the same time, high degrees of specialization lead to higher costs in collating and making sense of information coming from highly specialized units at the organizational level, thus contributing to increases in coordination costs (Stigler, 1951).

A prerequisite for the exploitation of specialization is the setting of a common knowledge base among individuals. At this point, the building up of common knowledge is

particularly important since it contributes to build up a common cognitive frame among the individuals. The sharing of such common cognitive frames prove to be of great importance since they ease coordination among members of the structure. Furthermore, they contribute to build the individuals' identities as members of the structure. Finally, they contribute to state the overall objectives as well as the knowledge already held at the organizational level. The conjunction of those three aspects contributes in turn to 1) enhance the efficiency of any further specialization process (as conducted by the individual) by mitigating redundancies among individual specialization and 2) to raise a sense of common identity (Anderson, 1996), thus increasing the agents' commitment to the group.

The creation of a common knowledge base could be achieved through two highly related processes: knowledge integration and interaction (Becker, 2003a). Knowledge integration corresponds to the action of linking and combining pieces of dispersed knowledge in order to create a coherent structure (Becker, 2003a). Knowledge integration could be operated at several levels. At the organizational level, the integration of pieces of dispersed knowledge might be operated either in a centralized way, under the influence of a knowledge leader (who influences the direction of knowledge integration by providing a coherent vision of it) (Witt, 1998, Foss, 2001) or in a decentralized way, through the multiplication of linkages among the holders of knowledge parcels (Hansen, 1999). At the individual level, bodies of distinct knowledge may be integrated by a specialist (Becker, 2003a). Such actions, which correspond to the building of bridges among parcels of distinct knowledge, may translate into the building up of new, interdisciplinary, bodies of knowledge and competences (Gibbons, *et al.*, 1994). Finally, knowledge integration may occur at the level of artefacts[7].

Interaction constitutes an other vehicle of the building of a common knowledge base. It does so by reducing the cognitive distance among agents (see e.g. Axelrod, 1997b, Weisbuch et al., 2002). Cohendet and Diani (2003) point out a bidimensional decomposition of interactions according to their frequency and their richness. The frequency of interactions stimulates the exchange of information and knowledge, thus constituting a condition for the building of a common knowledge base. But the frequency of interactions doesn't constitute a sufficient condition for the building of common knowledge. At this point, the richness of the

[7] The ability of artefacts to facilitate knowledge integration comes from their three defining properties : they represent knowledge, they represent a reference for a group of people endowed with differentiated knowledge and, serving as reference points, they enhance communication and coordination among the members of the groups (Becker, 2003).

interactions corresponds to the cognitive efforts to disclose in the most comprehensive way information and knowledge as well as to the effort to interpret and make sense of them. At this stage, the creation and the activation of routines (defined as recurrent patterns of interaction) and of common codes and language prove to be critical in contributing to the richness of the communication by allowing to save on communication costs and to enhance its efficiency (Cohendet and Diani, 2003).

In situations characterized by high levels of uncertainty, the degree of specialization imposed to the agent while joining the structure (firm or community) is much lower than in the case of the classical firm. Within the area of mutually acceptable behaviors (as defined during the joining phase), the agent enjoys a certain degree of freedom of choice of his most satisfying behavior. This gives rise to a process of further specialization which is led, this time, in a decentralized manner. But, to be viable, such a process must be accompanied by the building of a common knowledge base incorporating the basic knowledge common to the whole group as well as its basic objectives and which is perpetually fed by the further processes of knowledge integration and by further interactions. In this manner, one can observe an imperfect matching between the division of labour and the division of knowledge.

III.3. The nature of the relationships between the individual and the cooperation structure (team/community).

In this section, the nature and the strength of the relationship binding each individual to the rest of the cooperation structure (team or community) is under focus. In studying its nature, one may decompose two kinds of relationships: the relationship between the individual and the structure and the relationship between the individual and his peers. The distinction is of importance since it induces two distinct effects which have been often separately discussed in the literature: loyalty and trust.

Loyalty has commonly be advanced as a justification to the observation that organization members commonly do not adopt free riding behaviors (Simon, 1991b). Organizational loyalty refers to the ability of an organization to rise the support of its

members to the overall objectives. An important determinant to the adhesion to the common objectives of the group comes from the identification of the members to those objectives. In this manner, the theoretical framework, as set forth in the model of group dynamics described earlier in this chapter, proves to be of particular relevance to the argument. Obviously, the identification of the members to the overall objectives corresponds to the perception of the formers that it is in their own interest to contribute to the pursuit of the goals set at the group level. This, in our model, translates in the fact that the most satisfying behavior, from the individual point of view, is close enough (or even belongs) to the set of mutually acceptable behaviors.

Furthermore, according to the model, there is a positive relationship between the degree of specialization, as established at the joining stage, and the ability for the structure to trigger the identification to its objectives. Indeed, high degrees of induced specialization, by leading to a reduction in the number of acceptable behaviors, contribute to reduce the likelihood of a matching between the individual objectives and the organization's area of acceptance. This, in turn, decreases the likelihood of raising a voluntary adhesion to organizational objectives. It is consistent with the observation of Leibenstein (1987) of the relationship between the induced degree of specialization and the fragmentation of the members' motivation. Since the contracts concluded in the frame of classical firms are characterized by rather high degrees of completeness, the degree of specialization (as set at the joining phase) is relatively high and the degree of adhesion to the common goals might be low. At the other extreme, as communities are characterized by the absence of any contractual scheme, their survival is largely determined by the voluntary adhesion of their members to the common objectives, thus making loyalty a basic condition for their pursue.

Apart from directing the loyalty of the individual to the cooperation structure, the existence and the degree of contract completeness influences the nature and the evolution of trust relationships between members of the structure. It has traditionally been operated a distinction between calculative trust and cognition based trust.

Historically, calculative trust has been first introduced in the economic analysis. As pointed out by Gambetta (1988, p. 217), it refers to "a particular level of the subjective probability with which an agent assesses that another agent or group of agents will perform a particular action, both *before* he can monitor such action (or independently of his capacity

ever to be able to monitor it) *and* in a context in which it affects *his own* action". In this case, trust refers to an individual's ability to rely on his partner because the former believe that it is not in the interest of the latter to misbehave and to adopt an opportunistic behavior. This kind of trust is closely related to the ability of the involved parties to bind contractual relationships (cf. Gambetta, 1988, Brousseau, 2000a). More precisely, as pointed out by Brousseau (2000b), incomplete contract and calculative trust are both highly complementary: a contract, by describing the most salient features of a relationship, delimits the set of mutually acceptable behaviors as well as the possible sanctions in the case of any contravention. Conversely, trust, by corresponding to an expectation in the partner's behavior, allows to save on contracting costs. In this way, calculative trust correspond to the adoption of a strategic behavior for which individuals expose themselves in the limits set by the degree of uncertainty characterizing the relationship and by their degree of risk aversion. However, since calculative trust relies on the ability to write contract, its efficiency may decline as the level of uncertainty increases.

High degrees of uncertainty require a more cognitive oriented form of trust grounded on the acquisition of knowledge about a partner's behavior. Generally, cognitive trust is a type of trust grounded on rational motivations (Lewis and Weigert, 1985). It refers both to a judgement of competence (based upon verifying the quality of the behavior) and of reliability about the partner (referring to the congruence between words and actions) (Rocco et al., 2001). Cognitive trust refers to the belief that 1) the partner holds competences which may benefit to the individual 2) since the relationship is perceived by both partners as mutually beneficial, the partner is inclined to act benevolently and not to betray the relationship. Cognitive trust is supported by a partial knowledge of the partner's behavior, between total knowledge and total ignorance. In this perspective, one of the determinants of trust lies in the existence of commonalities among partners in such a way that cognitive trust is in fact grounded on the existence of common knowledge and common values (McAllister, 1995). In circumstances characterized by strong uncertainty, the necessary existence of commonalities supposes the necessity to build a knowledge base common to all cooperating individuals: it not only contributes to increases in the efficiency of further specialization but it contributes to the building up of trust relationships among individuals too.

Summing up, the nature of the relationship (contractual or not) between the entrepreneur and the group is of paramount importance. In the frame of a classical firm, the

consequences of a contractual type of relationship are of 3 orders: 1) the entrepreneur, who concentrates most of the property rights over the firm's resources, exercises his monitoring task through the implementation of explicit incentives devices. 2) contracts (especially contract characterized by a high degree of completeness), by detailing the objectives and the appropriate ways to reach them, tend to limit the capacity of the individual to engage into further specialization. 3) The relationship between the individual and the organization is characterized by a low level of loyalty and by the adoption of strategic behaviors. Conversely, in the frame of communities, 1) the influence of the entrepreneur is limited in its extent. He is not able to hold any monitoring task and he has the ability to propose new directions for the community's cognitive advance but not to impose them. 2) the degree of specialization imposed to the agent while joining the community is much lower than in the case of the classical firm. He therefore enjoys the ability to operate further specialization. However, to be efficient, this specialization has to rely on the existence of a knowledge base common to all members of the community. 3) a central condition of the persistence of communities lies in the loyalty expressed by their members and the existence of relationships characterized by high degrees of trustworthiness among them.

Conclusion.

The starting point of this chapter was the observation that, although being the subject of an increasing stream of literature, some aspects of the concept of community of practice still remained rather unexplored. More precisely, the unexplored aspect that is under focus in this chapter is dealing with the emergence of communities. Some contributions tried to stress this problem and to propose a model of morphogenesis (e.g. Dupouët, 2003) but those attempts were rather limited in their scope since the model they developed assumed that communities

formed within firms. Thus, a high number of communities were totally dismissed from the analysis.

The central question underlying this chapter is about the conditions under which communities of practice emerge. More precisely, the objective of this chapter is to propose a model aiming at explaining the emergence of communities of practice within an institutional environment (a firm or an association) as well as in the absence of any existing framework (as in the case of numerous open source communities).

The starting point of the model necessitates the existence of an individual wanting to fulfil a cognitive project (and who is designated under the term “entrepreneur”). This project may be dealing, for instance, with the publication of a particular software. The model decomposes into two step. The first step is related to the degree of uncertainty the entrepreneur is facing. In this manner, whereas low levels of uncertainty enable the entrepreneur to ground a firm (in the neoclassical sense) by allowing him to write (almost) complete contracts, higher degrees of uncertainty imply the writing of incomplete contracts. From one point, a comparison between the costs (incurred by the time spent in writing contracts and the limitations due to their increasing incompleteness) and the benefits of contracting leads the entrepreneur to ground a community.

The second step of the model is related to the degree of matching between the project’s objectives, as set by the entrepreneur, and the individuals’ objectives. The existence of contractual relationships enables the entrepreneur to set explicit incentive mechanisms influencing the performance of the firm. The survival and the development of communities rests on the relatively high degree of matching between the projects requirements and the individuals’ objectives.

This exploratory model sets aside numerous important issues for the comprehension of the emergence of communities or firms. Among these, it is assumed that the entrepreneur only reacts to the degree of uncertainty he is facing. Hence, several motivations for the choice between firms and a communities are ignored. First, the entrepreneur’s behavior can be driven by ideological motivations which influence his choice towards grounding a community or a firm. For instance, Richard Stallman grounded the Free Software Foundation in reaction to the appropriation of the UNIX operating system source code by AT&T.

A second motivation influencing the entrepreneur refers to the wish to market or not the outcome of the project. In this manner, although being both operating systems, Microsoft Windows and Linux are grounded on two different philosophies. For instance, Windows is grounded on a proprietary architecture, allowing thus Microsoft to sell the product on the market. At the opposite, Linux is based on the open source philosophy, consisting in disclosing the source code associated with the application. In this manner, Linux is downloadable on the Internet and the source code, by being open, allows to customize the system.

Chapter III. The Use of Numerical Simulation for the Comprehension of Social Systems.

Introduction.

The use of computer simulation as a modelling methodology is subject to a growing interest from scientists in the fields of social sciences. For instance, a search in the Econlit database (accessed from EBSCO - September the 22nd 2004) using the word "simulation" as a title word gave the following results[1]:

[1] Those statistics might be biaised by the inclusion of articles using statistical techniques. Moreover, it only accounts for a small portion of the number of articles actually using simulation. Given those limitation in the statistics, the drastic evolution they exhibit might nevertheless provides a good picture of the growing interest in computer simulation as a modelling methodology.

Period	01/1980 to 12/1984	01/1985 to 12/1989	01/1990 to 12/1994	01/1995 to 12/1999
Number of articles	150	318	353	464

Table III-1: evolution of the number of articles containing the word "simulation" in their title.

By referring to the drastic evolution in the values, one can easily deduce that an increasing number of scientists in economics sees computer simulation as a promising field of enquiry. However, as a young methodology, computer simulation still suffers from a lack of well established procedures and methods. This finding motivates the present chapter which aims at justifying the use of computer simulation as an adequate methodology for the modelling of social processes in general and of communities of practice in particular.

In fact, like numerous social systems, one of the main characteristics of communities of practice lies in the fact that they constitute complex system. As a matter of fact, it becomes rather difficult to model their evolution by resorting to traditional methodology. “Traditional” models of complex systems such as networks give commonly rise to a static analysis (cf. e.g. Jackson and Wolinsky, 1996, Jackson and Watts, 2002b) and are more concerned with the determination of basins of attraction than with the description of the actual dynamics of the system. In this respect, computer simulation constitutes a methodology that might be viewed as complementary to traditional modelling methods (like statistical inference or analytical models) by precisely focusing on the dynamics of a system.

However, as a young field of enquiry, computer simulation still suffers from methodological issues which are mainly related to a relative lack of a stabilized body of methods enabling to guaranty the robustness of the conclusions. Another aim of this chapter is precisely to provide the reader with a survey of the state of the art and to propose some clues to address the existing methodological issues related to computer simulation.

This chapter is organized as follows. Section I is devoted to a description of the concept of complex systems. Apart from their self-organizing capacity, those systems are characterized by a large number of distinct parts, by non trivial interactions among those parts and by the existence of non-linear trajectories among the components of the system. Section II assesses the issues dealing with the modelling of complex system and argues for the relative

advantage of computer simulation over other modelling methodologies in handling this type of systems. More precisely, it is argued that computer simulation, by dealing with heterogeneous agents and by explicitly introducing the notion of time to the model, constitutes a well suited methodology in dealing with complex social systems. Section III and IV are motivated by methodological issues dealing with simulation. Section III exposes some shortcomings of computer simulation and proposes some hints in order to solve them. Section IV provides a description of a particular class of simulation models: agent-based models. This approach, which is extensively used throughout this dissertation, constitutes a bottom-up approach putting the emphasis on the emergence of structures and of group behaviors as a result of the accumulation of decisions taken by individual agents.

I. Communities of practice as complex social systems.

As argued in Chapter I, self-organization constitutes a key feature of Communities of Practice. This property confers the community an adaptive ability to evolve and acquire new features by itself and beyond the explicit control of any established hierarchy or pre-determined goal (Lesourne, 1992). As Wenger (1998) puts it :

> "Students of self-organizing systems have noted the generative nature of the "edge of chaos" […]. The ability to include both structure and dynamism, to walk the line between chaos and order, is a characteristic that makes communities of practice a likely locus of creativity. In this sense, a community of practice has the characteristics of what organizational theorist Dee Hock (1995) calls a "chaordic" organization." (p.289).

Self-organization is the outcome of two combined effects : self-regulating processes tending to stabilize given structures and self-augmenting processes tending to destabilize structures and, thus to give rise to new structures (Witt, 1997). As an illustration, let's make the (unrealistic) assumption that a social system is at an equilibrium state (that is, the system has adopted some relational structure given the function it performs and the environmental landscape) and that changes are occurring in the environment. The variations in the environment's settings lead the system to fluctuate (in terms of performed function as well as in terms of internal structure) in order to reach an other stable state considering changes in the environment or, in other terms, to maximise the entropy of the system in regard to the new features of the system. However, in the case of biological, social and economic systems, considering the close relationship between the system and its environment, fluctuations of the former may have an effect on the latter, thus contributing to further fluctuations of the system which eventually lead to self augmenting phenomena.

More generally, communities of practice, as self-organized entities, constitute instances of complex social systems. A complex system might be broadly defined as made up of a large number of part that interact in a non-trivial way (Simon, 1962). Apart from their self-organizing property, complex systems are characterized by several distinctive traits, among which: a large number of distinct parts, non trivial interactions among the parts and the emergence of hierarchical levels, non-linear trajectories among the components of the system and symmetry breaking.

I.1. Large number of heterogeneous parts.

A basic feature of complex systems lies in the fact that they are formed by a large number of simple components which may differentiate from each other in their internal characteristics. According to Fontana and Buss (1996) (who drew the argument from Weaver (1948)), dealing with varying entities constitutes a radical shift in respect of the classical, newtonian approach to the study of dynamical systems.

The success of the Newtonian approach was due to the possibility of representing the phenomena of interest by means of few variable and a small number of relations among those variables. For instance, Newton's law of acceleration states that, the magnitude of the gravitational force on an object of mass *m* near the surface of the Earth is given by $F = mg$, where *g* is the acceleration of gravity near the surface of the Earth. To reach this result, it is notably assumed that the experiment is led with an object of an homogeneous structure, it doesn't undergo any qualitative changes in its internal structure and doesn't interact with its direct environment (e.g. the interaction between the object and the air or the ground doesn't give rise to frictions).

According to the complex system approach, those over-simplifying assumptions do not hold any more. It is assumed that the components of the system are heterogeneous and that their characteristics are likely to evolve notably in relationship to their environment. Communities of practice are heterogeneous systems since each member is characterized by his past experience and knowledge which are idiosyncratic by nature. They are therefore likely to adopt different learning behaviors and trajectories in such a way that, while facing two similar situations, they may behave differently. In this way, the overall behavior of a community may not be predicted by only relying on the observation of the behavior of some of its members.

I.2. Non-trivial interactions and the emergence of "hierarchical" levels

A distinctive trait of communities of practice lies in the fact that members enter into collective learning processes: they disclose and exchange knowledge with other members. Interactions among members of a community of practice therefore contribute to shifts in their internal characteristics (e.g. in their knowledge structure or behavior). But those shifts might be of different nature and extent according to the nature of the relationship between the members (for instance, the influence of one member on an other might be conditioned by his level of trustworthiness).

In the same line to Granovetter (1973) who operated a distinction between weak and strong ties, Simon (1962) drew an important distinction between strong and weak relationships. Roughly, this distinction allows to partition a complex system into a set of several subsystems which are interconnected to each other in a more or less complex way. Any subsystem is constituted of elements which are strongly bound together while the interactions between those subsystems are of a weaker intensity. For instance, a human body is made up of different organs (heart, liver, stomach, kidneys and muscles). Although they interact with each other (for instance, the lungs irrigate the blood in oxygen while a prominent function of the kidneys is to filter the blood from toxins and other microbes which might have not been filtered at the lung state), the distinction between those organs lies in the fact that the interaction between them is weak and indirect (mediated by the blood network) and that they perform different tasks (oxygen irrigation in the case of the lungs and filtering the blood in the case of the kidneys).

In parallel, each organ is made up of cells whose aims are similar (filtering toxins from the blood in the case of the kidneys) and interactions are strong among them. This distinction between subsystems gives rise to another effect related to the emergence of hierarchical levels[2] within the system. In fact, one can think of a subsystem which is, in turn, made up of several subsystems whose connections within them are stronger than between them. In fact, human cells are made up of a nucleus, a cell membrane and mitochondria. Similarly, the nucleus is made up of several chains of proteins (the chromosomes) which, in turn, are made up of numerous sequences of amino acids.

The literature on communities of practice offers numerous instances of such a distinction between strong and weak relationships and of the subsequent emergence of hierarchical levels. More specifically, in a study of the Freenet project, Von Krogh, Spaeth and Lakhani (2003) found evidence of strong specialization effects among community members, each member specializing in only a subset (a module) of the project (such as the the graphical interface, the management of the communication or the security protocols, etc…) and mainly interacting only with few other members while their relationships with members of the community were weaker. Furthermore, once engaged in a community, most of members tend to further specialization in a given function related to each module.

[2] Simon (1962) made clear the fact that the term hierarchy is, in those particular circumstances, not used in order to induce the idea of subordination relationships but to refer to complex systems analyzable into successive sets of interlinked subsystems.

I.3. Non-linear trajectories among components of the system.

This phenomenon occurs when the trajectory followed by one element of the system is not linearly related to the trajectories of other elements of the same system. Social systems are "open" by nature, in that many factors have a strong, and possibly decisive, influence on the behavior of the subsystems and, therefore, on the behavior of the overall system. Those factors might be of different nature: either internal to the system or external. Internal factors are due to the interdependencies among components of the system. The rules of interactions among subsystems might differ. Let's assume a simple system containing four components C_1, C_2, C_3, C_4, each component enjoying distinct behaviors. It is furthermore assumed that the law of connexions between those components is given in figure III-1.

	C_1	C_2	C_3	C_4
C_1	0	1	0	1
C_2	0	0	1	1
C_3	0	1	0	0
C_4	0	0	1	0

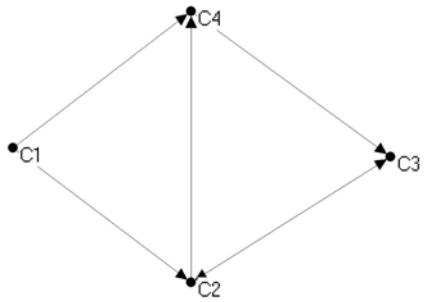

Figure III-1: Matrix and graph representations of a network.

Finally, it is assumed that those influence relationships affect the behavior of each component. In this way, C_1 influences the behavior of C_2, C_3 and C_4; C_2 influences the behavior of C_4; C_3 influences the behavior of C_2; C_3 influences the behavior of C_2. Comparing the behavior evolution of, for instance, C_1 and C_3, since C_1 undergoes no influence while C_3 undergoes the influence of C_2 and C_4, those components are likely to enjoy different behaviors. Out of this simple example, the pattern of interactions among the components of a system may lead them to adopt different trajectories. This, in turn, may affect the behavior of the whole system. One should however note that, in the long run, the accumulation of interactions among those components may end up in an homogenization of their internal

characteristics. For instance, the component C_4, by influencing C_3, also exerts an indirect influence on C_2 which, in turn, influences C_4. Moreover, both components are influenced by C_1. As a matter of fact, in the long run, the internal characteristics of C_2, C_3 and C_4 might converge to those of C_1 as a result of the accumulation of influence relationships.

An other factor inducing changes in the components' behaviors comes from the interaction of components of the complex system with its environment. It follows that the social system constitutes a dissipative system in the sense of Prigogine (see Prigogine, 1976, Prigogine and Stengers, 1992). In fact, since the work of Prigogine we know that the interactions between complex systems and their environment may lead the components of those systems to adopt different behaviors from each other.

As previously argued, members of a community of practice are not only endowed with knowledge and past experience, their personal knowledge constantly evolves notably as a result of collective learning processes. In this way, a distinction should be drawn between two types of learning. First learning might be internal to the community: members share and exchange their knowledge through, for instance war story (Brown and Duguid, 1991). The community behaves as a close system given the fact that the accumulation of internal collective learning leads to an homogenization of the knowledge held by the members.

Second, members, given their integration in a wider social context, may also learn from other individuals and they are able to provide the community with their new knowledge. This contributes to increase discrepancies in the knowledge held by community members. Communities of practice are therefore constantly subject to this tension between, on the one hand, the convergence in the knowledge held as result of the accumulation of internal collective learning and, on the other hand, the perpetual creation of novelty resulting from external learning.

I.4. Symmetry breaking and the introduction of time.

A main difference between “classical” systems and dissipative systems lies in the consideration of the interactions with their environment. Taking the example of the oscillating pendulum introduced by Prigogine and Stengers (1992), in the absence of any interactions with its environment (frictions with the air, etc…), the pendulum oscillates indefinitely with a period depending on the initial total energy (defined as the sum of potential and kinetic energy) transmitted to it. The movement of the pendulum is therefore mainly defined through its period of oscillation. The movement is fully reversible in the sense that, at each period it reaches the same position as in the preceding one: the next oscillations of the pendulum are identical to the present and the past ones. It follows that classical systems are characterized by the conservation of symmetry and the ability to periodically reproduce their current state. Hence, time is reversible in the sense that the starting point can be also correspond to its end point and vice versa.

At the opposite, introducing interactions with environment to the initial movement of the pendulum leads to different qualitative results. In fact, as an outcome of the interactions with its environment, the pendulum progressively dissipates the total energy transmitted to it at the start of the process. It follows that the movement of the pendulum is not periodical and symmetrical any more. The level of energy of the pendulum at time t is not the same as the level at time $t-1$ or at time $t+1$. It follows that dissipative complex systems are characterized by symmetry breaking for which the current state of the system cannot be exactly reproduced. Thus, time is irreversible.

II. Modelling consequences and the use of computer simulation.

As complex social systems, communities of practice are hard to deal with through the construction of analytically solvable models. Computer simulation seems to be much more suited to the modelling of communities of practice. This is due to several advantages of computer simulation over analytical models: the ability to account for differentiated agents and to explicitly introduce hierarchical levels and the ability to control and to monitor the dynamics and the evolution of the system. The aim of this section is to inspect some of the main characteristics enabling simulation models to sustain an advantage over analytical models.

II.1. Differentiated agents and the introduction of hierarchical levels.

The first concern identified in complex systems lies in accounting for individuals endowed with distinctive characteristics and the fact that those characteristics are likely to evolve over time. The use of computer simulation proves to be of particular relevance by solving problems belonging to the class of bottom-up approaches. This type of approaches is characterized by the fact that hypotheses are made on individuals' behaviors, motivations and interaction patterns. Then, is established and discussed a relationship between the evolution of their behavior at a microscopic level and the pattern adopted by the system at a macroscopic level (Epstein and Axtell, 1996). In this respect, it differs from top down approaches, for which microscopic behaviors are deduced from the observation of the macroscopic evolution of the system.

However, a problem may arise while adopting a bottom-up approach, namely that of choosing a programming language supporting the modelling of individuals characterized by distinct properties. Object oriented programming (OOP) precisely enables to take up this

challenge. Formally, the aim of object oriented programming is to model systems or real entities (which become objects in the program) with the goal of separating their internal structure from their external, visible interactions (Wegner, 2000). Another advantage of OOP languages lies in that they enable to gather those objects in wider categorizes, the classes[3]. It is precisely in that respect that OOP languages (like C++, Java, SmallTalk or Simula) differ from other types of languages such as procedure oriented programming languages (like Algol, Basic or Pascal): OOP languages enable the programmer to define the prototype of an object and to define all of his desired features during the definition of the class. Starting from this prototype, the program automatically builds as much instances of this object as desired by the programmer.

OOP languages, due to the ability to embed objects in sub-classes and in classes (the data structure) mimic human classification systems (see figure III-2 for a comparison between OOP languages and an equivalent in real systems).

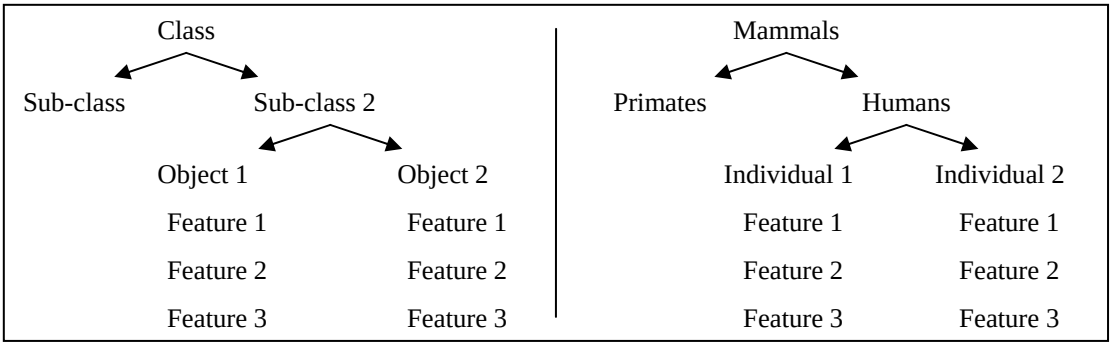

Figure III-2: comparison between the data structure in an OOP language and the human classification system.

We previously described complex systems as 1) dissipative systems made up of 2) multiple distinct components, 3) interacting with each other in a non-trivial way. In the light of our preceding description of OOP languages, it becomes clear that this type of languages is well suited for the modelling and the simulation of the evolution of complex system. Indeed, the modelling of the interactions between different complex systems might be done in the following way: a primary class defines the environment in which the systems evolve and interact. Those systems (i.e. communities) may, in turn, be defined as classes containing several objects (i.e. the members). Those classes define the features of the objects as well as their pattern of interactions (see figure III-3).

[3] Moreover, OOP languages allow the interlocking of classes in wider classes through a process of inheritance.

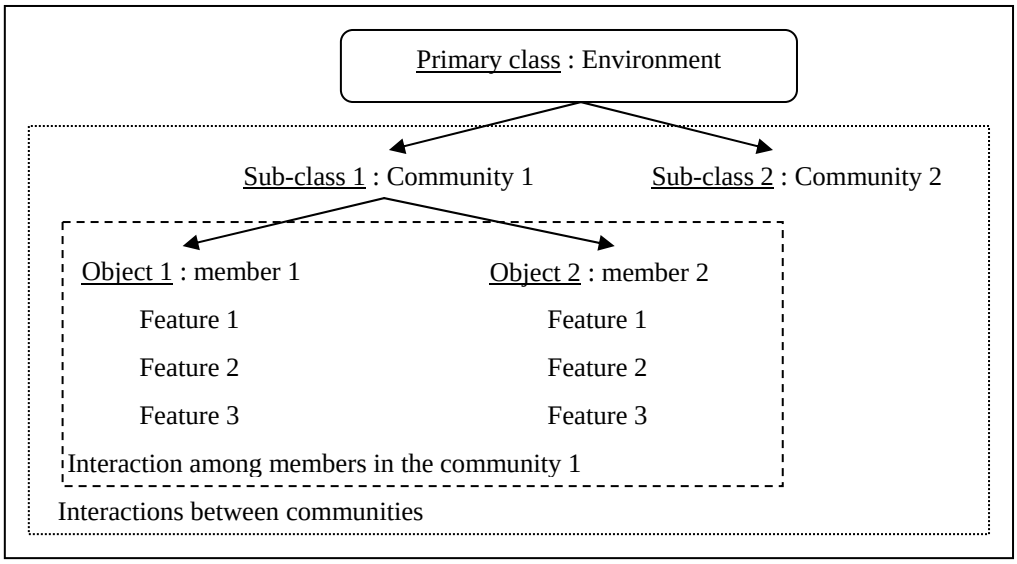

Figure III-3: example of the data structure used to model the interaction between communities of practice.

II.2. Dynamical aspects: the introduction of time in the model.

A primary aim of computer simulation lies in the study of the evolution of a model in "time" (Coquillard and Hill, 1997). More precisely, the aim of any computer simulation is to observe the evolution of the abstraction (or, similarly, the model) representing the complex system, to watch the progress of the internal behavior of its components and of the relationships among them.

The evolution of the system results from the implementation of an appropriate algorithm aiming at producing end results from the starting conditions specified in the data structure through the succession of simple actions specified by the programmer. Formally, an algorithm is characterized by four properties (Korfhage, 2000):

1. The application of the algorithm to a particular input set results in a finite sequence of actions.

2. The sequence of actions has a unique initial action.

3. Each action in the sequence has an unique successor, meaning that each action specified in the algorithm directly induces one and only one action.

4. the sequence terminates with the production of end results.

Properties 2 and 3 account for the sequential architecture of an algorithm, ensuring that no more than one action is undertaken in the same time. This comes in opposition to a parallel architecture in which two or more actions might be undertaken in the same time. The algorithm accounting for the evolution of a model always has to adopt a sequential architecture. The reason for this is that one of the main threats associated with a parallel architecture comes from the possibility that actions undertaken in one thread of actions might interact with another thread of actions, thus blurring the results of the simulation.

Often, computer simulation relies on the multiplication of iterations of the algorithm. The determination of the appropriate number of needed iterations is directed by two motivations. First the results obtained after the last iteration must correspond to the expectation of the modeller. Those expectations are shaped by several factors such as results obtained in previous works or with empirical observations (e.g. stylized facts) or, if both are absent, by the commonsense of the modeller. Second, during the last iterations, the results have to display a stable pattern of evolution with smooth changes (or, even, no changes) in the end results.

By determining the dynamics of the system, the algorithm contributes to shape the representation of time. Thus, a distinction is often drawn between different representations of time (Amblard (2003), Amblard and Dumoulin, (2004)):

⇒ **Discrete time**. The variable representing time is an integer and the evolution of time is represented as a “stair-shaped” function. Most often, the algorithm is iterated several times and the value taken by the time variable corresponds to the number of time thes algorithm has been iterated. For instance, the time variable takes a value of five when the algorithm has been iterated five times. Taking the analogy with a human life, this type of representation of time would correspond to count it in years. For instance, a human life would correspond to eighty iterations corresponding to eighty years.

⇒ **Continuous time**. In this case, the variable representing time is a real number. A relationship exists between the value of time and the state of the system. Instances of a continuous representation of time are found in models of plant growth. In this case, the relationship between the representation of time and the algorithm might be of different types. Either the algorithm (which might be iterated several times or not) embeds the evolution of the time variable. Or, starting from a discrete time approach, continuous time can be approximated by the implementation of the algorithm over a very long timespan (several hundred thousand or millions iterations). In reality, this representation would correspond to a representation of a human life in seconds. A human life would therefore last $2{,}5.10^9$ iterations.

⇒ **Discrete event approach**. The focus is put on the occurrence and the succession of events rather on a direct, explicit account of time. This approach is used, for instance when an element of the model or the model itself undergoes a qualitative change (exogenous or endogenous to the model) in its structure or in its characteristics. This type of approach is to be found in simulations of chain production processes in which the event corresponds to an "accident" in the production process (e.g. a product doesn't correspond to some quality requirements, …). In reality, this representation would correspond to a representation of human life in terms of historical events such as the end of studies, wedding, the birth of children or the first moon landing.

Computer simulation constitutes a powerful tool enabling to account for models characterized by high degrees of complexity both in their assumptions and in their dynamics. This higher degree of complexity allows, in turn, to increase the degree of realism of the model. However, as every modelling methodologies, computer simulation faces some limitations which may hinder its applicability. The purpose of the following section is to describe the major shortcomings of computer simulation as a modelling methodology and proposes some ways to reduce their effects.

III. Some limitations of computer simulation as a modelling methodology.

Although simulation arouses an increasing interest in many scientific fields such as physics, biology and social sciences, it is still confined as a "second-hand" methodological tool and is often used when traditional methodologies (e.g. analytical modelling, statistical inference) are not relevant. The purpose of this section is to shed light on some of the reasons underlying the reluctance of researcher to use computer simulation by pointing out some of its shortcomings as a modelling methodology. Those methodological limits are of different orders. Axelrod (1997a) identified several weaknesses which can be ordered in two categories: weaknesses linked to programming and weaknesses related to the results of simulations. The aim of this section is twofold. First, following Axelrod's typology, it aims at describing programming issues and issues related to the results. Second, it proposes some clues to circumvent them.

III.1. Programming issues.

The programming of a simulation model implies two main issues : validity and usability (Axelrod, 1997a).

The issue of validity lies in the fact that the program has to correctly implement the model (Axelrod, 1997a, p. 28). Simulation programming can be summarized as a two step process. In a first step, the modeller tries to build a model of the phenomenon under focus. By doing so, he tries to identify 1) the main entities composing a model (for instance, firms) and their environment (firms belong to a networked industry); 2) the behaviors of those entities (firms disclose knowledge in order to signal their competencies and they try to bind joint ventures (see Muller and Pénin, 2004). In a second step, the modeller translates this model in a computer program. This last step corresponds to the programming task *per se*.

In fact, both steps entail some limitations. The validation of the first step might be threatened by an inaccurate identification of the basic logic underlying the phenomenon under study. This type of danger is common to all modelling methodologies and can be mitigated by a careful comparison between the internal logic of the model and the existing theoretical literature as well as the individual's common sense.

As any translation from one language (the human language) to another (the programming language), the second step of the programming process is under the threat of misinterpretation. As in any language, translation errors may lead to actual outcomes which sensibly differ from the expected ones. This translation problem is of paramount importance since it gives rise, by nature, to an ambiguous interpretation from the modeller. In this situation, he is confronted to a double alternative. First, the problem may arise out of a programming error. This type of error is quite common although rather hard to detect and to solve. It may be the consequence of the wrong attribution of a function to a certain variable or, more simply, to an error in the writing of the code (e.g. writing a + instead of a -). The second possibility corresponds to a problem in the internal logic of the model. This type of error forces the modeller to return to the first step of the programming sequence and to re-specify the model.

Various simple verification procedures allow to eradicate or, at least, to reduce the consequences of the validity problem of a program (Bratley, Fox and Schrage 1983):

⇒ **Manual verification of logic** : this procedure consists in running the model for a short timespan and in comparing the results with the expected outcomes of the simulation.

⇒ **Check against known solutions** : this procedure is only to be applied if the simulation is close to other models. It consists in comparing the outcomes of the simulations for the same sets of parameters.

⇒ **Sensitivity testing** : this procedure tests the robustness of the model to variations in the parameter values. It consists in varying the values of parameters while keeping the other fixed and to check that the behavior of the model is sensible.

⇒ **Stress testing** : this procedure consists in setting the parameters of the model to strange values and check if the model "blows up" in an understandable manner.

Each of those procedures allows to acquire knowledge of the dynamics of the system and to better understand its internal functioning. Thus, a combination of all the verification procedures allows to effectively remove bugs arising out of logic and programming errors.

According to Axelrod (1997a), the aim of usability is to allow the researcher having programmed the simulation and his followers to run the program, to interpret its output and to understand how the simulation works. Related to this issue is the question of the ability to extend existing simulation models by adding new features or processes. The usability issue is central for the generalization of computer simulation as a methodological tool in its own right. One of the main reasons of the relative confidentiality of computer simulation lies in the fact that it seems, at first sight, rather complex in its use because of the absence of a common analytical framework and of common analytical tools. This problem is also deepened by the fact that computer simulation is often viewed as requiring computing skills.

The problem raised by the issue of usability is reduced by the multiplication of simulation platforms such as LSD[4] (see Valente, 2000) or Swarm[5] which are completed by the ability to perform basic simulation by using software such as Excel®, Maple® or Mathematica®. The aim of simulation platforms is to facilitate the access of social scientists to the simulation methodology by providing them with a simulation environment including the basic building blocks of the simulation model by reducing the workload of the modeller and the basic requirements in terms of programming skills. For instance, they may help the modeller to define the data structure of the model and provide him with the most common macro-commands[6]. The existence of pre-programmed macro-commands contributes to reduce the number of programming lines necessary for the simulation. This contributes to clarify the programming code by reducing it to a stream of equations. As a matter of fact, it contributes

[4] LSD can be downloaded at http://www.business.aau.dk/~mv/Lsd/lsd.html
[5] http://wiki.swarm.org
[6] For instance, LSD allows the researcher to define the data structure by a succession of visual menus and feature some common evolutionary models such as NK models or a replication of the Nelson and Winter model of industrial dynamics (Nelson and Winter, 1982).

to increase its comprehensibility for other social scientists and allows them to operate changes or refinements on the model.

III.2. Issues related to the results.

One advantage of simulation over other methods such as statistical analysis or experimental studies lies in the fact that it generates its own data. Hence, there is normally no problem of missing data or of uncontrolled variables. However, in the same time, it generates several issues related to the results generated. Those concerns are of three orders and are dealing with results analysis, results sharing and results replication (Axelrod, 1997a).

A major issue in the analysis of the results lies in the adopted point of view. In fact, the output of a model might correspond to different levels of aggregation. A first approach consists in adopting an aggregate level: some statistics might be computed over the whole population in order to obtain an average behavior. However, this type of level doesn't account for the variety of individual behaviors which might occur at the micro-level. A second approach consists in adopting a micro-level. The aim of this approach is to shed some light on the evolution of some representative agents of the model. Those agent may be viewed as "representative" in the sense that they gather some of the most common characteristics of the simulation. If agents are ordered in several categories, the statistics would be exhibiting the evolution of a sample of agents of each category. Although avoiding the shortcomings raised by the aggregate level approach, the micro-level approach might be exposed to other types of pitfalls. The agent considered as "representative" might actually adopt a different behavior in comparison to the ones adopted by other members of its category. This raises some issues in terms of the significance of the results obtained at that level. The flaws in both aggregate and micro-level approaches lead us to advocate the adoption of a meso-level approach. More precisely, this approach adopts an intermediary posture by computing statistics for each categories of agents. This approach appears to be the most appropriate since it allows, in the same time, to obtain statistical results which are robust to individual variations and to account for the variety of behaviors characterizing the model.

Apart from the issues raised by the choice of the level of analysis, the introduction of random elements to the model might also be a factor impeding result analysis. Hence, the analysis of results coming from a single simulation might be misleading. It becomes then necessary to do several simulation runs using identical parameters in order to obtain robust conclusions. Still, despite the caveats related to the statistical analysis and the significance of its outcomes, an appreciable advantage of social simulation over other types of methodologies (such as case studies) lies in the fact that the researcher can re-run the simulation model for different parameter values and monitor the impact of each parameter on the model. Those multiple runs may be compared as a counterfactual statement methodology (see Cowan and Foray (2002) for further developments on this point). Indeed, the researcher enjoys the possibility to rerun the model to see whether particular patterns observed for a single parameter set are typical or idiosyncratic.

Another type of problem is related to the sharing of results by other researchers. A primary method of sharing the research output is through peer reviewed publications and conference presentations. In the case of social science simulation, there are several shortcomings linked to this mode of sharing. In most cases, conference presentations are limited in time (generally between 15 to 20 minutes) and journal editors often restrict the number of words (around 7 500 words) for a publication in peer-reviewed journals. The problem lies in the fact that social simulation are hard to present briefly. There are two reasons for this (Axelrod, 1997a). First, simulation results are sensitive to the details of the model: as shown in the case of time management, a seemingly insignificant detail such as the activation of agents (synchronous or asynchronous) may generate significant differences in the results (*cf.* Section IV of this chapter). This possibility sometimes motivates authors to publish the simulation source code (or, at least, the pseudo code) as an appendix or in their websites. By doing this, the interested reader has the opportunity to re-run the original program.

Related to this issue, lies the fact that the presentation of results often requires to constantly refer to the details and the basic hypothesis of the model and to explain its influence on the shape of the evolution. Moreover, as a relatively young field of enquiry, social simulation doesn't enjoy standard terms and methods as in the case of other methodologies. In the case of statistical inference, the term "$p<0.1$" stands for the sentence "the probability associated with this result is less than 10%". In the case of social simulation,

the relative lack of standardized concepts and techniques for the presentation of data implies that the modeller cannot communicate this type of information very efficiently. This issue is even accentuated when simulation results address an interdisciplinary audience (such as instances of agent-based models which might interest both economists and sociologists). The lack of common, standardized, terms and methods deepens the problem arising out of the relative lack of common concepts and methodologies which sometimes characterizes distinct academic disciplines. It then becomes necessary to explain very carefully the motivation and premises of the work.

A third type of issue is dealing with the replication of results. In fact, very few works have tried to replicate models (excepted, for instance, the notable attempt of Axtell *et al.* (1996) which tried to replicate Axelrod's (1997b) model of cultural dissemination by making use of Epstein and Axtell's (1996) sugarscape model). The replication problem is of prime importance since it allows to test the limits and the robustness of results obtained in previous simulations. A first stream of problems corresponds to the relative inability to offer an exhaustive description of the simulation model. This problem is of prime importance since, in this case, the details of the model and of its programming have a strong influence on the results. Axtell *et al.* (1996) provided an extensive description of the methodology they adopted to replicate Axelrod's model of cultural replication. It came out that Axelrod had to provide the authors with a very detailed description of the model. The replication process took about 60 hours to be performed.

Another type of shortcomings is dealing with the usual introduction of random elements in the simulation. In fact, those random elements are generated via a pseudo-random number generator. The pseudo-random number generator is a mathematical function which, for a given argument (generally called a seed and which is often a real number), generates a stream of pseudo-random numbers. For the same seed, different pseudo-random number generators deliver different output numbers, thus complicating the replication of results. Those issues motivate Axelrod (1997a) to establish a replication typology which evaluates the degree of identity between the results of the model and of its replication:

1. Numerical identity states that the results are to be reproduced exactly. It constitutes the most demanding standard of replication. In order to attain numerical identity, programs have to be reproduced in great detail. Moreover,

since simulation usually entails the use of random elements, the same random number generators must be used.

2. Distributional equivalence is achieved when the distributions of results cannot be distinguished statistically. Since the model and its replication are characterized by the same dynamics, distributional equivalence is, for most purposes, sufficient.

3. Relational equivalence constitutes the weakest degree of identity and is to be found when the two models have the same internal relationships among their results (i.e. they follow the same pattern of evolution or display the same sensitivity to parameters of the model).

Although numerical simulation constitutes a very promising methodology which is likely to compete with traditional methods such as statistical inference or experiments, it still suffers from some pitfalls which are, to some extent consequences of its relative novelty. Two types of issues are at stake. First, since simulation consists in the translation of a theoretical model in a programming language, a researcher wishing to apply this methodology has to learn a programming language. In addition, the simulation program may imperfectly translate the theoretical model, thus giving rise to errors in the output. This first stream of issues is mitigated by the multiplication of simulation platform aiming at simplifying the use of the methodology. A second type of issues is linked to the analysis, the sharing and the replication of results. This issue is of prime importance since it conditions the credibility and the visibility of computer simulation as an analysis methodology in its own right. In conclusion, simulation may only benefit from the setting of standardized methods and processes aiming at simplifying their analysis and their reproduction.

IV. Description of agent-based modelling.

The aim of this section is to present in details the agent-based approach. Historically, social scientists have been interested in modelling several social phenomena. In so doing, they have used a wide range of modelling approaches borrowed from other sciences such as physics and biology. As time went by, some classes of simulation models have emerged and are now the most widely used in social science. Indeed, scientists interested in social simulation have favoured a relatively small set of approaches. To our knowledge, three approaches have been principally used in simulating social phenomena: the social network approach, which has been particularly used to model the dynamics of technological adoption (see Cohendet *et al.* (1998)) ; the genetic algorithm approach in order to model evolution and learning (see Vallée and Yildizoglu (2001) for a survey on this topic) ; and the agent-based modelling approach, which has been used to model interactions between agents (see Nooteboom *et al.* (2002)). The agent-based approach, by allowing to concentrate the network approach and the genetic approach, appears to be the most complete one. This observation motivates this section which aims at describing the agent-based approach.

To put it shortly, an agent-based model consists of individual agents, commonly implemented in programs as objects, whose are affected states and rules of behavior (Axtell, 2000a). This approach proves to be particularly interesting since it is more general than the two other approaches by possibly encompassing social structure and learning issues. More precisely, agent-based modelling is defined along four aspects: time, the individual (its characteristics and their evolution), the interactions between agents and the environment of the system (Amblard, 2003). This section provides a description of agent-based modelling by detailing those four aforementioned characteristics.

IV.1. The management of time.

Time constitutes a central aspect which has to be account for in an agent-based approach. Indeed, a rising stream of literature insists on the strong role played by the notion of irreversibility and of path dependency in social systems (e.g. Dosi and Metcalfe, 1991 and Allen, 1988). For instance, individual knowledge are affected by previous interactions with other agents through a process of collective learning (see Allen, 1983). Learning contributes to changes in their internal characteristics which, in turn, influences agents' behaviors. Different time perspective may be considered, the choice between those perspectives being notably driven by the phenomenon the model wish to account for. In the case of **discrete time**, the variable representing time is an integer and the evolution of time is represented as a "stair-shaped" function. In a **continuous time** framework, the variable representing time is a real number. Instances of a continuous representation of time are found in models of plant growth. Finally, in a **discrete event approach**, the focus is put on the occurrence and the succession of events rather on a direct, explicit account of time.

Differences in the representation of time in the simulation entail differences in its management (Amblard and Dumoulin, 2004). The problem of time management, which can influence the model's output (Axtell, 2000b), principally corresponds to the problem of action scheduling: the algorithm has to specify not only the actions of the agents but their timing and ordering too.

In the discrete event approach, the time of occurrence of the events are normally calculated and updated during the simulation run. The events scheduling is therefore often endogenous to the model and depends on the value of the parameters defined at the start of the simulation (Amblard and Dumoulin, 2004). For instance, in modelling technological adoption, the dynamics of technological adoption and, therefore, the time at which a given technology becomes a standard, may depend on several factors. Those factors may correspond to the shape of the underlying social network or the sensitivity of agents (Deroian, 2000, 2002).

In the discrete time approach, several types of time management are offered to the modeller among which (Amblard and Dumoulin, 2004):

⇒ Synchronous activation, corresponding to a two-step state activation process. In a first step, the next agents' states are calculated *ceteri paribus* and are stocked in temporary variables. The actual updating process is only occurring once the new states have been computed for all agents.

⇒ Asynchronous activation, in which the agents' states are computed and updated one after the other.

The importance of such a distinction is particularly sensible if several agents are activated at each timestep. In this way, the choice between synchronous and asynchronous updating may lead to different outcomes. Synchronous activation amounts to updating an agent's state by considering the values of the model at the previous timestep. The asynchronous activation mode is likely to calculate new states using values which have already been updated during the same timestep. But the choice of the modeller between those two modes has to be driven by two consideration. The synchronous activation mode allows to keep a strict simultaneity in the agents' actions. It has to be chosen in simulating processes characterized by frequent and important discontinuities in their dynamics. However, since it implies the computation of temporary state variables, this type of activation may be time consuming and gives rise to a higher workload on the side of the modeller.

IV.2. The individual.

Agent based modelling belongs to the class of bottom-up approaches. This approach, is characterized by the fact that hypotheses are made on individuals' behaviors, motivation and interaction patterns. The agent-based approach accounts for an explicit introduction in the model of a population of distinct individuals (Axtell, 2000a). The agent-based approach enjoys two main advantages over analytical approaches.

The first advantage lies in the ability to easily introduce heterogeneous agents. The introduction of heterogeneities is a direct consequence of the hierarchical architecture adopted

for agent-based models (cf. Figure III-4). Heterogeneities lie on the agents' characteristics and on their behavior.

The degree of realism of a multi-agent model depends on the number of features as well as the degree of heterogeneities in the agents' characteristics and rules of behavior. An increasing degree of realism entails more complex interactions with the environment and among agents. However, increasing degrees of complexity rise several costs related to the ability to interpret the results of the model. Indeed, the introduction of a high number of features and of high degrees of heterogeneities are likely to blur the relationship between the results and the causes underlying them. This is why, multi-agents modelling (and, more generally, all types of simulation models) requires to find the right balance in the degree of realism of the model. An appropriate methodology consists in building a stream of models characterized by increasing degrees of complexity.

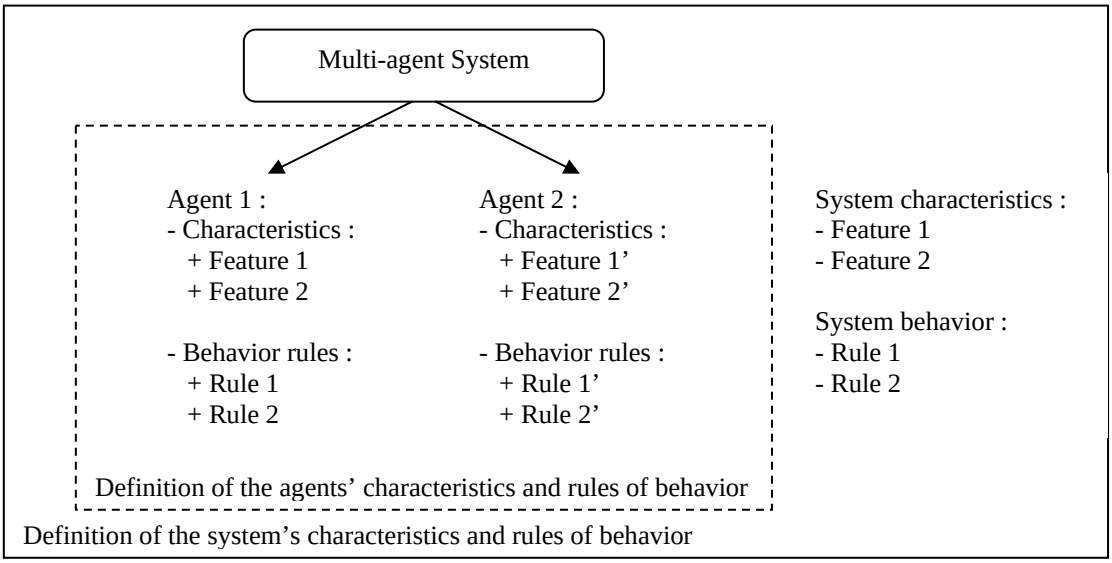

Figure III-4: Architecture of a multi-agent system.

A second advantage of multi-agent systems lies in the ability to implement evolutions in the agents' characteristics and behavioural rules. More precisely, agent are able to learn from their past experience (e.g. learning by doing) or through interactions with other agent (learning by interacting). In this manner, agent-based models can be combined with genetic algorithms (see e.g. Dupouët *et al.*, 2003, Lant and Mezias, 1990).

In a very broad sense, we can define genetic algorithms as algorithms of stochastic optimization which are rooted on natural selection and on genetics (Vallée and Yildizoglu,

2001). Fundamentally, genetic algorithms, which have been introduced by Holland (1975), have two fundamental properties. First, it uses a fixed length string of numbers. Those numbers are either binary or integers. This string of numbers represents the genetic code of the agent: each component or portion of the code commands for a particular rule of behavior for the agent. For instance, in the case of a string of two components, each component may code the individual's behavior while facing a particular situation. The first component of the code commands the agent's behavior in the first type of situation while the second component of the code commands the behavior in the second type of situation.

As argued by Vallée and Yildizoglu (2001), the use of integers instead of binary numbers may be motivated by the wish to account for more than two alternative behaviors while facing a given situation. For instance, a genetic code made up of 3 integers (say 0, 1, 2) allows the modeller to account for three different types of behaviors for a given situation. The use of integers instead of binary codes is often motivated by the wish to save on the genetic code's length. This reduces the probability of errors related to the manipulation of longer strings of code (e.g. errors in the identification of the right situation, …).

The second distinctive trait of genetic algorithms lies in their capacity to evolve resulting from the combined action of three operators (Vallée and Yildizoglu, 2001): the selection operator, the crossover operator and the mutation operator.

The **selection operator** determines the individual capacity to persist in a population and to diffuse. An individual's survival is generally linked to its relative performance within the population. Individual performance is computed by making use of a performance function. Formally, if we assume that A is the sequence coding for an individual's genome, the performance function corresponds to a positive value function $f : A \rightarrow f(A) \in \mathbb{R}^+$. The higher the value of $f(A)$ (relatively to other members of the population to which A belongs), the higher the likelihood for A's genotype to persist and to diffuse within the population.

The **crossover operator** allows the creation of new individuals (called offsprings) through a simple process of recombination of the code among "parents". Formally, let's assume two individuals whose coding sequences are A and B. The crossover operator consists in exchanging a portion of the code A with a portion of the code B in such a way that it gives rise to two offspring: an offspring whose genetic code is A', which mainly consists in the

code of A excepted a portion coming from B. The second offspring is endowed with the code B', which mainly consists in the code of B excepted a portion coming from A (cf. Figure III-5). In social systems, the crossover operator can correspond to a process of learning by interacting. If we assume that an individual's knowledge is represented by a coding sequence, knowledge exchanges can, at the first approximation, be viewed as exchanges of portions of individuals coding sequences.

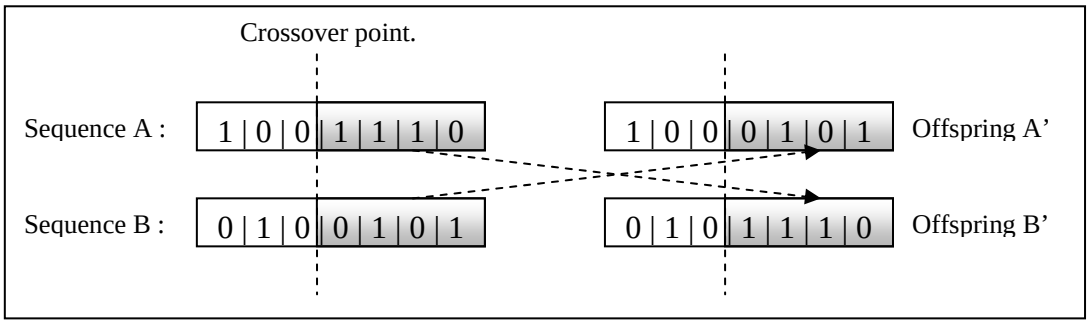

Figure III-5: description of the crossover operator.

The **mutation operator** constitutes an alternative to the crossover operator for the generation of variety in a population. The role of this operator is to introduce, with a given probability, random modifications to the genetic code of an individual in a population. This operator is rarely used in comparison to the crossover operator (Banzhaf et al., 1998). As pointed out by Vallée and Yildizoglu (2001), it nonetheless constitutes an important operator by enabling to explore the whole set of possible combinations. For instance, the coding sequence for a population might be characterized by the fact that the i^{th} component of the sequence is the same for every individuals (e.g. a 1) which might lead to lower levels of efficiency than in the case that some of the members' sequences would be characterized by a 0. This problem could obviously not be solved by the use of the crossover operator (given the fact that all members of the population are endowed with the same value for the i^{th} component. On the contrary, the use of the mutation operator solves this problem by replacing (with a low probability) the 1 by a 0. In social systems, the mutation operator corresponds to an activity of exploration of new solution taking the form of a process of trial and error.

IV.3. The interaction between agents.

The emphasis put on the interactions between agents has been motivated by the wish to model the effect on agents of local influence relationships or of limits in the access to information (Amblard, 2003). Although some models of herd behaviors (Orléan, 1995) or of technological adoption (Arthur, 1989) relax the hypothesis of local influence and assume global influence relationships, many other retain the assumption of behaviors as influenced by local relationships. In this case, a major challenge facing the modeller is to formalize the nature of the space in which the agents evolve. A distinction is drawn between models in which the agents are integrated to a social space from graph models.

The basic principle underlying models of social space consists in constructing a particular social space in which the agent is localized. This type of network focuses more particularly on spatial interactions, as in the case of neighbourhoods in a city. More precisely, agents are distributed on a grid and are subject to the influence of their spatial neighbours. Several types of neighbourhoods can be defined: a Von Neumann neighbourhood defines the case in which the agent is under the influence of four of his neighbours (located on his north, east, south and west side). A Moore neighbourhood defines the case in which the agent is influenced by eight of his neighbours (N, NE, E, SE, S, SW, W and NW) (cf. Figure III-6).

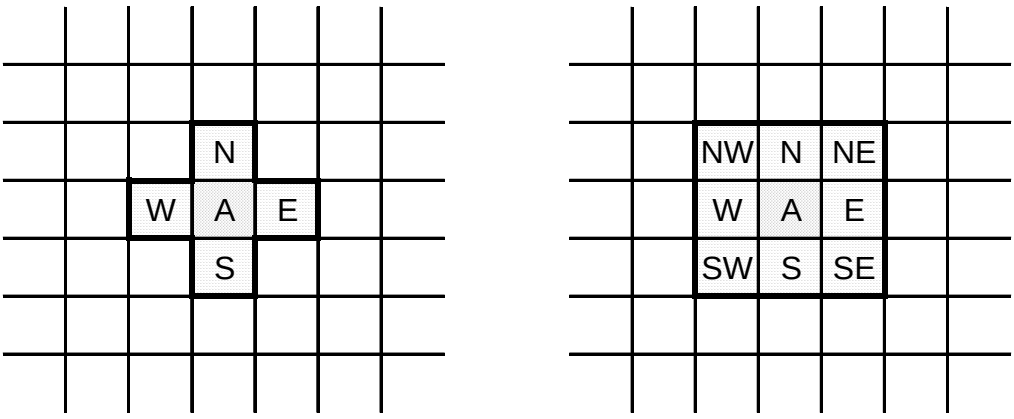

Figure III-6: Von Neuman (left) and Moore's neighbourhood (right).

The spatial position approach has been notably used in models of percolation (Cohendet, 1998), models of cultural evolution (Axelrod, 1997b) or in models of segregation (Schelling, 1971).

Another type of approach relies on graph theory. A network is approached as a collection of individuals who are connected with each other by edges or vertices. A common way to depict a graph is to represent agents as a set of dots and edges link these dots if the corresponding agents are partners (cf. Figure III-7). Relationships might be either unidirectional (for instance agent A is linked to agent B but B is not linked to A) or bidirectional.

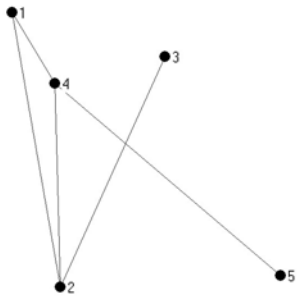

Figure III-7: network representation.

Several models of graphs have been developed, the most common classes being random graphs, regular graphs, small-worlds and scale-free networks.

Random graph is among the oldest models of graphs and has been introduced by Erdõs and Rényi (1959). Formally, a random graph is defined as a graph containing a set of n vertices, in which every one of the possible $\binom{n}{2}$ edges (or connections between vertices) exists with a probability $p \in [0,1]$, the attribution of each edge being independent from each other (Bollobas, 1985). Practically, the construction of a random graph consists in considering each of the $\binom{n}{2}$ possible pairs of vertex. Then, a pair is connected with a probability *p* (cf. Figure III-8). Random graphs are characterized by low values of path length (i.e. each vertex of the graph is attainable from any other vertex through a relatively small number of intermediate vertices) and a low degree of clustering (i.e. the neighbours of a given vertex may not be connected with each other).

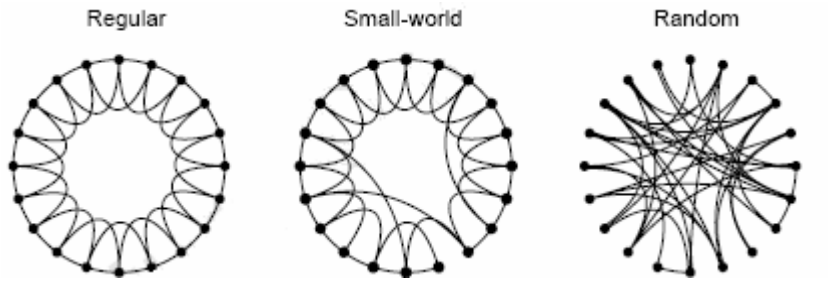

Figure III-8: Models of network: regular - Small World – Random (Watts and Strogatz, 1998).

The **regular graph** model is commonly opposed to the random graph model. Formally, a regular graph of dimension d is a labelled, unweighted, undirected simple graph containing n vertices in which any vertex v is joined to its lattice neighbours, u_i and w_i, as specified by: $u_i = \left[\left(v - i^d\right) + n\right]$ and $w_i = \left(v + i^d\right)$ (Watts, 1999). Practically, a regular graph of degree 4 is constructed in the following way: Let's suppose a set of n vertices, those vertices being labelled. Each vertex is connected to its four nearest neighbours (for instance, vertex n°10 is connected to the vertices n° 8, 9, 11, 12). At the opposite to random graphs, regular graphs are characterized by a regularity in its construction (cf. Figure III-8). Moreover, regular graphs are characterized by high path length values and a high degree of clustering.

The **small world** model constitutes an intermediate case between regular graphs and random graphs (cf. Figure III-8). Small worlds are characterized by low path length values and high degrees of clustering (Watts and Strogatz, 1998). They are constructed in the following way: starting from a regular graph, each edge is considered and is randomly redirected with a probability *p*. For $p \in [0.01, 0.1]$, the graph exhibits small-world features with a high degree of clustering and low path length values (cf. Figure III-9).

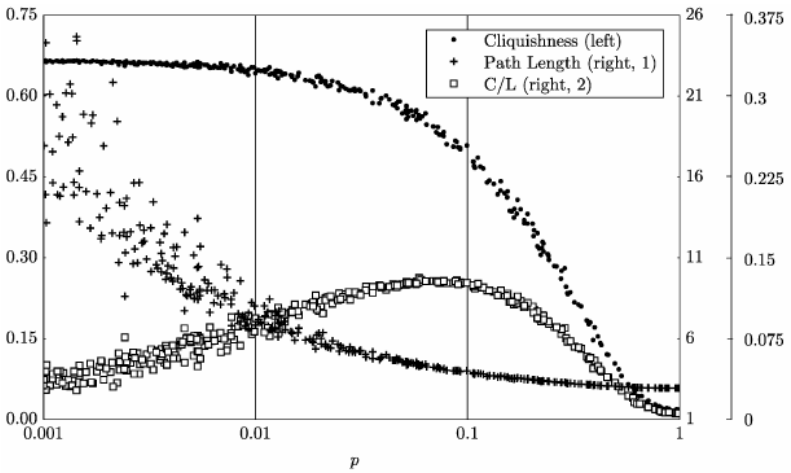

Figure III-9: evolution of path length and cliquishness as a function of p (taken from Cowan and Jonard, 2003).

The **scale free networks** model is rooted in a double observation in real networks (e.g. the Internet, networks of scientific collaborations) : 1) networks expand continuously by the addition of new vertices and 2) new vertices attach preferentially to well connected vertices (Barabasi and Albert, 1999). In this way, scale free networks are networks featuring growth and preferential attachment. Practically, scale free networks are constructed as follows: starting from a small number of m_0 vertices who are connected to each other in a random way. Vertices are continuously added to the existing network and each new vertex is connected to m ($m< m_0$) vertices with the probability proportional to their degree. Scale free networks are characterized by the facts that the distribution of degrees among vertices follows a power law and the graph exhibits a fractal architecture (Albert and Barabasi, 2002).

IV.4. The environment.

The environment is a medium separate from the agents, on which they evolve and with which they interact (Epstein and Axtell, 1996). It has commonly been reduced to a communication structure although it may be richer than this. In fact, the environment aims at setting the rules of behaviors that are common to all agents of the systems (cf. Figure III-4). In this manner, it not only regulates the interactions between agents but it incorporates other features too, such as the definition of the performance function in the case of a genetic algorithm.

One of the main issues of agent-based models is dealing with the closure of the model. In fact, in modelling complex systems, the modeller commonly has to face the challenge of determining the limits of the system to be modelled while keeping it as “open”. The introduction of an environment precisely helps in addressing this issue by setting some parameters as fixed and exogenous. For instance, agent-based models can assume that the social system under study is embedded in an institutional setting whose characteristics are assumed to be exogenous.

Apart from containing values of the parameters, the environment can be assumed to provide the system with consumable resources. For instance, Kirman and Vriend (2001) have proposed an agent-based model of the Marseille fish market in which they study the emergence of loyal behaviors from fish buyers and the persistence of a price dispersion. In this model, it is assumed that the sellers are exogenously supplied in fish.

Lastly, the evolution of the environment can have an influence on the evolution of individual behaviors. This effect has been notably introduced in environmental models (Amblard, 2003). For instance, in models concerned with the influence of environmental pollution or the management of environmental resources on individual behaviors, it can be assumed that the current state of the environment is conditioned by past human activity which, in turn, determines current individual behaviors (cf. e.g. Franchesquin, 2001).

Conclusion.

The aim of this chapter was to justify the recourse to computer simulation in the modelling of complex social systems. It started with the description of social systems as exhibiting three distinctive features (apart from self-organization). The first feature corresponds to a large number of components, those components being likely to differ in their characteristics. The second aspect of complex systems lies in the existence of non-trivial interactions among components. More precisely, components of a complex system may only interact with a small subset of other components of the system. A complex system may therefore be viewed as a network of relationships among components. The third aspect of complex systems lies in the fact that components follow trajectories which may differ from

each other. Those possibly diverging trajectories are rooted on the influence exerted by interacting parts and by the environment on each of the components of the system.

A second section explored the relative advantage of computer simulation over other modelling methodologies in dealing with complex systems. The first attribute of computer simulation corresponds to its ability to account for systems made up of heterogeneous components. More precisely, by opposition with analytical approaches, simulation, due to the extraordinary computing capacity of computers, enables to address complex problems made up of several thousand variables (each variable representing an individual characteristic). Second, A major shortcoming of analytical approaches is that they are mostly interested in determining the final states of the system but face limits in providing an account of its transition. Numerical simulation allows to avoid this pitfall by monitoring the evolution of the system over time.

However, as a young field, numerical simulation still suffers from two kinds of limitations. The first type of issues is dealing with the programming of a simulation model. Programming issues are of two orders. First, only few social scientists master computer languages (preferably an object oriented language like C++ or Java), thus restricting the diffusion of computer simulation as a modelling practice. Second, the programming task consists in the translation of a theoretical model into a computer language. The computation of a simulation model may give rise to some errors of translation which are independent from the internal logic of the underlying model. This first stream of issues motivates the development of simulation platforms (LSD or Swarm) aiming at simplifying the programming task. A second type of issues is dealing with the analysis of results. If one of the main strengths of numerical simulation is to enable to build complex models, it could also become a weakness if this strength is not mastered. Indeed, one of the main caveats of numerical simulation is to add too many independent processes in such a way that it rapidly becomes impossible to draw a clear relationship between the results and their causes. In order to keep track of the relationships between the results and their causes, it is therefore highly recommended to first build a very simple model containing only very few processes and to progressively increase its complexity.

The fourth section of the chapter was more specifically devoted to the description of the agent-based approach. This class of models, which is adopted as the primary modelling

approach in this dissertation, is commonly made up of individual agents, whose are affected states and rules of behavior. Four distinctive features characterise agent based models. The first characteristic corresponds to the management of time in the simulation. More specifically, the activation of the agents in the simulation depends on the representation of time which has been adopted in the simulation (continuous or discrete time approach or the discrete event approach). A second defining characteristic of agent-based models lies in the definition of the individual in the model. Individuals, are endowed with distinctive characteristics as well as distinctive behaviors and they can also engage in learning processes. A third feature lies in the interactions between agents. The interactions between agents can occur in different ways: either they can be global, each agent having the ability to interact with any other of the system or they may be local. In this latter case, agents can be limited by a physical space (they can interact only with their neighbours) or to a relational space represented by a network of acquaintances. A last distinct feature of agent based models lies in the introduction of an environment in which the agents evolve. This environment, which influences the agents' behaviors by providing some common rules of behavior, can also be influenced by the individuals' former actions.

Following chapters will constitute an implementation of the previous discussions on the evolution of cooperation structures within communities of practice (exposed in Chapter I) and on the simulation methodology. More precisely, next chapters will propose several models showing the emergence of community leaders. Chapter IV will exclusively focus on the role of reputation in the construction of leadership, Chapter V will include a further ingredient with the study of the effect of trust in the evolution of a community's internal organization. Finally, Chapter VI will be focusing on the influence of community leaders on the behaviors of community members.

Chapter IV. Reputation and the emergence of communitarian leaders.

Introduction[♦].

This chapter aims at describing the role of reputation within communities of practice. Is here developed the idea that reputation contributes to fulfil two important roles by providing in the same time a direct incentive to contribute and an indirect coordination mechanism.

The concept of reputation has been introduced in economic analysis along with the economics of information. Its main purpose is to tackle the issues raised by the introduction of informational asymmetries among economic agents. Reputation is viewed as an important factor enabling market transaction or the well functioning of organizations by contributing to explain the persistence of cooperative behaviors. More precisely, reputation corresponds here

♦ Parts of this chapter are based on Muller, Paul and Pénin, Julien. 2004. Why do firms disclose knowledge and how does it matter ? Paper presented at the DRUID Summer Conference 2004: Industrial Dynamics, Innovation and Development, Copenhagen, june 14-16.
The model presented in the chapter is based on Muller, Paul. 2003. On Reputation, Leadership and Communities of Practice. Paper Presented at the EAEPE Conference. Maastricht. The Netherlands. November 7-10.

to a record of past behaviors which influences the probability with which potential partners engage into a cooperative relationship or not. In this way, reputation is commonly viewed as a rather "binary" concept: either good or bad.

The existence of reputation in communities has been widely acknowledged notably in the frame of open source development (Foray and Zimmermann, 2001, Dalle and Julien, 2003). It appears to be of richer nature than a simple probability index determining the decision whether to cooperate or not. Still, its very notion seems to remain rather blurred and the different perspectives to reputation put forward in past contributions are sometimes characterized by a certain lack of consistency. For instance, Lerner and Tirole (2000) operate a distinction between reputation as related to career concern and ego gratification as the expression of a peer recognition (which, in fact, appears to gather several effects such as reputation *stricto sensu* or reciprocity).

One argument developed in this chapter is that, in the frame of communities of practice, reputation has to be perceived as a two-layered concept. The first level of analysis is concerned with the community as a whole. In this way, reputation refers to the competences possessed by the community and its level of success in the accomplishment of its basic objectives. The second level of analysis, internal to the community, is more concerned with the individual and is dealing with his behavior and the competences he possesses. This distinction is of importance since it induces different consequences. Communitarian reputation might affect the relationships among members of different communities by, for instance, contributing to shape their respective bargaining power[1]. Individual reputation aims at reducing the uncertainty associated with one's competences and behavior, thus contributing to their coordination and the binding of new relationships.

The chapter is organized as follows. A first part is devoted to a review of the literature on classical treatments of reputation. One of the main finding concerning the concept of reputation in the Economics of Information refers to its calculative nature: reputation is here mainly understood as an index determining the decision whether to enter into a cooperation or not. Section II develops the concept of reputation in the frame of communities of practice. It is operated a distinction between communitarian reputation and individual reputation.

[1] For instance, due to the reputation of the project, an active member of the Linux community might benefit from an advantage in terms of career prospects than members of other, less famous, development projects.

Whereas communitarian reputation corresponds to the competences held by the community, individual reputation is here understood as a set of information concerning past individual activity within the community. Both communitarian and individual reputation form the basis of the coordination of agents by, for the former, contributing to reduce the uncertainty associated with the right behavior to adopt and, for the latter, reducing the costs associated with the occurrence of first interactions. Sections III, IV and V proposes a simulation model focusing more particularly on individual reputation. A basic idea underlying the model is that the emergence of community leaders is the outcome of a self-organizing process.

I. The classical treatments of reputation.

Perfectly competitive markets are characterized by the fact that economic agents have full information about prices and the quality of goods. The price at which exchanges are taking place is unique and optimal. The introduction of the hypothesis of imperfect information in the economic analysis led economists to rethink the principal results obtained in the frame of pure and perfect competitive markets (Stiglitz, 2002). The introduction of imperfect information can give rise to enduring price dispersions due to the costs incurred by buyers in searching for the best offers (cf. Stigler, 1961). Moreover, differentials in product quality coupled with asymmetries of information give rise to possible effects of adverse selection, originating a market failure (Akerlof, 1970).

Problems of informational asymmetries among economic agents, as pointed out in theories of organizations[2] (notably in the frame of Transaction Costs Economics (cf. Williamson, 1975) and Theories of Teams (see chapter II)) and in the literature on economic networks (cf. the doctoral dissertation of Julien Pénin (2004) for a survey on the issue), motivate the introduction of effects such as reputation in the economic analysis (Kreps, 1990). In this section, we will see that the concept of reputation embeds different significations when applied in the field of markets and organization or in the frame of economic networks. While, in the former context, reputation is approached in a game theoretic perspective, it is of a quite different nature in the frame of economic networks.

I.1. Reputation in markets and organizations.

As evidenced by Adam Smith (1896) in his *Lectures on Justice, Police, Revenue, and Arms*, economists were long concerned with the issue of reputation as an important mechanism for ensuring that the contracts are honoured. Although this long lasting prominence in the economic analysis, the concept of reputation was progressively alienated with the hypothesis of perfect information. It has only been reconsidered as a subject of matter after the introduction of the imperfect information hypothesis in the 60's. In this perspective, reputation has been mainly analysed through the building of game theoretic models. Two streams of models can be distinguished: while the first stream is concerned with market issues, the second type of models is focusing on cooperation within organization.

In order to analyse reputation in the context of trade relationships, we consider a game inspired by the model of Akerlof (1970). This game considers a market in which are taking place transactions involving two types of players: sellers and buyers. The sellers have the choice between selling two types of goods: high quality goods and low quality goods. The costs of producing one unit of the high quality good and of the low quality good are C_{High} and C_{Low} respectively with $C_{High} > C_{Low}$. It is furthermore assumed that the selling price p is the

[2] Even though some theories such as Transaction Costs Economics or the theory of teams (cf. chapter II) have highlighted the use of incentives in inducing economic agents to reveal their private information, significant other streams of literature have pointed out reputation as an other device.

same for both types of goods in such a way that $p > C_{High} > C_{Low}$. The sellers don't incur fixed production costs and automatically adapt their supply to the demand expressed by the buyers in such a way that individual profit in the case of no demand is 0.

On their side, buyers have the choice between two alternatives: to buy the good or not. The satisfaction provided by the high quality good is given by U_{High} while the utility provided by the low quality good is given by U_{Low}. U_p corresponds to the disutility (taken in absolute value) of buying the product in such a way that $U_{High} > U_p > U_{Low}$. We are in a situation of asymmetric information: only sellers know the actual quality of the product.

The gains associated with each action is given in the following matrix (Table IV-1):

		Buyer	
		Buy	Don't buy
Seller	High quality product	$p - C_{High}, U_{High} - U_p$	0,0
	Low quality product	$p - C_{Low}, U_{Low} - U_p$	0,0

Table IV-1: Payoff structure of the market game.

The outcome of the game depends on its structure. In the case that agents are not able to communicate with each other about the past behaviors of the sellers, they are likely to take the "don't buy" decision since they know that sellers are prompted to sell only low quality products. Indeed, since $U_{Low} - U_p < 0$, the Nash equilibrium consists for the buyer not to buy the product, independently from sellers' behaviors, thus leading to the failure of the market.

Now, we assume that buyers are able to identify each seller and have knowledge of their past behavior. In this case, the market failure can be avoided in the following way: at the start, buyers can deviate from their preceding strategy and choose to buy the product. From this moment, the firm can also consider the perspective of cooperating by offering high quality products. This strategy is rational for sellers in the sense that it can yield further transactions. Sellers acquire a good reputation because buyers believe that they sell high quality products. Conversely, sellers selling low quality products acquire a bad reputation and can be excluded from the market (see Shapiro, 1983, Klein and Leffler, 1981).

Reputation therefore corresponds to a record of the past behavior of economic agents: they acquire a good reputation if they exhibit a permanent cooperative behavior while they

can be penalized by a bad reputation if, at any time, they choose to act in an opportunistic way. Apart from explaining the permanence of cooperative behaviors, other authors also emphasised reputation as a factor accounting for the possibility that actual prices in a market are above competitive prices (Allen, 1984). In this type of model, sellers enjoying a good reputation are prompted not to reduce their prices at lower levels in order to gain market shares because any price decrease can induce a signal interpreted by consumers as a consequence of decreases in the quality of goods.

The literature on organizations has stressed the difficulties in ensuring the convergence of interests between the agents and the rest of the organization. In fact, individuals may enter an organization because it enables them to reach higher degrees of satisfaction: working for an organization as an employee allows to earn a loan. This make possible other exchanges in the markets for goods and services and increases the individual level of satisfaction. However, it does not mean that the individuals' optimal behaviors coincide with the organizational goals. This divergence may give rise to opportunistic behaviours (the issue of the convergence of interests has been elaborated in chapter II). Moreover, as highlighted by Orléan (1994), even if individual interests converge with organizational goals, the ambiguity raised by the contract incompleteness may give rise to a coordination failure. Those issues have been gathered by Leibenstein (1987) under the term "hidden prisoner dilemma".

In a famous article on corporate culture, Kreps (1990) highlighted the role of reputation is solving the problem of coordination of individual behaviors. Addressing the issue of coordination, he advanced the existence of a corporate culture as a mechanism coordinating individual behaviors. Corporate culture refers to a set of basic principle, routines and rules which serve as basic references for decision making and shared expectations that employees are taught (Milgrom and Roberts, 1992). In this respect, it serves as a focal point common to the whole organization and on which members can rely on in their decision making process. This focal point might also correspond to the external reputation of the firm in the market. For instance, Milgrom and Roberts (1992) related the case of Nordstrom, a department store chain, in which the corporate culture consisting in a strong commitment to customer satisfaction translated in the reputation of the firm.

Addressing the issue of opportunistic behaviors, the external reputation arising from corporate culture can be complemented by individual, internal reputation[3], defined here as the behavior usually observed in past interactions with other members of the organization. In this context, individual reputations (and, therefore, behaviors) are also influenced by corporate culture or, similarly, the external reputation of the firm (see also Crémer, 1986). In this case, the problem is relatively similar to the one described in the frame of market transaction. Individuals have the choice between complying to the corporate culture or disobeying it. Good or bad individual reputation is determined according to their past behavior and determine their future in the company: whereas individuals with a bad reputation can be punished or even fired, individuals enjoying good reputation can be rewarded for their cooperative behavior.

I.2. Reputation in networks.

Economic networks can be considered as coordinating devices aiming at facilitating the mutual exchange of complementary forms of knowledge between members (see Kogut, 2000). They refer to interfirm coordination that is characterized by organic and often informal social systems, by contrast with bureaucratic structures within firms or with contractual agreements (see Jones *et al.*, 1997, Gerlach, 1992). Since firms belonging to networks are characterized by complementarities in their possessed knowledge, they can organize its circulation through a structure that renders compatible those different segments of knowledge (Kogut, 2000). In turn, firms specialize in a given body of knowledge, because they expect other agents to specialize in complementary forms of knowledge.

Jones *et al*. (1997) identified four types of situations in which the network organization is particularly efficient: 1) High degrees of demand uncertainty which favour cooperation among small and flexible firms. 2) Customized exchanges high in human asset specificity which create strong interdependencies among actors. 3) Complex tasks under intense time

[3] As we shall see in the discussion of trust in organization in chapter V, Kreps tended to merge trust and reputation under the same term.

pressure: since an intense time pressure does not allow the firm to enter into learning processes, it becomes more rational to seek complementary forms of knowledge. 4) Frequent exchanges among actors, contributing to the creation of interdependencies by the development of common specific assets.

A basic challenge at the root of industrial networks lies in the identification of appropriate, complementary partners. Indeed, a core assumption grounding industrial networks corresponds to the fact that knowledge is not viewed as a pure public good due to its significant tacit component. This gives rise to a situation of information asymmetry about which firms possess complementary forms of knowledge likely to give rise to mutually beneficial partnerships. In order to tackle this challenge, some firms adopt open knowledge disclosure policies: they allow their scientists to present their work in conferences or even to publish some of the knowledge produced internally. By assuming that knowledge is a pure public good, this behavior can be perceived as irrational. In this perspective, the only way to enjoy the returns stemming from the production of new knowledge and to hinder competitors from its use is to keep it secret.

Acknowledging the fact that knowledge isn't a pure public good (notably embedding a strong tacit component) yields different consequences. First, open disclosure of knowledge only concerns its codified part. Since the practice of innovation generates both tacit and codified knowledge, important parts of knowledge remain hidden to external competitor in such a way that potential imitators can face difficulties in implementing the disclosed knowledge, thus providing an incentive to innovating instead of imitating (von Hippel, 1988). Second, through this practice of knowledge disclosure, firms can build up a reputation. The aim of reputation mainly consists in signalling to potential partners the competences held by the firm. Reputation is here understood as a way of reducing the uncertainty associated with the competences held by a firm. It results from the accumulation of signals disclosed to potential partners through publication or conferences.

As previously argued, networks aim at binding together distinct firms characterized by complementary knowledge. This type of arrangement brings in several advantages over other types of arrangements such as contractual partnership, (vertical or horizontal) integration or an internal production of knowledge. It notably allows to save time and resources on the process of knowledge acquisition or to increase the degree of flexibility in the partners'

behaviors. However, in the same time, it implies difficulties linked to, on the one hand, problems of identifying most competent potential partners and, on the other hand, the risk of hold-up (Williamson (1975)). As an uncertainty reducing device, reputation allows to tackle those two issues. First, as previously argued, it eases the binding of interfirm agreements by providing potential partners with information about their internal competences. Moreover, in line with the view of reputation developed in the frame of the Economics of Information, reputation can inform about the firm's behavior. Apart from their competences, firms can also be perceived by other members as cooperative or opportunistic. In this respect, information about cooperative behaviors can be at least as important as information about the competences held by the firm and potential partners have to compute a trade-off between the value of the newly accessed knowledge and the risks associated with the possible adoption of an opportunistic behavior.

Reputation constitutes a device allowing to tackle adverse selection problems raised by the existence of informational asymmetries among economic agents. More precisely, by informing potential partners about an individual's past behavior, reputation affects individuals behavior in a way that they are not directed by the maximisation of instant profit (or satisfaction). Rather, the introduction of reputation forces agents to adopt a wider perspective encompassing future opportunities with other potential partners. In complement to this influence exerted on behaviors, reputation in the frame of industrial networks embeds a further dimension related to a reduction of the uncertainty about the competences held by a given firm.

II. Reputation in communities of practice.

As in networks, one of the principal challenges facing communities of practice lies in the high degree of uncertainty related both to the competences and the behavior of each member. This high degree of uncertainty prevents them to engage into new relationships. Moreover, due to the absence of any contractual schemes, the actual coordination of individual behaviors may not be ensured. Following the example of organizations, communities of practice address those issues through the coexistence of two types of reputation: a communitarian reputation combined with an individual reputation.

Communities of practice are characterized by the absence of any contractual schemes aiming at regulating individuals behaviors. However, coordination is carried out in the first place by other means corresponding to the development of a common practice. The development of a common practice is highly conditioned by the domain of focus of the community. It follows that the knowledge developed within the community is, to a great extent, directly related to the domain of focus characterizing the community. A very basic observation stemming from Lakhani and von Hippel's (2003) study of the Apache helpdesk community is that all questions and contributions to the community were exclusively dealing with issues related to the Apache software. In this respect, the Apache helpdesk differs from other types of communities such as chats and forums and for which the domain of focus is not clearly defined.

The development of the common practice in relation with the domain of focus contributes to determine the external reputation of the community. Indeed, by opposition to formal organization, individuals are, most of the time, not bound to a single community, they can belong in the same time to several communities of practice. This social integration within a wider environment does not only yield consequences for the community by allowing members to apply their extra-communitarian experience to the internal practice, but it also shapes the reputation of the community in its environment. In the same way as in economic networks, the knowledge developed internally to the community can also prove to be of great use in other types of communities. For instance, a module or pieces of code developed in an open source project can also be applied in other projects. Similarly, knowledge developed in

one academic community diffuses across distinct communities through publications or conferences speeches.

In this perspective, apart from contributing to the knowledge base of other communities, one important consequences related to those spillovers lies in increases in the reputation of the community having originated the piece of knowledge. In fact, the knowledge developed within a community and broadcasted to other communities does, in some sense, still belong to the former one. This disclosed piece of knowledge only constitutes the final outcome of collective learning processes which are specific to the community and can be hardly imitated. Hence, this spillover fulfils the role of a signal for the competences held by the community, thus reinforcing its external reputation. Instances of this relationship between knowledge disclosure and community reputation can be easily found in academia. In fact, the visibility of communities forming research labs such as the Wharton School or the Sloan School is mainly relying on the reputation of their researchers which, in turn, builds on the quality and the number of their publications.

This external reputation possesses a strong public feature since every members of the community can benefit from it. Reputation can be, in some way, viewed as a public good. Indeed, agents can enjoy the reputation of the whole community or of their peers without having necessarily contributed to it. This effect can be found in parts of economic activity. It is well known that a main factors conditioning the hiring of a freshly graduated individual corresponds to the reputation of the institution in which he studied or the influence exerted by other individuals having studied in the same institution. The individual benefits from the reputation of the institution or of some of its former members without having necessarily contributed to it, thus posing a problem of contribution to public good. This problem is mitigated by the close coupling between the social norms of the community and individual reputation.

As already introduced in chapter I, individual reputation is here understood as a set of information dealing with constant and recurring elements of an individual's behavior, those information being the object of a perpetual assessment by other members of the community. It relies on social norms which aim at describing the basic objectives of the community as well as the way to reach them. They contribute in shaping the behavior of each member of the community by offering them an alternative: either they comply to social norms and reinforce

their own reputation or they do not and choose to sacrifice their reputation. More precisely, if an individual's personal preferences don't match the social norms prevailing within the community, this agent has to operate a trade off between the costs and the advantages incurred by the compliance to norms or the adoption of opportunistic behaviors. Complying to social norms is likely to reinforce his reputation, hence providing him with further opportunities to interact with other members. At the opposite, the adoption of an opportunistic behavior may penalize the agent's reputation, thus impeding his faculty to interact with other members of the community.

Besides providing potential partners with information about the agent's behavior, a reputation can also provide information about the knowledge and competences he possesses. In the frame of communities of practice, cooperation is often associated with processes of collective learning in which knowledge and information are exchanged. Each partner broadcasts some parts of his knowledge. This, in turn, provides other members with clues about the knowledge and competences possessed by their respective partners. After this interaction, each partner can interact with other individuals and inform them about the knowledge and competences held by the former partners. Hence, information about the competences of each member can diffuse across the community and contribute to their reputation.

Individual reputation is therefore constituted of two parts: the first part is related to the knowledge and competences possessed by the member while the second part is dealing with his actual behavior (cooperative or not). In turn, reputation constitute a strong incentive for contributing to the advancement of the community. A positive reputation provides numerous advantages such as a reduction of the costs (e.g. the time spent in defining a common vocabulary for the interaction and negotiating the objectives of the interaction) as well as the uncertainty and the risk related to a first interaction. Individuals enjoying a good reputation within the community are able to bind numerous relationships with other members. By enjoying a higher number of acquaintances, the individual acquires a central position within the social network of the community. Knowing this, other members of the community tend to copy his behavior by adopting a behavior of informational mimesis (Orléan, 2001). The adoption of such a behavior is rational for two reasons. First, since he is supposed to possess a richer and more accurate information than other members, the central individual is able to

take more relevant decisions. Second, the adoption of mimetic behaviors allows members to save on costs associated with the search and the processing of information.

It follows that the relationship between individual reputation and the motivation for contributing to the community is rather direct. As argued before, individual reputation builds on the multiplication of signals emitted by members of the community and those signals diffuse across the community through further interactions involving other members. Increases in the reputation yield an increased capacity to bind new relationships with members and enables the individual to reach a central position within the community. Lastly, since higher degrees of centrality in the social network of the community yield higher degrees of influence in the community, those leaders enjoy the capacity to direct individual behaviors.

Summarizing, reputation within communities of practice covers two dimensions. The first dimension is dealing with the external reputation of the community which builds on the spillovers affecting the knowledge produced by the community. This external reputation allows to increase the visibility of the community within the environment by informing about the knowledge and competences it possesses. However, since communitarian reputation is shared by all members of the community, members may not be motivated to contribute to it and are therefore tempted to adopt free-riding behaviors. This problem is mitigated by the existence of an individual form of reputation. This latter form of reputation provides individuals with incentives for contributing to the practice since it is closely connected to influence and leadership relationships within the community.

Next sections will focus more particularly on individual reputation. More precisely, they will propose a model simulating the relational dynamics of communities of practice as an outcome of differentials in the levels of reputation enjoyed by members.

III. Reputation and the dynamics of communities of practice.

An important issue tackled by the present model deals with the process of relationship formation among members of a community of practice. The final structure of the social network forming the community is determined by individual decisions made by individuals characterized by heterogeneous behaviors, as opposed to models of network structure such as random graphs (Erdős and Rényi, 1959) or Small Worlds (Watts and Strogatz, 1998, Watts, 1999). Our model departs from traditional models of network formation (Jackson and Wolinsky, 1996, Jackson and Watts, 2002a) because it assumes cooperative behaviors from individuals. The individual characteristics governing relationship binding decisions are endogenous. The dynamics of the model refers rather to the literature on scale-free networks (Barabási and Albert, 1999).

III.1. The individual characteristics.

At time 0, let us consider n individuals located on an undirected[4], sparsely connected random graph $G_0 = (V, \Gamma_0)$, where $V = \{1,\ldots,n\}$ is the set of members and $\Gamma_0 = \{\Gamma_0^i, \forall i \in V\}$ is the list of connections where $\Gamma_0^i = \{j \in V \mid \{ij\} \in G_0\}$ ({ij} representing the link between members *i* and *j*) constitutes the neighbourhood of agent *i* at time 0 or, similarly, the set of individual *i*'s acquaintances at time 0.

Each individual $i \in V$ is characterized by an absolute degree of engagement to the community, φ_i, which is assumed to be fixed over time. This level of engagement is positively related to the level of activity of the individual within the community. The level of engagement might be understood as the level of agent *i*'s interest in the open source project.

[4] Since the maintaining of any relationship requires the mutual consent of both partners, the graph describing the social network of the community is undirected.

Beside any consideration related to the level of engagement, each agent benefits from relationships he has established within the community. The benefits stemming from those relationships may be numerous and take the form of a greater access to tacit knowledge or to some information which might be of use to the development of his personal knowledge and competences. However, those gains are submitted to decreasing returns due to the fact that individuals are assumed to be boundedly rational: as the number of acquaintances increases, the volume of knowledge and information (from each of his acquaintances) he is able to process decreases.

Once a relationship has been established, it is assumed that both partners constantly exchange information and knowledge. Hence, those relationships imply a cost related to the disclosure of information and knowledge. Those costs take several forms such as the resources (time and material resources) spent in knowledge codification (Cowan and Foray, 1997, Cowan, David and Foray, 2000).

For the sake of simplicity, the gains and costs arising from one's relationships are expressed as a function of the number of acquaintances a member of the community enjoys. From the preceding discussion on individual characteristics, the behavior of agent *i*, during the rewiring process, is formalized in equation (1).

$$\Phi\left(k_{i,t},\varphi_i\right)=\begin{cases} k_{i,t}^{\gamma}-ck_{i,t}+\varphi_i & \text{if } k_{i,t}^{\gamma}+\varphi_i > ck_{i,t} \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

where *c* represents the individual cost of a relationship and φ_i, the degree of engagement of individual *i* to the community. The return of any new relationship is decreasing at rate γ. It is assumed that individuals are of two types : either they are highly committed to the community (i.e., they choose to contribute extensively to the community's work) or they choose to slightly commit (by choosing to profit from other agents' contributions), leading, respectively, to $\varphi_i=\varphi_{Max}$ and $\varphi_i=\varphi_{\min}$ with $\varphi_{Max}>\varphi_{\min}$. Such a distinction based on the level of engagement has been documented in several contributions on open source software (e.g. Von Krogh, Spaeth and Lakhani, 2003, Hertel, Niedner and Herrmann, 2003). We define $\Delta\varphi=\varphi_{Max}-\varphi_{\min}$ as the difference in engagement between agents

of the system. Highly engaged agents and slightly engaged agents respectively represent a share π and $1-\pi$ of the total number of agents in the system.

III.2. The dynamics of the system.

The aim of our model is to show the structuring process of a community of practice as the outcome of the dynamics of reputation among its members. The dynamics of our system lies at the individual level. Periodically, members of the system take the decision to cease a relationship. The individual initiating this relationship breaking connects with an other member of the community according to the reputation of the latter.

At time 0, a sparse random graph including n agents is built, this graph figures the community of practice. At each timestep, an individual decides to break an existing relationship with one of his acquaintances. This decision is motivated by the fact that the relationship is running short of trust[5] (this point is elaborated in Chapter V). He then tries to bind a new relationship with another member of the community. At this stage, reputation plays a crucial role by reducing the uncertainty associated with the actual competences and behavior of other members of the community[6]. Reputation is a key variable in the process of relationship binding. The agent having severed the existing relationship first tries to link up with the individual with the highest reputation. If he doesn't succeed, he then tries to link up with the individual with the second best reputation. The process continues until he finds an individual to link with.

Contrasting with the relationship breaking up process, which might be led in an unilateral way, the rewiring process requires the mutual consent of both individuals, the individual originating the rewiring process and the potential recipient. In this perspective, at

[5] In order to keep the dynamics of the simulation as simple as possible, it is assumed that the individual initiating the relationship breaking up is randomly drawn.

[6] Reputation is here approximated by the degree of the individual (corresponding to the number of acquaintances). The use of this proxy is motivated by our former discussion on reputation: since it constitutes a device reducing the uncertainty associated with the competences and the behaviour of an individual, there is a positive correlation between reputation and the number of acquaintances an individual enjoys. Moreover, it avoids us to introduce some extra variables in the model, keeping it as simple as possible.

the end of the process, if, for the former, his personal number of acquaintances does not change, the latter's personal network increases of one node. Thus, the actual rewiring decision is subject to the decision rule described by equation (1). It comes out that individual *i* rewires with individual *j* with the following probability :

$$\Pi\left(j \in \Gamma_t^i \mid j \notin \Gamma_{t-1}^i\right) = \frac{k_{j,t-1}\Phi\left(k_{j,t-1}, \varphi_j\right)}{\sum_{s \in V - \{\Gamma_{t-1}^i\}} \left(k_{s,t-1}\Phi\left(k_{s,t-1}, \varphi_s\right)\right)} \quad (2)$$

IV. Numerical analysis.

IV.1. Statistics.

The structuring effects of the social network characterizing the community can be captured by making use of 2 main indicators. The statistics of interest correspond to measures of degree centrality and betweeness centrality. The distribution of degree (corresponding to the number of acquaintances) among individuals constitutes a standard measure of an actor's centrality in the social network (Wasserman and Faust, 1994):

$$\forall i \in V,\ k_{i,t} = \#\Gamma_t^i \quad (3)$$

The distribution of degree allows us to assess the ability of each individual to collect information and, by doing this, to be subject to informational mimesis (which corresponds to

the first attribute of community leaders). In this manner, we assume that the higher the degree, the easier it might be for an individual to collect information and knowledge through interpersonal interactions.

The second statistic, betweeness centrality, corresponds to a measure of the proportion of all geodesics[7] linking any pairs of vertices (which are distinct from each other and from *i*) which pass through vertex *i*. Betweeness is approximately a measure of the number of times an individual occurs on a shortest path between two distinct members of the community (Freeman, 1979). Let g_{jk} be the number of shortest paths (geodesics) linking nodes *j* and *k*. among those, let $g_{jk}(n_{i,t})$ be the number of geodesics linking *j* and *k* and containing *i* at time t (with $i \neq j$, $i \neq k$). The betweeness of node *i* is given by :

$$C_B\left(n_{i,t}\right) = \sum_{j,k \in V-\{i\}: j<k} \left(\frac{g_{jk}\left(n_{i,t}\right)}{g_{jk}} \right) \qquad (4)$$

Out of this definition, betweeness centrality approximately corresponds to an individual's ability to control communication flows occurring within the community. It constitutes an accurate measure of an individual's ability to perform the function of mediator.

For both degree and betweeness centralities, the main concern in this paper is about the evolution of the relational structure of a community which gives rise to the evolution of the social network of the community. This is assessed by making use of average measures for both degree and betweeness. More precisely, since a basic feature of the model lies in the distinction between highly engaged individuals and slightly engaged individuals, average measures of degree and betweeness for highly and slightly committed individuals are computed.

[7] A geodesic binding agents *i* and *j* corresponds to the smallest path linking *i* and *j*.

IV.2. Settings.

The basic structure of the simulation is as follows. We start with a random graph of N = 250 individuals linked to, in average, 10 individuals. Those links are bidirectional. The original network is a relatively sparse graph as it contains 250 x 10/2 = 1250 distinct edges[8] (for a complete graph, the total number of edges would be of 250 x 249/2 = 31125, so only 4% of the possible connections are active). Simulations are run for 15,000 periods by which fluctuations in the statistics become marginal.

A major concern of this model is the assessment of the impact of inequalities (in the degree of commitment) on the relational dynamics of the community. Those inequalities take two forms. Inequalities of the first type, symbolized by the parameter $\Delta\varphi$, correspond to a gap in the degrees of engagement. The second type of inequality, symbolized by π, corresponds to the share of highly committed individuals in the community.

The parameters we vary are therefore two. The first parameter to be varied is the share π of highly engaged individuals. The choice of π as a varying parameter is motivated by the observation of that the organization of communities of practice (and, in particular, open source communities) tend to stretch between two polar cases. At one extreme, they adopt an organization of the Linux type. Such a community, which evolves around Linus Torvalds, relies on his very strong leadership. In practice, the development process is very centralised, few individuals enjoying high degrees of recognition within the community. This case corresponds to the situation of low π values. At the other extreme, the process of development is federal: an important share of the community enjoys a significant influence over the development process. This case, which corresponds to the situation of high π values, might be found in the Apache community.

The second parameter to be varied corresponds to the differential in the levels of commitment of each individual, $\Delta\varphi = \varphi_{Max} - \varphi_{\min}$. The values of the parameters are given in Table IV-2.

[8] Since the links are assumed to be bidirectional, to obtain the number of nodes of the system, one as to divide the sum of degrees of the system by two for the following reason. Let's assume one edge {ij} linking two nodes i and j, since the link is bidirectional, the degree of i and of j are increasing of 1 unit each.

Parameter	Definition	Value
	Individual characteristics	
γ	Individual's behavior elasticity	0.1
c	Marginal cost of a relationship	0.01
$\varphi_{\min}$	Degree of commitment for slightly committed individuals	0.1
φ_{Max} $(\Delta\varphi)$	Degree of commitment for higly committed individuals (gap between highly committed and slightly committed individuals)	0.5 (0.4) – 0.8 (0.7) – 1.5 (1.4)
π	Share of highly committed individuals	0.1 – 0.3 – 0.5

Table IV-2: Parameter settings.

V. Results.

In a first section, we describe the structuring dynamics giving rise to the emergence of leadership by evaluating in particular the dynamics of degree and betweeness for highly and slightly committed individuals. In a second section, we discuss the results by drawing a parallel between the results of the simulation model and open source communities.

V.1. The dynamics of the system and the emergence of leadership.

Figure IV-1 shows the evolution of the average degree for highly engaged and slightly engaged individuals. As in the figures that follow, the results are shown in several panels. In the left panels, the value of $\Delta\varphi$ is of 0.4, indicating a low gap between highly engaged individuals and slightly engaged ones. In the middle panels, the value of $\Delta\varphi$ is of 0.7. The left panels show a wide gap, the value of $\Delta\varphi$ being of 1.4. In all panels various value of π are shown (corresponding to the share of highly committed individuals in the system). The parameter π takes several values: 0.1, 0.3 and 0.5. Upper (respectively lower) panels depict the evolution of the average degree for high (respectively slight) contributors to the community.

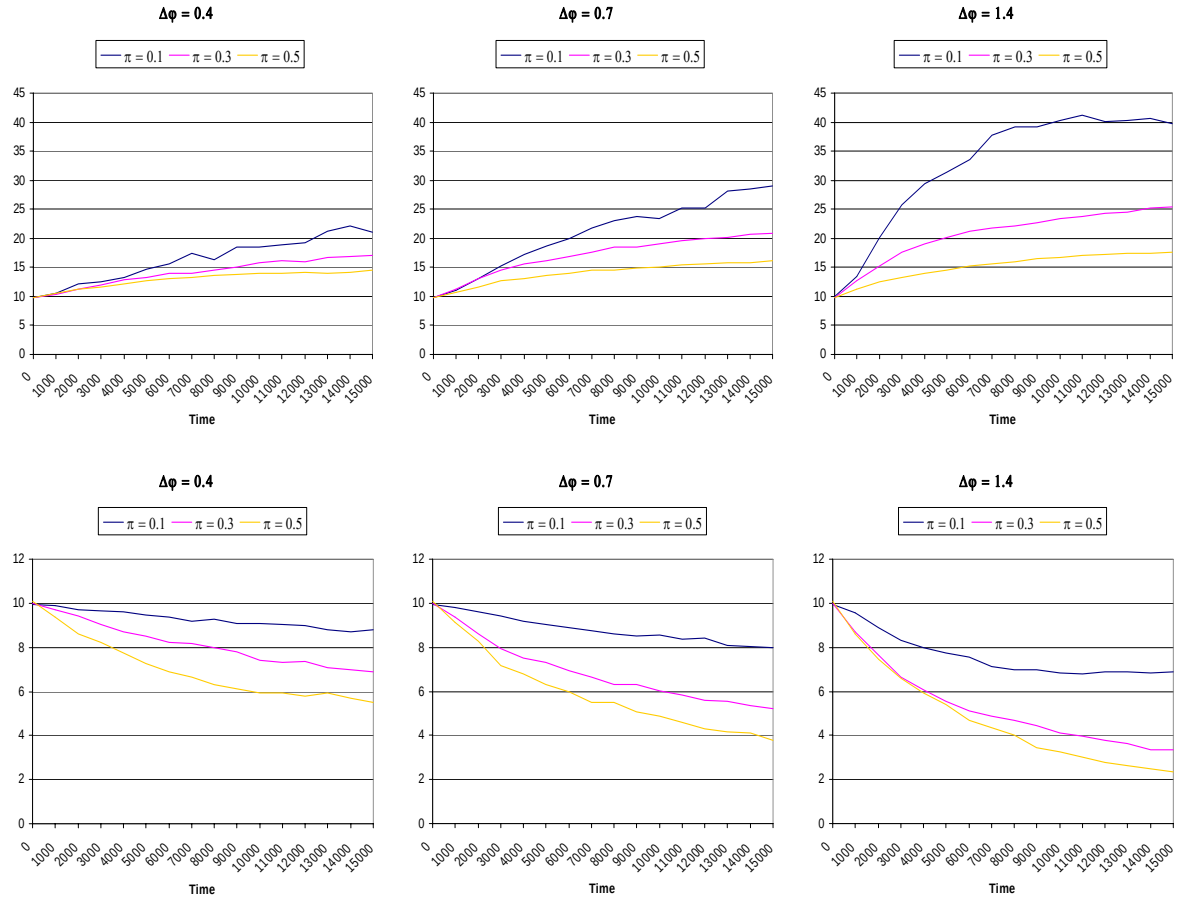

Figure IV-1: Evolution of average degree for highly committed individuals (upper panels) and slightly committed individuals (lower panels).

The average degree for high contributors increases over time (Figure IV-1). On the other hand, the average degree for low contributors steadily decreases. This constitutes a strong evidence of an increase in the variability of degree among members of the community, most of the links being directed towards highly committed individuals. This can be interpreted as a strong polarization of the social network of the community where high contributors attract a significant share of the links.

For highly committed individuals (upper panels), the impact of both parameters under control on the relational dynamics seems to be rather balanced. We nevertheless observe that the impact of the share of highly committed individuals (π) tends to be slightly more important than the impact of discrepancies in the levels of commitment ($\Delta\varphi$) (especially for low values of π). This might be explained in the following way: individual reputation is positively correlated with the degree of commitment. As fewer individuals enjoy a high reputation, other members of the community, when faced with the decision of binding a new relationship enjoy knowledge about only a few individuals. It follows that fewer individuals enjoy new relationships, giving rise to higher discrepancies in the average degree between highly and slightly committed individuals. This is evidenced by the gaps between the curves in each panel.

Both parameters seem to have a marginal effect on the speed of convergence toward the final values of degree, excepted in the case in which the share of highly committed individuals is of 10%. Indeed, in this latter case, it seems that the higher the gap in the commitment levels, the higher the speed of convergence. For slightly committed individuals (lower panels), the impact of both parameters (the gap in the levels of commitment and the share of highly committed individuals) is more ambivalent. In this case, the effect induced by the share of highly committed individuals (π) outperforms the impact of the gap in the levels of commitment.

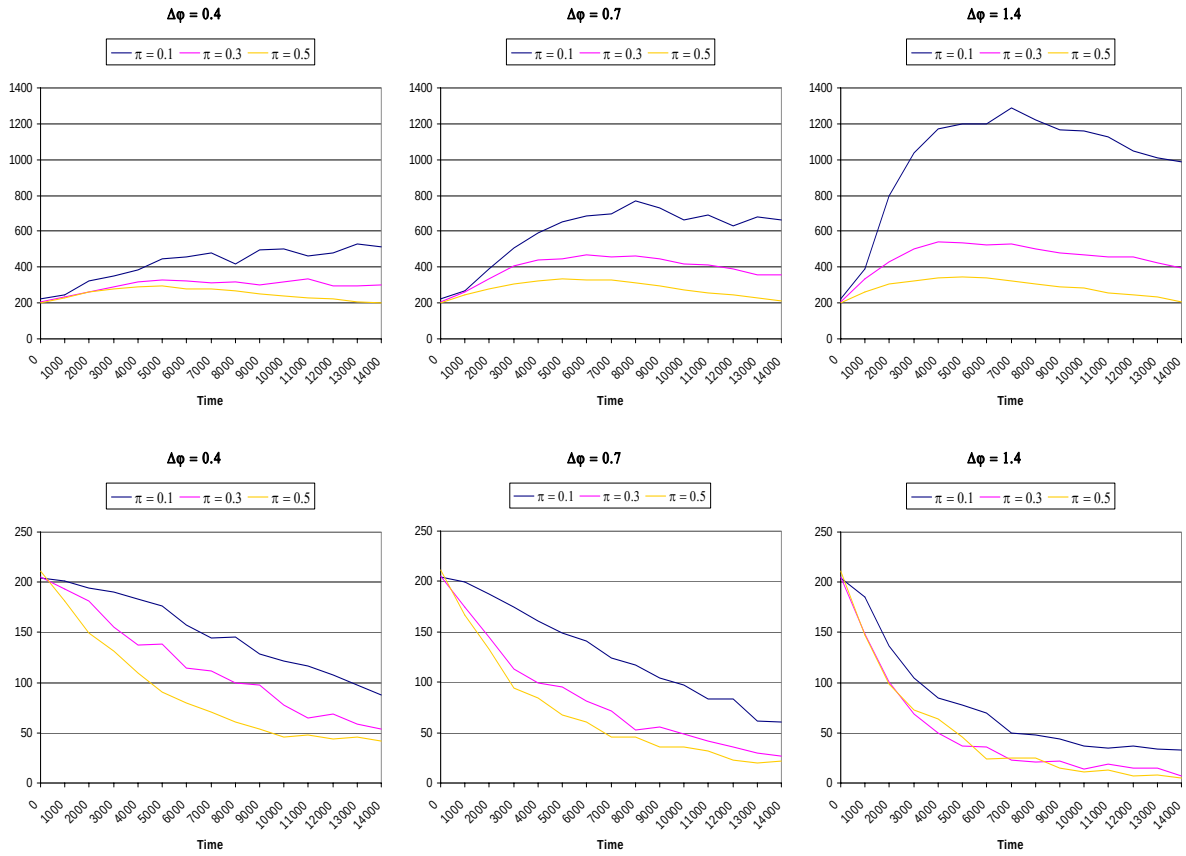

Figure IV-2: Evolution of average betweeness for highly committed individuals (upper panels) and slightly committed individuals (lower panels).

As evidenced in Figure IV-2, the evolution of the average betweeness centrality for high (respectively slight) contributors follows the same pattern of evolution as the average degree (Figure IV-1). Indeed, betweeness is defined as the ability to constrain communication flows among members of the community. Its measure corresponds approximately to the number of times an individual occurs on a shortest path (geodesic) between two distinct individuals. Thereby, higher values of degree increase the individual's probability of belonging to a geodesic between those individuals, increasing in turn the individual's betweeness.

For highly committed individuals, most of the impact of the discrepancies in the degrees of commitment, $\Delta\varphi$, are arising for low values of π. Indeed, when the share of highly committed individuals is low (π = 10%), one can observe that the higher the gap between highly and slightly committed individuals, the higher the highly committed individuals' betweeness centrality. For higher values of π, the value of $\Delta\varphi$ does not have a significant

effect on the dynamics of betweeness centrality. For slightly committed individuals, the values of both parameters, $\Delta\varphi$ and π, do not have a significant impact on the final values of average betweeness. However, they determine the speed of convergence to those final values: the higher the value of $\Delta\varphi$ and the lower the value of π, the quicker the convergence towards the final average values of betweeness centrality.

V.2. The dynamics of the system and the emergence of leadership.

The aim of this section is to confront the results of our simulation study to real cases of communities of practice. Open source software communities are of particular interest since they stretch between two polar types of organization (Kogut and Metiu, 2001). At one extreme, they adopt an organization of the Linux type. Such a community, which evolves around Linus Torvalds, relies on his very strong leadership. In fact, the development process is centralised and subject to hierarchical control. New code is submitted to Torvalds or to one of his few trusted "lieutenants", who decides whether or not to accept it, or requests modifications before adding it to the Linux kernel. In this case, the community organization is very centralized, including multiple layers, new layers being added as the project and the community grow in size. This case corresponds to the situation of a low π value. As evidenced in the simulation results, central members of the community enjoy a very strong leadership status. First, since they enjoy high betweeness centrality values, they are able to act as efficient mediators (Figure IV-2). Second, they are able to concentrate a significant share of the links in the community. This may imply that they are subject to strong informational mimesis effects (Figure IV-1). As evidenced by Bezroukov (1999), the Linux community is structured as an authoritarian mode of governance. Only a small share of the members are allowed to include modifications into the source code of the project. This insures a higher coherence in the outcome of the project.

At the other extreme lies the Apache model. Here, development is federal. While access to the source code and the history information of changes is available to anyone, the ability to make changes is reserved for the Apache board, comprised of people who have been chosen

because of proven ability and past contributions. The submission of new lines of codes is discussed in mailing lists. Mailing-list discussions typically achieve consensus on changes that are submitted. However, particularly controversial topics may call for a vote (Kogut and Metiu, 2001). Apache has adopted a coalitional type of organization which corresponds to a high π value. This model of community is characterized by a weak leadership. First, the ability of highly committed individuals to function as mediators is limited by the fact that they enjoy low betweeness centrality values (Figure IV-2). Second, since they enjoy only low degree values, the extent to which they are subject to informational mimesis effects might be limited.

Conclusion.

The aim of this chapter was twofold. First, it attempted at proposing a definition of reputation applied to the frame of communities of practice. Second, it aimed at highlighting the role of reputation in the dynamics of communities of practice. This chapter started from the observation that classical approaches to reputation, as exposed in the theory of information, were rather inapplicable to the context of communities of practice. One reason for this lies in the fact that they principally rely on game theory as an analytical tool. Hence, reputation is the outcome of an economic calculation: individuals are motivated to behave in a cooperative way (and, therefore, to grow a good reputation) because this allows them to expect subsequent benefits.

This approach to reputation cannot be applied to the context of communities of practice. This is due to the fact that one of the basic traits of communities lies in the existence of knowledge asymmetries (see chapters I and II) while the Theory of Information assumes only

the existence of informational asymmetries. This is why this chapter advocated for a "knowledge based" approach to reputation. More precisely, reputation in the frame of communities of practice is a two-layered concept. The first level corresponds to the communitarian reputation. This reputation is related to an external representation of the knowledge and competences possessed by the community as well as of the social norms the community is based on. Communitarian reputation, by serving as a focal point (in the sense of Kreps (1990)) for community members, constitutes a first coordinating mechanism.

Since every member of the community enjoys the benefit of communitarian reputation, problems of contributing to this public good might appear. This motivates the existence of a second type of reputation which is grounded on individual behaviors. This individual reputation is internal to the community. It allows other members to build their own representation of an individual's knowledge and the intentions through the accumulation of indications about his past activity. Individual reputation fulfils two roles. First, in reducing the uncertainty related to one's competences and behavior, it improves the coordination of agents within the community. Second, by easing the occurrence of first interactions, reputation allows individuals enjoying high reputation levels to benefit from an informational advantage over other members of the community. This translates in increases in their influence over them. Thus, reputation also constitutes an incentive mechanism for contributing to the community by forming the basis to the emergence of community leaders.

However, the scope of reputation in communities of practice is rather limited in its extent. In fact, reputation can only be considered for a first interaction among community members. The present discussion does therefore not account for the basic mechanisms at work in persisting relationships. This issue constitutes the starting point of chapter V which will focus on the evolution of trust in the frame of persisting relationships.

Chapter V. Trust and cooperation in communities of practice.

Introduction♦.

This chapter aims at introducing trust as an important element of the organizational dynamics occurring in communities of practice. More precisely, this chapter argues that the notion of trust constitutes an important factor in legitimizing individuals as leaders or, at least, as full members of a community of practice.

The existence of relationships characterized by high levels of trust has commonly been viewed as a basic feature of communities of practice (see e.g. Cohendet and Diani, 2003) but, to our knowledge, very few contributions tried to provide an "operational" account of the

♦ The theoretical argument of this chapter is based on Cohendet, Patrick, Diani, Morad, Li, Jun and Muller Paul. 2003. Knowledge-intensive Communities and Trust. Paper prepared for the colloquium « La structure cognitive de la confiance », Ecole des Hautes Etudes en Sciences Sociales. Paris, 25-27 septembre.
The simulation model presented in this chapter is based on Muller, Paul. 2004. Reputation, trust, and the dynamics of leadership within Communities of Practice. Paper Presented at the 3rd ETE Workshop, January 29-30, Sophia-Antipolis, France.

notion of trust in the frame of communities of practice (excepted, for example, Bogenrieder and Nooteboom, 2004) and to establish an explicit relationship between the organizational structure of a community and the dynamics of trust. Furthermore, the traditional views of trust have contended its calculative nature: individuals trust each other because they are able to implement deterrence mechanisms aiming at forcing the partner to behave in the expected way. This view proves to be rather unsatisfying in the context of communities of practice principally due to the absence of any contract schemes within the community and the existence of strong knowledge asymmetries among members.

This chapter advocates for a cognitive view of trust: trust is here based on the accumulation of knowledge about a partner's competences and intentions. This knowledge is acquired through the multiplication of interactions among members. Those interactions give rise to an exchange of information about competences and intentions. Furthermore, trust largely affects the credibility and, therefore, the influence of an individual: individuals endowed with low degrees of trustworthiness experience low degrees of credibility in their positions and behaviors and can hardly influence members' opinions. This is why an effective coordination of agents require community leaders not only to enjoy high degrees of reputation but high degrees of trustworthiness too.

This chapter is organized as follows. Section I describes the treatment of trust in classical economic theory. It draws a distinction between the approach to trust in the literature on organization and trust in the literature on networks. It is shown that, although trust in organizations and in networks differ in their nature, both adopt a calculative perspective. Section II tackles the problem of trust in communities of practice. Trust is viewed as a product of cognition in the sense that it builds on the accumulation of knowledge about individual competences and intentions. Furthermore, since the formation of trust embeds two aspects (routinization of behaviors and the construction of a common knowledge base), it goes along with the coordination of individual behaviors. Third, trust, by contributing to the credibility of individual positions, contributes to the relations of influence within the community: individuals enjoying high degrees of trustworthiness are likely to enjoy higher degrees of influence within the community. In this respect, the construction of trust can be associated with an incentive to contribute to the community. Sections III, IV and V propose to simulate the dynamics of trust within communities of practice. In this manner, it is shown that community leaders concentrate high degrees of trustworthiness along with high degrees of

reputation as an outcome of higher levels of contribution to the community. The concentration of high degrees of reputation and of trust allows them to hold their function in a satisfactory way.

I. Classical treatments of trust.

Traditional approaches to trust are generally characterized by their strong calculative nature. Two reasons for the adoption of this calculative perspective can be advanced. The first one lies in the assumption of low degrees of uncertainty associated with the potential outcomes of decisions. In this perspective, it is often assumed that the structure of the problems are sufficiently well-structured to enable agents to forecast (at least approximately) the distribution of outcomes associated with actions. The second reason lies in the strong tradition in economics to model decisions as resulting from trade-offs weighting the known costs and the expected benefits associated with the cooperation with other agents.

Let's consider a prisoner dilemma game. It is here assumed that players 1 and 2 are involved in relationship lasting several periods. They have the choice between two alternatives: either cooperate or betray. It is furthermore assumed that they don't have the possibility to communicate with each other (thus eliminating the reputation factor). The gain associated with each action for each period is given in the following matrix (Table V-1):

		Player 2	
		C	B
Player 1	C	(R ,R)	(S, T)
	B	(T, S)	(P, P)

Table V-1: Payoff structure of the prisonner dilemma game.

The payoffs are ordered as follows : $T > R > P > S$. It is furthermore assumed that $R > \frac{S+T}{2}$ in order to ensure that players 1 and 2 do not exploit the possibility of betraying each on his turn. Two alternative situations may arise:

⇒ Both players have knowledge of the time horizon and know the number of repetitions of the game. In this case, they adopt the betraying behavior and choose not to cooperate. This behavior yields the result P for each player. Such a behavior is produced by backward induction: at the last stage, each player chooses to betray. Knowing this, each player chooses in the preceding stage to betray too. After several iterations of this reasoning, each player is led to play the betrayal strategy at the first round.

⇒ In a famous contribution, Axelrod (1984) relaxed the assumption of known time horizon. In this case, the backward induction reasoning is not valid any more. This gives rise to the possibility of adopting cooperative behaviors for both players.

This model has strongly influenced the neoclassical view of trust as the outcome of an economic computation activity. This view was further anchored by the definition of trust provided by Gambetta (1988, p. 217):

> "trust (or, symmetrically, distrust) is a particular level of the subjective probability with which an agent assesses that another agent or group of agents will perform a particular action, both before he can monitor such action (or independently of his capacity ever to be able to monitor it) and in a context in which it affects his own action […]. When we say we trust someone or that someone is trustworthy, we implicitly mean that the probability that he will perform an action that is beneficial or at least not detrimental to us is high enough for us to consider engaging in some form of cooperation with him."

Two streams of literature have traditionally been concerned with the issue of (calculative) trust: the literature focusing on organizations (and, in particular, the theory of transaction costs) and the literature dealing with interfirm networks.

I.1. Trust in organizations.

In a seminal article, Coase (1937) argued that the use of price mechanisms entails some costs: costs of finding the relevant prices or of concluding a separate contract for each individual transaction taking place on the market. In the case that those costs are too high, the emergence of firms becomes desirable for several reasons. Firstly, the firm becomes a sole source supplier to transactions that are shifted out of the market and into the firm, thus suppressing costs associated market transactions. Secondly, the organization substitutes a single incomplete contract for many complete contracts, thus economizing on costs for negotiating and concluding separate contracts.

However, as argued in chapter IV, the grouping of individuals within a single organization does neither necessarily imply a convergence of interests between the agents and the rest of the organization nor an immediate coordination in the individual actions. Those problems were evocated by Leibenstein (1987) as "hidden prisoner dilemmas". This author introduced the existence of trust as a basic effect explaining the persistence of cooperative behaviors in firms. More precisely, in this context, the notion of trust covers two aspects.

The first aspect is related to the relationship between the individual and the organization[1]. Let's consider a game involving two players, the employee and the organization. Each player has the choice between two decision. The organization (or, similarly, the employer) has the choice between providing the employee with good or bad work conditions. On his side, the employee has the choice between furnishing a high degree of productivity and a low level of productivity. Under the assumption that the collaboration between the individual and the organization is characterized by an undefined time horizon, the best strategy for both players consists in collaborating: the employee furnishes a high productivity rate while the employer provides the employee with satisfying work conditions. In this respect, trust is perceived as the expression of a cooperative behavior.

One should note that this first aspect of trust has been severely questioned by Williamson (1993) who only sees the reciprocal aspect of trust. In this manner, this author gets even further by arguing : "I submit that calculativeness is determinative throughout and that invoking trust merely muddies the (clear) waters of calculativeness." (p. 471). For

[1] One could refer to the treatment of reputation in the frame of organization developed in chapter IV.

Williamson, trust must be limited to personal and loving relations. In economic analysis, rather than a blind trust, it is the agents' calculativeness that allows to determine costs and benefits of cooperation. Hence, the recourse to the concept of trust (in this context) is superfluous and misleading.

The second aspect, which has been notably highlighted by Orléan (1994) and by Williamson (1993), corresponds to the social integration and the existence of reciprocal interest. Members of an organization are often involved in team work (in the sense of Alchian and Demsetz, 1972). One characteristics of team work lies in the strong interdependencies among members: their cooperation yields higher productivity rates. However, the overall productivity rate is often strongly influenced by the least productive individual. For instance, in a chain factory, an employee's productivity rate depends not only on his own productivity but on the productivity of the employees located at earlier stages in the production process. The adoption of shirking behaviors by a few individuals may imply lower productivity rates for the whole team. This social pressure forces each employee to adopt a high productivity rate.

If the first aspect of trust is obviously calculative, the calculative dimension of the second aspect of trust has to be further discussed. In fact, the cooperation of individuals in the frame of a team relies on the integration of a reciprocal dimension. Each individual furnishes high degrees of productivity because they know the negative consequences they would incur if any other member of the team adopts a shirking behavior and furnishes a lower productivity rate. In this manner, this perspective of trust embeds a strong calculative dimension.

I.2. Trust in networks.

As argued in Chapter IV, economic networks can be considered as coordinating devices aiming at facilitating the mutual exchange of complementary forms of knowledge between members. However, to be efficient, the network form of governance relies intensively on the building of mutual trust in the production of knowledge. Indeed, the absence of trust in the

relationship impedes the comparative advantage of network relationships over other types of arrangements (such as integration or formal contracting) since it implies the implementation of costly monitoring devices. This, in turns, contributes to decrease the ability of both partners to adopt flexible behaviors. As stated by Zuscovitch (1998, p. 256), trust in a network context corresponds to:

> "a tacit agreement in which rather than systematically seeking out the best opportunity at every instant, each agent takes a longer perspective to the transactions, as long as his traditional partner does not go beyond some mutually accepted norm."

In the frame of network relationships, trust is relevant in regard to the reliability of other specialized producers of complementary knowledge and reveals in such a context a rather calculative base. Trust in networks is mainly grounded on the actors' embeddedness. As argued by Jones et al. (1997) the relationship between two actors not only influences both partners (relational embeddedness) but influences the relationship with other connected actors too (structural embeddedness). This is due to the fact that each firm can also have knowledge of the evolution of a relationship involving one of their partners. In this perspective, Buskens and Raub (2001) pinpointed two closely related mechanisms through which embeddedness in social contexts may affect trust: learning and control.

⇒ In learning, actors obtain information from previous trust situations about incentives, beliefs and other characteristics of other actors. This information can be obtained from the focal trustor's past interactions. The learning mechanism shapes trust through the formation of common norms, routines and codes of behavior applying to the whole network.

⇒ Control refers to the fact that the firm realizes that its partner has short-term incentives for abusing trust, but that these short term incentives may also be balanced by some long-term motivation for acting benevolently. Long term incentives increase as the density of the network increases since other members have more quickly knowledge of any "problem" occurring in a bilateral interaction. The sanctions triggered by opportunistic behaviors rank from a decrease in the access to external resources to ostracism in some extreme cases.

The traditional conceptions of trust elaborated in the frame of the theories of organization have been mainly translated into a problem of prisoner dilemma. In this case, and under the assumption that both players (the organization and the employee) are engaged in a long term relationship and have no knowledge of the time horizon, the concept of trust corresponds to the expression of both parties having adopted cooperative behaviors. By contrast, the notion of trust developed in the literature on industrial networks puts the emphasis on trust as the outcome of the firm's structural embeddedness. More precisely, the challenge consists here in gathering information about a firm's behavior. Those information are obtained through the accumulation of direct interactions with the considered firm. Firms' cooperativeness is then ensured by the possible appeal to sanctions which can rank from an exclusion from some resources to ostracism. The approaches to trust in both organization theories and the literature on networks pinpoint the strong strategic aspect of trust, cooperative behaviors being ensured by the possible application of sanctions in case of deviating behaviors.

This strategic aspect is much less patent in the case of communities of practice, partly due to the relative difficulty in identifying deviating behaviors (because of the heterogeneities in the possible admitted behaviors) coupled with the limited effectiveness of sanctions (coming from the informal character of communities). Those limitations call for a different type of trust which is mainly grounded on the gathering of information about partners' knowledge, behaviors and beliefs. Moreover, the relative ineffectiveness of sanctions in the frame of communities doesn't necessarily mean the generalization of opportunistic behaviors. In fact, cooperative behaviors are induced in other ways which are also related to trust.

II. Trust in communities of practice.

Beyond their diversity, communities of practice share some common important traits. Such communities are bound by relations of common interest, purpose, or passion, and held together by routines and varying degrees of mutuality (with no implicit reference to moral order or homogeneity of membership). Among these common traits, one is repeatedly underlined by the literature: members of a given community share common values, and the interactions between them are governed by a type of trust grounded in the respect of the common social norms of the community. Trust within the community can be measured when one can observe that the behaviors of the participants, exposed to an unexpected event, are not guided by their short run interest but adopt a cooperative behavior. This question of trust is central to the understanding of a community. In such a perspective, Nooteboom (1999a, pp. 347) argues that non-calculative trust is not unavoidably blind:

> But I accept that trust should not be blind because trustworthiness has its limits: it may be breached by a "golden opportunity", and some people are more resistant to such temptation than others. Here I retain some of the perspective of TCE."

The aim of this section is to describe in more details the notion of trust employed in communities of practice. In this perspective, it will be first proposed a definition of trust. The emphasis will then be put on the properties of trust in a coordination and in a motivational perspective.

II.1. A definition of trust applied to communities of practice.

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. It is a situation where the other part cannot be forced to fulfil this expectation, i.e. there is a risk of betrayal. Therefore, trust consists in accepting a certain level of risk (or vulnerability) and all relations of trust suppose such bet (Coriat and Guennif, 1996). This bet is validated then by the experience and the practice. Due to the existence of this bet, trust can therefore hardly be reduced to a simple index of calculative probabilities. In this manner, agents' decisions and behaviors are the partial[2] outcome of cognition and correspond to their specific, qualitative and idiosyncratic evaluations (cf. Rocco *et al*. (2001).

This cognitive form of trust refers to a current state, the ability of the individual to perform tasks related to the practice. The cognitive dimension focuses on the "rational" bases for trust. It emphasizes that trust is based on partial knowledge and thus frequently involves a search for evidence on which to base one's trust. It therefore focuses on characteristics of the trustee such as competence, reliability, and credentials and refers:

> "both to judgements of competence and reliability about the other members of a team (…). Judgments of competence are based upon verifying instances of predictably professional behavior (i.e., correct task execution), while reliability refers to the congruence between words and actions" (Rocco *et al*., 2000, p. 12).

The definition of cognitive trust provided by Rocco *et al*. highlights two of its characteristics: cognitive trust embeds a competence element as well as a judgement on the intentions of the individual (his reliability). In fact, according to Nooteboom (1999a), "There is an important difference between competence trust and intentional trust. The first pertains to someone's ability to perform, and the second to his intentions to do so." (pp. 346). The distinction drawn by Nooteboom proves to be particularly relevant in our framework since, from our preceding discussion, it turns out that trust (in the same way as reputation) is closely tied to practice. Competence trust refers to a current state, the ability of the individual to perform tasks related to the practice. Trust about intentions has to be understood in a prospective way. It corresponds to the belief that an individual will, in the future, behave for

[2] Even it will not be salient in our further developments on trust in communities of practice, one should note that cognitive trust is closely related to the existence of interpersonal feelings. This leads to the existence of an emotional form of trust as a close complementary to cognition based trust. Emotional trust refers to "development of non-calculative and spontaneous emotional bonds and affect among two or more people. Emotional trust is demonstrated through confidence and openness in sharing ideas, feelings and concerns" (Rocco et al., 2001, p. 11).

the good of the community either by contributing to the present practice or by contributing to an evolution of the practice in a beneficial way for the community.

II.2. Local coordination and the foundations of trust.

Cognitive trust has been defined as a subjective expectation about one's competences and intentions, this expectation being grounded on the information accumulated during past interactions. Trust relies on two effects. The first effect corresponds to the formation of a common knowledge base. The accumulation of interactions allows individuals to build up a common knowledge base which, by contributing to reinforce the commonalities among individuals, strengthens cognitive trust. In turn, this reinforces each partner's capacity to understand each other's behaviors (i.e. their reciprocal empathy) (Nooteboom, 2003). For high degrees of empathy, they are even more likely to forgive any deviation from the expected behaviors because they are more able to track the basic factor motivating it.

The second effect which can be highlighted is the formation of trust as grounded on the routinization of behaviors (Nooteboom, 2002) meaning that people adopt specific recurring patterns of interactive behaviors. In this perspective, Klein Woolthuis *et al*. (forthcoming) argued that:

> "Routinization […] emerges when a relation has been satisfactory for a while and awareness of opportunities for opportunism is relegated to 'subsidiary awareness' […]: one takes the relation for granted and does not continuously think about opportunities to gain extra advantage from it, nor does one consider the other to do so."

Routinization of behaviors entails two positive characteristics in the perspective of trust building. First, as pointed out by Klein Woolthuis *et al*., routinization allows to save on the costs associated with the negotiation of the objectives of the interaction as well as the relevant behavior to adopt during the interaction. This contributes to build trust since individuals

would engage into opportunistic behavior only if it yields significant gains relatively to the recurrent interaction pattern. Second, due to the use of common codes of behaviors, routinization allows to increase the richness and the effectiveness of the relationship which, in turns, contributes to reinforce the building of a common knowledge base.

The foundation of trust, by relying on the creation of a common knowledge coupled with routines of interaction among partners goes along with coordination among them. First, the creation of a common knowledge base allows each individual to shape a representation of the mental model of his partner. Second, as pointed out by Becker (2003b) routines contribute to the coordination of individuals due to several of their attributes: 1) by giving regularity, unity, and systematicity, it saves on the costs associated with the perpetual re-definition of the processes involved at the start of each interaction. 2) by providing instructions in the form of programs, routines complement the building of a common knowledge base by providing the actors with procedures allowing not to mobilize the entire knowledge base but only the parts relevant to the present circumstances. In fact, at each interaction, the whole common knowledge base is seldom fully mobilized. Rather, routines prescribe some basic rules guiding the choice of the elements to be mobilized during the interaction. 3) routines contribute to tame the risks associated with the possible adoption of conflicting behaviors (which may be adopted in reaction to evolution in the environment), thus contributing to establish a truce. In fact, the risk of adopting unexpected (and, in this way, possibly opportunistic) behaviors is determined by the evolutions of the environment. Taking into account the role of routines in an interaction implies a trade-off for each partner: either they choose to stick to their routinized behavior or they adopt an other behavior. But, in the latter case, the costs associated to the new, possibly opportunistic, behavior have to significantly exceed the costs associated with its experimentation.

Still, one may wonder about the existence of the starting point of this virtuous circle in which cognitive trust, common knowledge base and routinization reinforce each other. An answer to this apparent paradox lies, along with the recourse to reputation, in the adoption of a strategic behavior at the start of the relationship: in the absence of any commonalities, the agent engages in a relationship in the limits set by a comparison between the potential lost (in the case that his partners adopts an opportunistic behavior) and the potential gains (in the case that he acts benevolently). With the accumulation of successful interactions and of

information about the partner, there is a progressive switch from strategic behaviors to behaviors characterized by cognitive trust.

If trust builds on the disclosure and exchange of signals during interactions, they might also be linked with the cognitive advancement of the community. This motivates the approach of trust as an incentive device ensuring the actual contribution of community members to the common enterprise.

II.3. Trust and incentives.

If, by extensively relying on trust, the economic foundations of communities of practice deviate from standard institutions (Adler, 2001), this does however not mean a total absence of economic incentives underlying their action. In fact, if intrinsic motivations for contributing as well as some degree of altruism exhibited by members constitute an important device for the cognitive progression of communities, the role of extrinsic incentives has been also largely acknowledged:

> "Of course, altruism exists and can do marvels in certain circumstances, but the altruistic hypothesis fails to explain why programmers do not focus their generosity on more needy beings and why free riding would be less pervasive than in biotechnology or other industries." (Lerner and Tirole, 2001, p.822).

Internal motivations are commonly viewed as the direct, personal interest in contributing to the advance of the common enterprise. This constitutes an intrinsic motivation and translates, for instance, into a satisfaction arising from the resolution of a puzzle (Stephan, 1996) or from the satisfaction associated with a given work position (Kreps, 1997).

External incentives are generally viewed as related to career concerns such as the perspective of access to a well remunerating job or to an enhanced access to venture capital (Lerner, Tirole, 2001). However, starting from the argument of chapter I, we shall argue that another types of external incentives is related to a specific feature of communities of practice,

namely the development of specific interaction patterns. Those specific patterns of interactions are arising as the outcome of differentials in the level of trust enjoyed by individuals (see chapter I). More precisely, trust (along with reputation, see chapter IV) differentials lead the community to develop an internal "hierarchy" in which high levels of trust some members of the community enjoy allow to benefit from significant influence over other members (cf. Zand (1972) for further discussion on the relationship between trust and influence). Such types of internal organization have already been acknowledged in the frame of open source software where communities of free software development structure around an hierarchy of "kernel contributors" (Dalle, Julien, 2003). The relationship between trust and the motivation for contributing to the community is rather direct. As pointed out in chapter I, trust mainly builds on the accumulation of signals disclosed from an individual to his partners. Two attributes of signals feed trust relationships. First, it allows to decrease the uncertainty associated with one's competences since each signal embeds a strong informative content, thus fuelling competence trust. For instance, signals in open source communities consist in advices and pieces of codes. In this way, they can inform the partner about the knowledge and the degree of programming skills of the individual.

Second, the signalling activity is commonly viewed as implying some costs. Those costs may come from the codification of signals or from the feeling of being dispossessed from a private information. The existence of signalling costs induce the belief that the individual perceives an interest in maintaining the relationship. He will keep on acting benevolently, thus reinforcing intention trust.

One should however note that there is a strong gap between perceptions of the contribution cost on the contributor side and on the side of the partners: partners tend to systematically over-valuate the actual cost of contributions while this cost is, from the contributor's perspective, relatively negligible. The negligibility of contribution costs (as perceived by the contributor) is grounded on several factors. Firstly, as pointed out by Lakhani and von Hippel (2003) in a study of the Apache helpdesk, the time actually spent in contributing to the community is about 2% of the time spent in the communitarian activity (e.g. reading messages or seeking needed information). Secondly, the information and knowledge embedded in the signal are often considered as "almost" public. The individual does therefore not suffer from the feeling of being dispossessed from a crucial private piece of information or of knowledge (Lakhani and von Hippel, 2003). Finally, signalling can also be

viewed in a learning perspective. More precisely, a community member having disclosed a signal can expect potential feedbacks from his peers. This effect is common in open source communities in which pieces of codes can be significantly enhanced by the control and the corrections provided by peers.

In the frame of communities of practice, trust consists in taking a bet on a partner's behavior while being vulnerable against opportunism. Trust is therefore associated with the idea that the individual incurs the risk of opportunistic behaviors without being able to induce the partner to behave in the appropriate way. However, this bet is still considered as relying on a rational basis. First, the risk took by the individual to expose himself to a possible betrayal is motivated by the potential gains that may arise out of a successful interaction. Second, trust is not blind and rests on the accumulation of interactions with partners. In this perspective, routinization of behaviors and the building of a common knowledge, by facilitating the occurrence of the interaction and increasing its richness, play paramount roles in the building up of trust.

Finally, by its very nature, the process of trust is closely related to inter-individual coordination and motivation. Coordination is fulfilled through routinization and the creation of a common knowledge base among partners. On the same time, trust builds on the accumulation of signals of competence and of goodwill emitted by partners, those signals corresponding to contributions to the cognitive work of the community. In this respect, trust is associated with motivation since it is clearly related to influence relationships: higher levels of trust lead an individual to be more receptive to the influence of a partner, thus allowing highly trustworthy individuals to exercise some influence over their partners.

Next sections attempt to formalize the previous discussion on the foundations of trust in communities of practice. More specifically, it shows that communities tend to organize around a few individual enjoying high degrees of reputation and trust. The accumulation of relationships characterized by high degrees of trust allows them to exercise their influence over the whole community and acquire the status of community leaders.

III. A model of community's relational dynamics including trust.

An important issue tackled by the present model deals both with the process of relationship formation among members of a community of practice and the stability of those relationships. To put it shortly, the model decomposes as follows. A population of individuals is located on a graph, each agent having direct connections to a small number of other agents. The graph symbolises the community. Each agent is characterized by a degree of "engagement" which corresponds to the amount of time he wishes to devote to the community. Members of the community are bound together through links of different strengths, the strength of a link accounting for the level of trust. At each time step, all agents forming the graph consider the decision whether to disclose or not a signal to each of their acquaintances. This signalling process gives rise to a reassessment of the strength of the state of trust existing between members of the community. The disclosure of a signal gives rise to a reinforcement of the trust relationship binding the receiver to the emitter. In the other case, the trust relationship is weakened. If the level of trust between a member of the community and one of his acquaintances falls below a given threshold, the former ceases his relationship with the latter and engages in a new relationship with an other member of the community according to the reputation of the latter. This model does not take into account the problem of the genesis of communities. Rather, the model focuses on the relational dynamics as the outcome of the evolution of trust relationships

III.1. The individual characteristics.

At time 0, let us consider n individuals located on an undirected[3], sparsely connected random graph $G_0 = (V, \Gamma_0)$, where $V = \{1,\ldots,n\}$ is the set of community members (vertices)

[3] Since the maintaining of any relationship requires the mutual consent of both partners, the graph describing the social network of the community is undirected. However, in the frame of the relationship binding two agents A

and $\Gamma_0 = \left\{ \Gamma_0^i, \forall i \in V \right\}$ is the list of connections where $\Gamma_0^i = \left\{ j \in V \,|\, \{ij\} \in G_0 \right\}$ ({ij} representing the link between agents *i* and *j*) constitutes the neighbourhood of agent *i* at time 0 or, similarly, the set of individual *i*'s acquaintances at time 0.

Each individual $i \in V$ is characterized by an absolute degree of engagement in the community, φ_i, which is assumed to be fixed over time. This level of engagement, which is positively correlated with his level of activity within the community, determines individual's *i* signalling intensity. In this manner, the higher his level of engagement, the more signals he might disclose towards his acquaintances. The level of engagement might be understood as the level of agent *i*'s interest in the community's work.

Beside any consideration related to the level of engagement, each agent benefits from relationships he has established within the community. The benefits stemming from those relationships may be numerous and take the form of a greater access to tacit knowledge or to some information which might be of use to the development of his personal knowledge and competences. However, those gains are submitted to decreasing returns due to the fact that individuals are assumed to be boundedly rational: as the number of acquaintances increases, the ratio between the number of processed signals and the number of received signals steadily decreases.

During the rewiring process, the gains and costs arising from one's relationships are expressed as a function of the number of acquaintances a member of the community enjoys. Moreover, all signals are considered to be of equal quality. This assumption is technical since it allows us not to consider the quality of signals but the impact of signalling frequencies on the building of trust relationships among community members.

Any trust relationship implies a cost for members of the community. Indeed, trust relationships have to be submitted to constant exchanges of signals ensuring the partners of one's intention to maintain the relationship. Furthermore, the production of signals raises costs in terms of time and of mobilized resources.

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and B, the level of trust from A to B might be different from the level of trust from B to A. Put differently, whereas the graph describing the social network of the community is considered as undirected, the "trust network" describing the strength of ties binding each of the members of the Community is directed.

Trust is the outcome of a signalling process involving members of their community and each of their acquaintances. Trust results from the accumulation of signals an individual has emitted towards his acquaintances. But, conversely, each time an individual chooses not to disclose a signal to one of his acquaintances, the level of trust originating from the latter to the former decreases. Moreover, trust is not reciprocal: in a relationship between two individuals A and B, the level of trust A grants to B might not be equal to the level of trust from B to A. This is due to the fact that members of the community are endowed with different levels of motivation for contributing to the project of the community. They therefore enjoy different levels of activity in the community, implying different levels of trustworthiness. Finally, in line with Nooteboom (1999a), the level of trust one may enjoy from other members of the community of practice is limited. This is due to the fact that trust can apply "only up to some 'golden opportunity' of opportunism which goes beyond a partner's ability to resist temptation, or up to a crisis which may force a partner to defect in order to survive" (Nooteboom, 1999a, p. 347).

From the preceding discussion on individual characteristics, the behavior of individual *i*, during the rewiring process, can be formalized as follows.

$$\Phi\left(k_{i,t},\varphi_i\right)=\begin{cases}k_{i,t}^{\gamma}-ck_{i,t}+\varphi_i & \text{if } k_{i,t}^{\gamma}+\varphi_i>ck_{i,t}\\ 0 & \text{otherwise}\end{cases} \qquad (1)$$

where c represents the individual cost of a relationship, and φ_i, the degree of commitment of an individual to the community. The return of any new relationship is decreasing at rate γ. The parameters γ and c are assumed to belong to some interval [0,1[. It is assumed that individuals are of two types : either they are highly committed to the community (i.e., they choose to contribute extensively to the community's work) or they choose to slightly commit (by choosing to make few contributions to the community's work and to profit from other agents' contributions), leading, respectively, to $\varphi_i=\varphi_{Max}$ and $\varphi_i=\varphi_{\min}$ with $\varphi_{Max}>\varphi_{\min}$. We define $\Delta\varphi=\varphi_{Max}-\varphi_{\min}$ as the difference in engagement between agents of the system. Highly engaged agents and slightly engaged agents respectively represent a share π and $1-\pi$ of the total number of agents in the system.

III.2. The dynamics of the system.

The aim of our model is to show the structuring process of a community of practice as the outcome of the dynamics of trust and reputation among its members. The dynamics of our system lies at the individual level and decomposes into two main steps. The first step deals with the evolution of trust among members of the community. The second step occurs as soon as the level of trust between two members of the community goes below a certain threshold. At this stage, the relationship is broken and the individual initiating this relationship breaking connects with an other member of the community according to the reputation of the latter.

At time 0, a sparse random graph including n agents is built. Each relationship is characterized by a (randomly drawn) level of trust. At the start of the simulation, the levels of trust characterizing relationships have values ranging from $trust_{Min}$ to $trust_{Max}$. Moreover, trust is not reciprocal, meaning that, for two agents A and B, the level of trust characterizing the relationship from A to B is not equal to the level of trust in the relationship from B to A.

At each time step, for each of his acquaintances, each agent takes a decision whether or not to disclose a signal (consisting in information, knowledge or code). This decision depends on the degree of engagement φ of the agent. In practical terms, the signalling dynamics can be presented in the following way: At time t, each agent i (with $i=1,...,n$) scans the list of agents composing the network. For each agent j directly linked to agent i, agent i takes the decision whether to disclose a signal $s_{i\to j}$ to j or not. The probability for i to disclose a signal depends on i's level of commitment:

$$\Pr(s_{i\to j}) = \begin{cases} \sigma_{Min} \; if \; \varphi_i = \varphi_{Min} \\ \sigma_{Max} \; if \; \varphi_i = \varphi_{Max} \end{cases} . \qquad (2)$$

After the signalling procedure, agents assess for each of their acquaintances the degree of trustworthiness of the latter. For example, if an agent A got a signal from B, A reassesses positively his trust in agent B. This is operated through an increase of τ_{inc} units in the level of trust originating from A to B. In the opposite case, i.e. if A did not get any signal from B, the level of trust from A to B decreases of τ_{dec} units.

After this reassessment process, if the level of trust one member of the community addresses to an other goes below a threshold $trust_{thresh}$, the former breaks up the relationship and connects with an other member of the community. At this stage, reputation plays a crucial role by reducing the uncertainty associated with the actual competences and behavior of other members of the community[4]. Reputation is a key variable in the process of relationship binding. Agents having severed an existing relationship first try to link up with individuals with the highest reputation. If they don't succeed, they try to link up with the individuals with the second best reputation. The process continues until every individuals having initiated a relationship breaking find agents to rewire with.

However, contrasting with the relationship breaking up process which is led in an unilateral way, the rewiring process requires the mutual consent of both individuals, the individual originating the rewiring process and the potential recipient. In this perspective, at the end of the process, if, for the former, his personal number of acquaintances does not change, the latter's personal network increases of one node. Hence, the actual rewiring decision is subject to the decision rule described by equation (1).

It comes out that individual *i* rewires with individual *j* with the following probability :

$$\Pi\left(j \in \Gamma_t^i \mid j \notin \Gamma_{t-1}^i\right) = \frac{k_{j,t-1}\Phi\left(k_{j,t-1}, \varphi_j\right)}{\sum_{s \in V - \{\Gamma_{t-1}^i\}} \left(k_{s,t-1}\Phi\left(k_{s,t-1}, \varphi_s\right)\right)} \qquad (3)$$

In terms of trust, since, by definition, a new relationship is characterized by a strong uncertainty (even though reputation contributes to mitigate this uncertainty), any new relationship is characterized by a low level of trust. This level is set to $trust_{Min}$.

[4] Reputation is here approximated by the degree of the individual (corresponding to the number of acquaintances). The use of such proxy is motivated by our former discussion on reputation: since it constitutes a device reducing the uncertainty associated with the competences and the behavior of an individual, there is a positive correlation between reputation and the number of acquaintances an individual enjoys.

IV. Numerical analysis.

IV.1. Statistics.

The structuring effects of the social network characterizing the community can be captured by making use of 2 main indicators. As in chapter IV, the statistics of interest correspond to measures of degree centrality and betweeness centrality. The distribution of degree, $k_{i,t}$, (corresponding to the number of acquaintances) among vertices of the system constitutes a standard measure of an actor's centrality in the social network (Wasserman and Faust, 1994):

$$\forall i \in V,\ k_{i,t} = \#\Gamma_t^i \tag{4}$$

As argued in chapter IV, the distribution of degree allows us to assess the ability of each individual to collect information and, by doing this, to be subject to informational mimesis.

The second statistic, betweeness centrality, is approximately a measure of the number of times an individual occurs on a shortest path between two distinct members of the community. Thus, it constitutes an approximate measure of an individual's ability to control information flows. The betweeness of node i is given by:

$$C_B\left(n_{i,t}\right) = \sum_{j,k \in V-\{i\}: j<k} \left(\frac{g_{jk}\left(n_{i,t}\right)}{g_{jk}} \right) \tag{5}$$

Where g_{jk} is the number of (geodesics) linking nodes j and k and $g_{jk}(n_{i,t})$ is the number of geodesics linking j and k and containing i at time t.

Since a basic feature of the model lies in the distinction between highly engaged individuals and slightly engaged individuals, average measures of degree and betweeness for highly and slightly committed individuals are computed.

Finally, apart from our interest in the relational dynamics of communities of practice, our interest also lies in the evolution of trust among members of the community. A rather straightforward way to assess the evolution of trust is given by the average level of trust an individual enjoys. Let $\omega_{j\to i,t}$ be the level of trust individual i enjoys from individual j at time t, the average level of trust an individual i enjoys at time t is thus given by:

$$\bar{\omega}_{i,t} = \frac{\sum_{j\in\Gamma_t^i} \omega_{j\to i,t}}{k_{i,t}} \qquad (6)$$

The use of this statistic entails some advantages over other possible statistics such as the measure of the overall level of trust an individual i enjoys (given by $\sum_{j\in\Gamma_t^i} \omega_{j\to i,t}$). These are the following: firstly, it constitutes a very simple and clear statistic, thus easing the interpretation of the results. Secondly, the value taken by $\bar{\omega}_{i,t}$ does not depend on the size of the individual's personal network. However, by using such statistics, one always has to bear in mind that it constitutes only an instant measure of the current level of trust an individual enjoys within the community. For instance, since the building of trust constitutes a long term process, the use of such statistic might temporarily disadvantage highly active individuals who set up numerous new relationships in comparison with individuals with few, long lasting, relationships. Average measures of trustworthiness are computed for both highly and slightly committed individuals.

IV.2. Settings.

The basic structure of the simulation is as follows. We start from a random graph of N = 250 individuals linked to, on average, 10 individuals. Those links are bidirectional. The original network is a relatively sparse graph as it contains 250 x 10/2 = 1250 distinct edges (for a complete graph, the total number of edges would be of 250 x 249/2 = 31,125 so only 4% of the possible connections are active). Simulations are run for 10,000 periods by which fluctuations in statistics dealing with network structure become marginal. Indeed, as shown in

Figure V-1, after 10,000 time steps, for every set of parameters (the differential Δφ between highly and slightly committed individuals as well as the share π of highly committed individuals), the floating average converges to values inferior to 0.2.

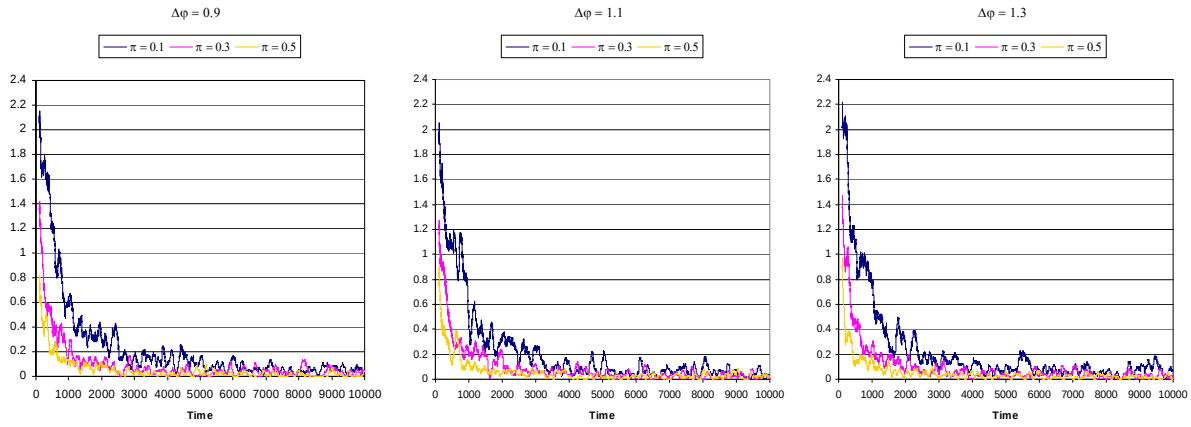

Figure V-1: Ties redirections (floating average over the last 100 time steps preceding the observation).

A major concern of this model is to assess the impact of inequalities on the relational dynamics of the community. Those inequalities take two forms. Firstly, $\Delta\varphi$ corresponds to a gap in the involvement of members in their community. Secondly, π corresponds to inequalities in the distribution of the characteristics of individuals. The parameters we vary are therefore two. By setting the value of $\varphi_{\min}$, we vary the value of the level of commitment for highly committed individuals, φ_{Max}. This allows us to assess the impact of $\Delta\varphi$ on the structure of the community. The second parameter under focus corresponds to the share π of highly committed agents present in the system. Parameter settings are given in Table V-2.

Parameter	Definition	Value
	Individual characteristics	
γ	Individual's behavior elasticity	0.1
c	Marginal cost of a relationship	0.01
$\varphi_{\min}$	Degree of commitment for slightly committed individuals	0.2
φ_{Max} $(\Delta\varphi)$	Degree of commitment for slightly committed individuals (gap between highly committed and slightly committed individuals)	1.1 (0.9) – 1.3 (1.1) – 1.5 (1.3)
π	Share of highly committed individuals	0.1 – 0.3 – 0.5
	Trust parameters	
$trust_{Min}$	Level of trust at the start of a relationship	2
$trust_{Max}$	Maximum level of trust	30
$trust_{thresh}$	Trust threshold for the interruption of a relationship	1
σ_{Min}	Signalling frequency for slightly committed individuals	0.2
σ_{Max}	Signalling frequency for highly committed individuals	0.85
τ_{inc}	Increase in the level of trust after signalling	0.5
τ_{dec}	Decrease in the level of trust	0.12

Table V-2: Parameter values.

As argued in chapter IV, the choice of π as a varying parameter is motivated by the observation of that the organization of communities of practice (and, in particular, open source communities) tend to stretch between two polar cases. At one extreme, they adopt an organization of the Linux type. Such a community relies on a very strong leadership. In practice, the development process is very centralised, few individuals enjoying high degrees of recognition within the community. This case corresponds to the situation of low π values.

At the other extreme lies the Apache model. Here, development is federal: since all members of the community has the right to express his opinion on the project or to disclose new code, a significant share of the community enjoy high levels of recognition as significant contributor to the community. The internal organization of the community is of a coalitional type which corresponds to high π values.

V. Results.

V.1. The dynamics of the system and the emergence of leadership.

Figure V-2 shows the evolution of the average degree for highly committed and slightly committed individuals. As in the following figures, the results are shown in several panels. In the left panels, the value of $\Delta\varphi$ is of 0.9, indicating a low gap between highly committed individuals and slightly committed ones. In the middle panels, the value of $\Delta\varphi$ is of 1.1. The left panels show a wide gap, the value of $\Delta\varphi$ being of 1.3. In all panels various value of π are shown (corresponding to the share of highly committed individuals in the system). The parameter π takes several values: 0.1, 0.3 and 0.5. Upper (respectively lower) panels depict the evolution of the average degree for high (respectively slight) contributors to the community.

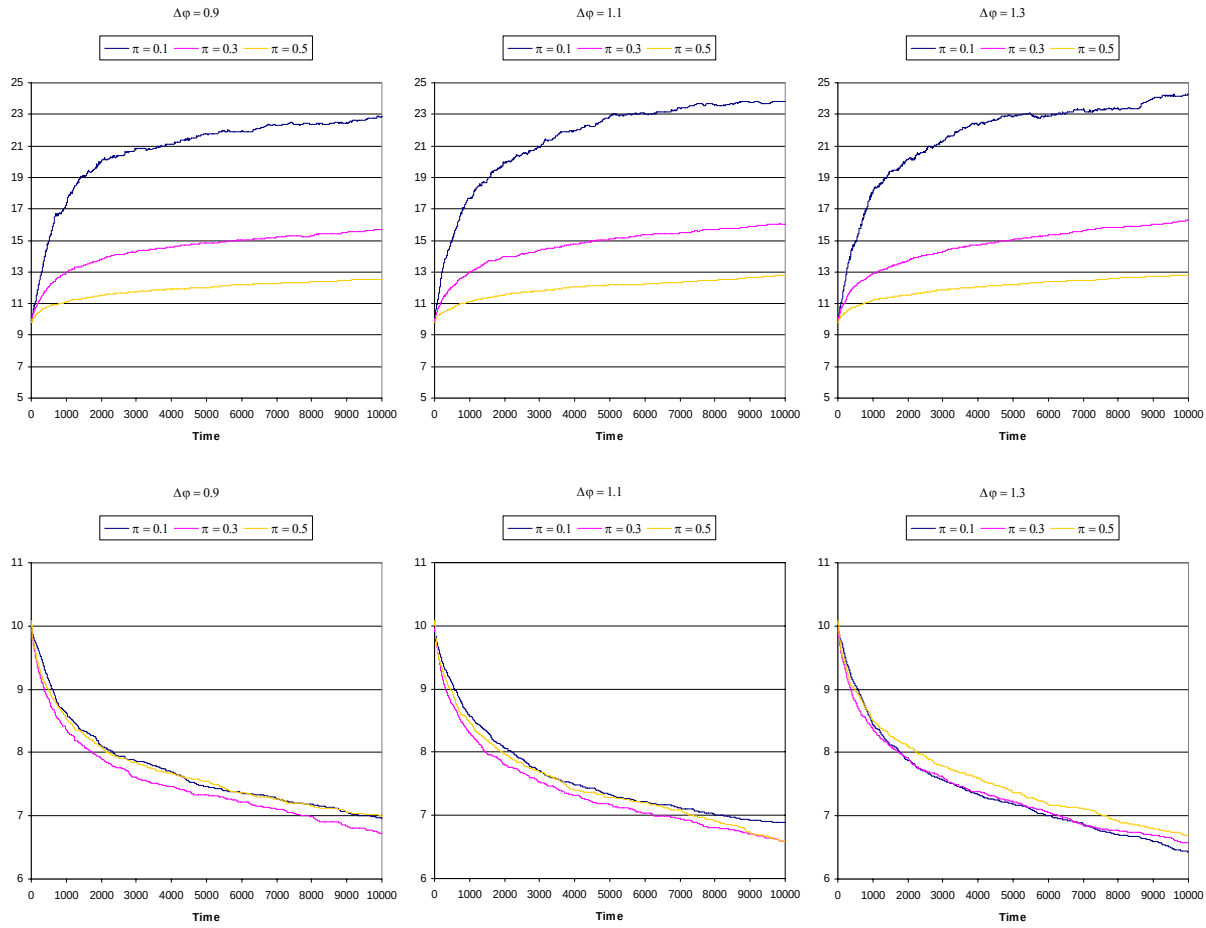

Figure V-2: evolution of average degree for highly committed individuals (upper panels) and slightly committed individuals (lower panels).

As in the model presented in chapter IV, one can easily observe that both average degree and average betweeness for high contributors increase over time (Figure V-2 and V-3). On the other hand, average degree and betweeness for low contributors steadily decrease. This can be interpreted as a polarization of the social network of the community where high contributors achieve central positions in the network whereas low contributors are rejected to peripheral positions. One may therefore conclude that, while highly engaged individuals become leaders, slightly engaged ones are marginalized by being rejected to the periphery of the community. However, we underline the fact that this polarization remains rather limited as shown by the maximum final values taken by average degree for highly committed individuals, which is of 24. Thus, we are far from a star-shaped network and leadership is held by several members of the community.

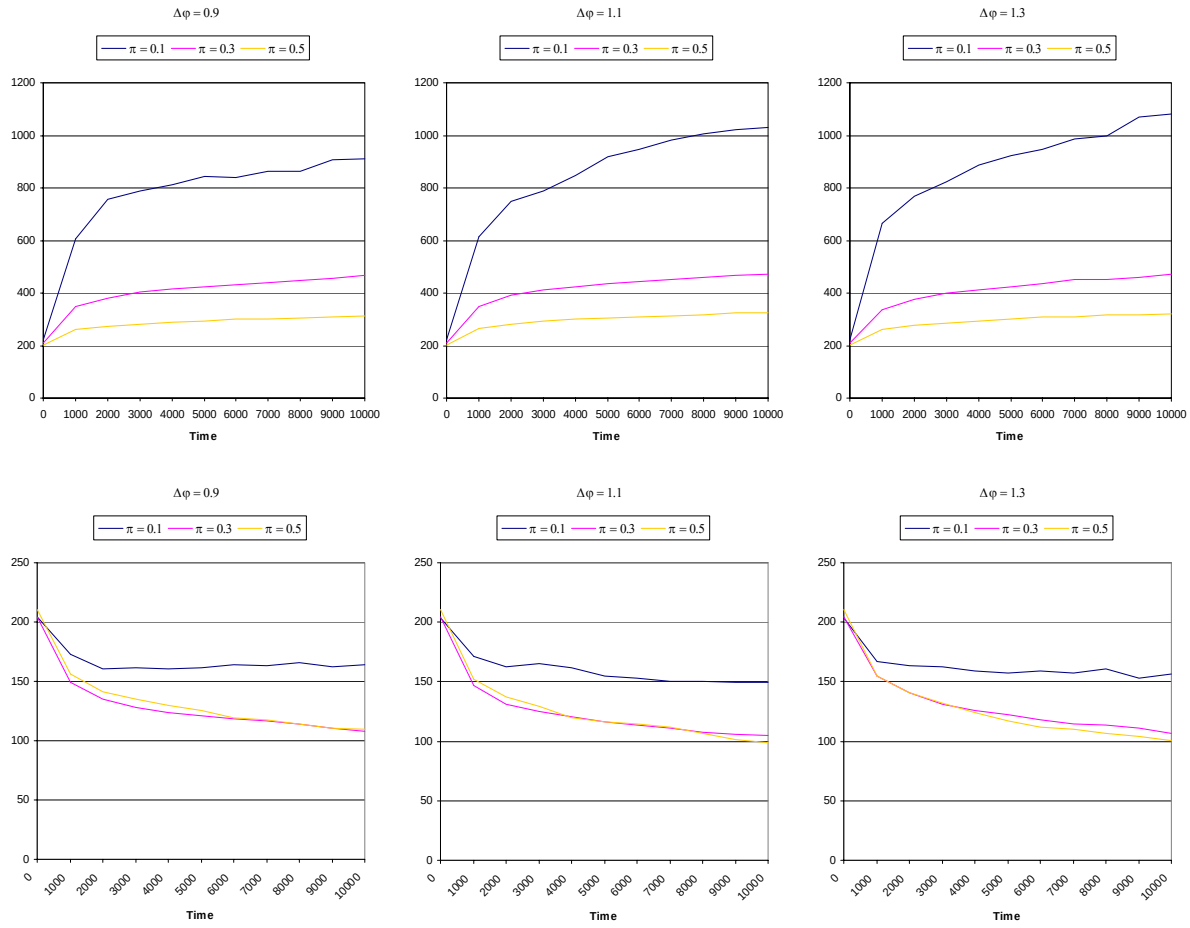

Figure V-3: Evolution of average betweeness for highly committed individuals (upper panels) and slightly committed individuals (lower panels).

Moreover, variability in both degree and betweeness tends to increase as the inequalities in the individual characteristics increase (through a higher value of $\Delta\varphi$ and a lower value of π). However, the impact of π exceeds the effect of $\Delta\varphi$. For high π values, more individuals choose to commit themselves deeply to the work of the community. Both degree and betweeness become distributed among more individuals, giving rise to a "distributed leadership effect". The hierarchical structure becomes flat. On the other hand, for low π values, leadership concentrates among few individuals, the hierarchy adopting a sharp, pyramidal structure.

V.2. Linking leadership and trust.

After having discussed the process of leadership settlement, we now turn to the issue of its legitimacy. Figure V-4 displays the difference between average trustworthiness for highly committed individuals and average trustworthiness for slightly committed individuals corresponding to $\bar{\omega}_{i,t}^{Max} - \bar{\omega}_{i,t}^{Min}$ where $\bar{\omega}_{i,t}^{Max}$ corresponds to the average degree of trust for highly committed individuals whereas $\bar{\omega}_{i,t}^{Min}$ is the average degree of trust for slightly committed members. Trust is conditioned by the emission of signals: the emission of a signal implies an increase in the level of trust from the recipient of the signal towards the emitter. If no signal has been emitted, the level of trust decreases.

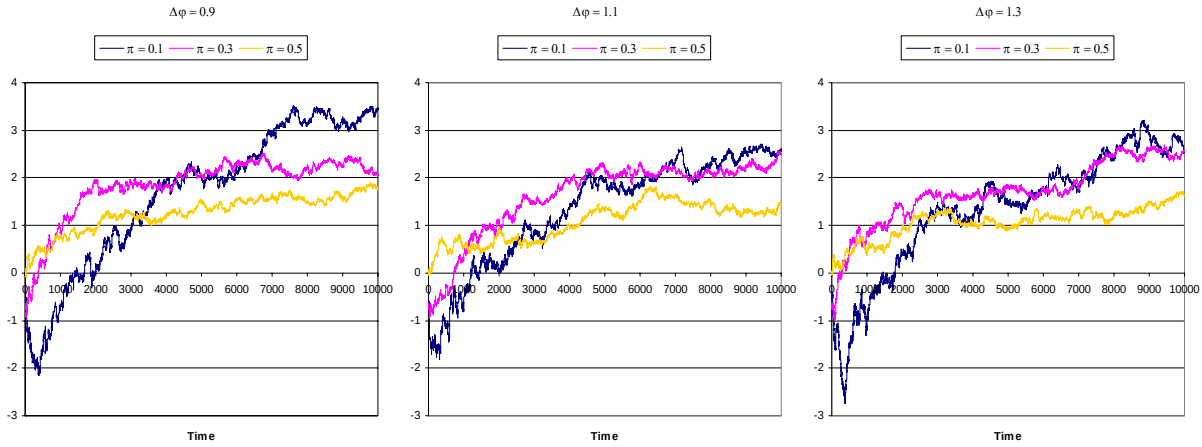

Figure V-4: Average trust for highly committed vs. slightly committed individuals.

The evolution of trust might be decomposed into two main stages (Figure V-4). The first stage, occurring at early times in the simulation, is characterized by the fact that highly engaged individuals are significantly less trustworthy than slightly engaged ones. This could be explained by referring to Figure V-1. According to this figure, early stages of the simulation are characterized by a high network activity with numerous relationship breakings and bindings. Such a process of relationship binding mainly advantages highly committed individuals at the expense of slightly committed ones (cf. Figure V-2). However, those benefits may imply some drawbacks which are the outcome of two effects. First, it has been argued that new relationships are characterized by low levels of trustworthiness. Establishing numerous relationships implies for highly committed individuals a decrease in their average trustworthiness. Second, slightly committed individuals operate a selection among their

relationships, retaining the more trustworthy ones and dropping the lesser trustworthy. This latter effect supports an increase in slightly committed individuals' average trustworthiness.

The second stage of the simulation is characterized by a reversal of the preceding observation: highly committed individuals become more trustworthy than slightly committed ones. It has been argued that trust is the outcome of a signalling activity. This signalling activity might be characterized along two main dimensions. The first dimension corresponds to a historical perspective. The construction of trust is a time consuming process and involves the exchange of numerous signals among partners. It follows that trusted relationships are characterized as being long lasting. The second dimension corresponds to the frequency in the signal exchanges: the higher the signalling frequency, the quicker the building of trust (cf. chapter I). At early stages of the simulation, slightly committed individuals mainly benefit from the former effect. But, as highly committed individuals have settled into long lasting relationships, they accumulate the effect of both the historical and the frequency dimension of trust building. This allows them to outperform slightly committed individuals.

Lastly, the length of stage 1 is determined to a great extent by the value of π. For low values of π, stage 1 lasts 1,500 periods and this value decreases as π increases. For low π values, few highly committed individuals concentrate most of the new relationships. This implies a strong decrease in their levels of trustworthiness. On the other hand, as π increases, the network activity tends to be more distributed, benefiting to a higher share of the community. This mitigates the negative impact of the number of new relationships.

The results of this simulation can be summarized as follows. First, in line with the model of chapter IV, the internal structure of the community is, to a large extent, determined by the share π of highly committed individuals. Low values for π imply a rather authoritarian mode of governance, a few individuals acquiring a central position within the social network of the community while most of the members are rejected to its periphery. By contrast, high values for π imply a more coalitional mode of governance, a significant share of the community enjoying an influence over the community. As it will be shown in chapter VI, the implementation of an authoritarian mode of governance insures a significantly higher degree of coherence in the communitarian activity in comparison to the coalitional model. However, as shown in the discussion on the evolution of trust, in an authoritarian model, leaders are also characterized by their difficulty in reaching high levels of trustworthiness.

Whereas, in the authoritarian mode of governance, the influence of community leaders over the community might produce higher degrees of coherence, a coalitional structure enables leaders to gain their legitimacy more quickly.

Conclusion.

The purpose of this chapter was to study of the role of trust in the internal organization of communities of practice. The starting point of this chapter lay in the observation that traditional approaches to trust usually failed to address this issue in the context of communities of practice. Traditional approaches to trust are mainly characterized by the possibility of applying deterrence mechanisms. In this perspective, trust exhibits a strong calculative dimension: the decision of trusting an individual results from the comparison between the potential gains and the potential lost the partner incurs in the case of an opportunistic behavior.

By contrast, trust prevailing within communities of practice is of a different nature. It corresponds to the capacity of taking a bet on the partner's behavior without being able to induce him to adopt the expected behavior. In this perspective, trust implies a certain level of vulnerability to opportunistic behaviors. However, in opposition to the argument of Williamson (1993) trust is not blind, it relies on the knowledge related to an individual's behavior, those knowledge being collected through the accumulation of interactions. More particularly, interactions give rise to the diffusion of signals from each partner. Signals consist in pieces of knowledge or information related to the practice of the community.

It follows that trust, *via* this signalling activity, fulfils two distinct functions. The first function consists in the coordination of individual members. It is fulfilled through the building up of commonalities among members of the community. More precisely, the construction of commonalities consists in routinization of interactions as well as the construction of a common knowledge base. Second, trust can also constitute an incentive mechanism for contributing to the community by legitimizing community leaders. Since trust relies on a signalling activity, higher degrees of trust are associated with higher signalling frequencies. In turn, higher degrees of trust imply higher degrees of influence of the trustee on the trustor, thus contributing to the efficiency of leadership (cf. Zand, 1972).

This discussion on trust allowed us to complement our developments on leadership in chapter IV. The simulation model we proposed in sections III to V not only showed that leaders don't immediately acquire their legitimacy immediately. In fact, the speed at which it is acquired depends on the internal structure of the community: while, in coalitional structures, the legitimacy of leaders is obtained relatively quickly, in the case of centralized structures, it takes them longer to be perceived as legitimate.

The discussion has so far only focused on the relational dynamics and the emergence of leadership within communities of practice. In particular, the issue of individual specialization has been largely overlooked. In fact, the models proposed insofar assumed that the field of specialization within the community had no impact on the decision of binding a new relationship with other individuals. Moreover, the emphasis has been only put on the individual relationship and the relationship between the individual and the community as a whole has been ignored. Finally, from a theoretical point of view, trust, by being grounded on the construction of commonalities among community members, only acts at a local level by contributing to the coordination of partners. The issue of the global coordination of communities of practice has been insofar the object of very little developments. The purpose of Chapter VI is precisely to tackle this series of important questions. In this way, the relationship between individual specialization and loyalty to the community will be described. This will give us the opportunity of exploring in more depth the role of community leaders in favouring the coherence of the community.

Chapter VI. Leadership and the global coordination and cohesion of communities of practice.

Introduction.

The aim of this chapter is to present the basic mechanism underlying the cohesion and the global coordination of agents within communities of practice. In this way, the role of community leaders in coordinating and contributing to the cohesion of communities of practice is highlighted.

Previous chapters have pointed out the roles of reputation and trust in communities of practice. Chapter IV was focusing on the concept of reputation within communities of practice. 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. Chapter V was concerned with the issues raised by trust. Trust corresponds to a psychological state enabling to take a bet on a partner's behavior without being able to induce him to adopt the expected behavior. Trust builds on the information gathered during previous interactions. Trust and reputation are central for learning to take place in communities of practice since they allow a certain degree of flexibility in individual behaviors, thus enabling agents to enter into learning and knowledge production processes.

Moreover, if trust contributes, through the building of commonalities among partners, to inter-individual coordination, it does, by definition, fall short in ensuring coordination at the community level. The aim of this chapter is to tackle this "macro-coordination" issue. This issue is of importance since it also conditions the problem of the cohesion and survival of communities of practice. Given that members are not bound to the community by any contractual schemes, they are able to exit it at any time. Since, apart from their degree of "affinity" with the goals of the community, an other factor conditioning their interest lies in the relative success of the communitarian activity, the issue of the coordination at the community level becomes crucial. If this coordinating task is partially fulfilled by social norms and the existence of a common practice, it is importantly complemented by the emergence of community leaders who build their status on their high individual reputation.

The objective of this chapter is to tackle the problem of the coordination and the cohesion of communities of practice. It more specifically focuses on community leadership as a coordinating device. This chapter is organized as follows. Section I 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. In this way, community leaders, through the influence they exert on individual behaviors, play an important role in the coordination and the success of the communitarian activity. Sections II and III will present a simulation model studies the conditions under which coordination through leadership is likely to be beneficial for the community.

I. The problem of exit in 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 argued in chapter I, this coordination problem is partly overcome by the existence of social norms. Social norms correspond to a set of general rules and principles of voluntary behavior. 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. However, due to their high degree of generality, social norms only partially succeed in coordinating individual behaviors. Coordination is achieved through the complementary action of community leaders.

The purpose of this section is to propose an hirschmanian interpretation of the coordination of members and the cohesion of communities of practice. More precisely, by drawing the argument from the famous work of Albert O. Hirschman (1970), "Exit, Voice, and Loyalty", we will, in a first part, explain the basic problems of the coordination and the cohesion of communities. It will notably been argued that the problems of voice and exit (according to Hirschman's terminology) are only partly mitigated by the existence of social norms. In a second part, we will point out the role of leadership as an important complement to the former coordination device.

I.1. The problem of exit and voice in communities.

The starting point of the argument lies in the observation that communities of practice are often subject to discrepancies between the individual objectives and the common goals.

The accumulation and the deepening of those discrepancies is reflected in a rising disagreement expressed by the individual. This disagreement, although not directly perceived by other members of the community, translates in two effects. The first effect consists in the exit of some of its members. The second effect at stake consists for them to enter into a process of protest (of voice in Hirschman's terminology).

Exit has been subject of an important focus in economics. It stems from decreases in the interest expressed by the individual to the common enterprise or from his growing interest for alternative communities. This absolute or relative decrease in the individual's interest in contributing to the community gives rise to the expression of a dissatisfaction from members of the community and they choose to manifest it by their exit. The efficiency of exit as a response to declines in the interest for the common enterprise depends on the leaders' ability to perceive those exit and to correctly interpret them.

Voice is defined by Hirschman as "any attempt at all to change, rather than to escape from an objectionable state of affairs, whether through individual or collective petition to the management directly in charge, through the appeal to a higher authority with the intention of forcing a change in management, or through various types of actions and protests, including those that are meant to mobilize public opinion" (*ibid.* p.30). Voice is viewed as a political alternative to exit by raising discussions or disputes between members. The efficacy of voice depends on its volume as well as on the position of the individual having expressed his dissatisfaction. More precisely, the efficiency of a protest movement reaches higher levels if it is initiated by central members of the community than by peripheral individuals. Hirschman envisions voice as an alternative mechanism to exit in the case that the latter is not possible (as in the case of the relationship between states and their citizens or of the relationship between a monopolist firm and its customers).

The recourse to voice and exit options depends on several factors such as the existence of viable alternatives for the individual or the costs of entering such a process. Another factor, which has been particularly highlighted by Hirschman, is the loyalty to the community. Loyalty has been defined in chapter II as the capacity of a community to rise the support of its members to the overall objectives. The basic purpose of loyalty is to make exit less likely even though it would give rise to more frequent recourses to the voice mechanism (Hirschman, 1970).

Increases in the levels of loyalty presuppose that individuals are convinced of the usefulness and the efficiency of their action (and, possibly, of their protest) to the community. This implies several aspects. The first aspect, which has been sketched earlier in this discussion, is dealing with the social position of the individual. Central individuals are more likely to be loyal than more peripheral members because they are convinced of their capacity to influence the whole community.

Since the effectiveness of the voice option depends on the capacity for protesting people to be understood by other members, the second aspect of loyalty is dealing with the cognitive distance between the individual and other members of the community. Cognitive distance among individuals is the outcome of differences in their mental categories yielding differences in their capacity to perceive, interpret and understand their environment. Cognitive distance induces increases in the degree of diversity within the community, thus triggering more opportunities for the community to develop. However, too high degrees of diversity in the cognitive frames of the members may jeopardize the cohesion of the community for several reasons. First, it impedes their capacity to transmit their ideas and knowledge to the rest of the community. Second, cognitive distances between members contribute to increase the dispersion in individual motivations: individuals tend to favour their own centres of interests while ignoring others' objectives (Leibenstein, 1987). The existence of a balance between cognitive distance and cognitive proximity is therefore central for communities to raise a high degree of loyalty without impeding the capacity of its members to propose beneficial evolutions (Nooteboom, 1999b and 2000).

As argued in chapter I, social norms, along with the building of a common knowledge base, contribute to reduce cognitive distance while preserving a certain degree of freedom in individual behaviors. They allow to guide individual behaviors by informing members about the basic objectives of the community as well as the ways to reach them. Yet, norms leave them a relatively high degree of freedom since the prescribed goals are general enough to leave a certain degree of flexibility in individual behaviors.

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. This yields different and even conflicting perspectives among members of the community as well as between the community (as a whole) and its members. Moreover, in a more dynamic

perspective, loyalty is always evolving due to the accumulation of individual experiences (Akerlof, 1983) and evolutions in the environment[1], thus motivating evolutions in the social norms of the community. The conjunction of those two limitations of social norms in raising loyalty to the community appeal for the use of leadership as a complementary mechanism in raising loyalty.

I.2. Leadership in support of social norms in maintaining loyalty.

In chapter I, leadership was defined as the capacity to influence individual behaviors through the influence exerted on information and knowledge flows. This involves two complementary effects: the ability to constrain communication flows and a preferential access to information and knowledge. The ability to constrain communication flows offers leaders the opportunity to filter knowledge and information flows. This selective screening allows them to affect individual beliefs, thus influencing their decisions in a given direction (Foss, 2001). Moreover, community leaders enjoy a preferential access to information and knowledge. This enhanced access to information and knowledge enables them to influence community members more efficiently through informational mimesis. Hence, community leaders play important roles in maintaining the loyalty 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.

It has been previously argued that an important factor influencing members' loyalty lies in the sharing of cognitive commonalities. Cognitive proximity, which translates in the sharing of common cognitive frames and perspectives, may emerge spontaneously from intense communication among members. However, the building of such common frames is a time consuming process involving the exchange of large amounts of (often tacit) knowledge. Moreover, this process of commonalities building presupposes the building of barriers to exit in order to force individuals to "stick" to the community. This is obviously in deep

[1] for instance, evolutions in the environment may lead to decreases in the value provided by the communitarian activity

contradiction with the very nature of communities of practice, whose activity is relying on the freedom offered to their members to set the nature and the level of their contribution. This explains why the role of leaders in raising loyalty in communities of practice is of paramount importance. Due to their central position within the communication network of the community, they are likely to shape the communication processes and, thus, to exert an influence on the collective outcome (Witt, 1998).

More precisely, due to their privileged position within the communication network, community leaders are likely to be more connected to each other and, in this way, to propose a more coherent vision of the community. This is due to the high degree of reputation they enjoy within the community of practice. As pointed out in chapter IV, the 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. The same argument can also be reversed: since binding new relationships entails some costs (e.g. the time and resources mobilized for exchanging signals), it might be rational for solicited leaders to condition their agreement to the reputation of the relationship-seeker. To put it shortly, new relationships are occurring at the first place among highly reputed leaders. At a second place, they can involve highly reputed leaders with slightly reputed members. A primary effect of this high degree of relationships density among community leaders is that they are more likely to influence each others' behaviors. It follows that a consensus among community leaders may emerge through the accumulation of interaction. This, in turn, allows them to propose to other members a coherent vision of the prospective evolution of the community, thus enhancing the loyalty to the community and the coordination of its members (Foss, 1999).

Another central aspect for maintaining loyalty lies for the community to maintain the (absolute or relative) interest of its members in the common enterprise. This notably implies the capacity for individuals to evolve in their behavior after evolutions of the community's environment. Social norms, by allowing a wide range of behaviors, partly address this issue. However, one factor likely to hinder new behaviors to be adopted lies in decreases in the levels of trust existing among individuals. It has been argued in chapter V that one factor affecting trust lies in the emergence of routinized behaviors. Since the reasons underlying the adoption of an unusual behavior might be not understood by the affected partner, any changes

in the behavior translates in a decrease in the level of trust among partners. Due to their numerous connections with other members of the community coupled with their high degree of trustworthiness, leaders can act as go-between between both partners, thus enhancing their cooperation.

In order to better grasp this effect, let's consider a coordination game involving two players, 1 and 2 who have to choose between two types of behaviors, A and B. The payoffs associated with each decision are given in the following matrix:

		Player 2	
		A	B
Player 1	A	1;1	-1; -1
	B	-1; -1	2;2

Figure VI-1: Payoff structure for the coordination game.

It is assumed that both players have previously adopted the strategy A. (A,A) and (B,B) are both Nash equilibria. One can observe that (B,B) yields higher payoffs than (A,A). However, since both players previously agreed on (A,A), it constitutes a focal point of this game, leading them to stick to this equilibrium in the absence of any external influence. As a go-between, a community leader can change each player's beliefs by convincing them to change their strategy and to choose B. The efficiency of the leader's action depends, in turn, on his degree of trustworthiness: the influence on players' beliefs is higher for high degrees of leader's trustworthiness.

A major issue conditioning the success of communities of practice lies in the problems of coordination and exit of its members. Those problems are closely related since the issue of coordination is linked to the problem of maintaining a high level of efficiency in the community's activity. In the same time, the issue of exit corresponds to a problem of maintaining and reinforcing their interest in contributing to the community or, similarly, their loyalty to the community. Members are motivated to actively contribute to the community's work only if they perceive the usefulness of their action. This is naturally conditioned by their capacity to be understood by other members, thus raising the question of the coordination of members.

An important factor affecting the coordination of agents lies in the building of commonalities among them. They are more likely to coordinate if they adopt common cognitive frames and a common behavior. This, in turn, reinforces their interest in contributing to the community and, thus, moves away the possibility of exit. Social norms, by partly conditioning agents' behaviors, provide a minimal mechanism for their coordination. However, it has to be complemented by community leaders who, through an influence exerted on members' behavior, enhances their coordination and, therefore, their loyalty. 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.

II. A model of behaviors 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.

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 the evolution in individual behaviors as the outcome of multiple external influences.

By contrast, 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. 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. 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. Indeed, unlike models of 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'. Finally, the model proposed in this paper focuses on the relationship between social characteristics and group dynamics. More precisely, the model assumes heterogeneities in the members' reputation and aims at evaluating the impact of the influence of communitarian leaders on the evolution of individual behaviors.

II.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 $\forall i = 1,...,N, x_{i,0} \in X = [0;1]$ 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). The behavior adopted by members of the community depends on the knowledge they possess. Thus, each member of the community is rational in the sense that he adopts the current behavior he supposes to be the most appropriate given his current knowledge. Influence relationships may therefore be viewed as acts of knowledge transmission.

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 resembles social stratification phenomena in which individuals tend to interact only with persons sharing the same behavior or some common traits. For instance, members of an OSS community are more likely to be influenced by other people the closer their behavior. Moreover, 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.

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[2] of the software. The knowledge of most of the contributors 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. Moreover, in the same study, von Krogh et al. 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 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

[2] A module corresponds to a piece of code related to a specific feature of the software. Each module is composed of several program files which code for one or several functions of the module.

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.

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. chapter I and IV). 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 allows to provide the individual with a higher visibility within the sub-community he is belonging to, thus increasing his ability to influence other members of the project. 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:

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

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.

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.

II.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:

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

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:

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

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:

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

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

Simulation were run for 80 000 periods and included 250 agents. The rate of behaviors' convergence, δ, is set to 5%. Ultimately, the concern of the model is twofold. First, to which extent does the degree of specialization of each agent affect the dynamics of individual behaviors ? More specifically, this analytical challenge is related to the impact of the building of a common knowledge base or, similarly, the level of overlapping in the knowledge held by community members on behavior dynamics. Second, does the structure of governance of the community affect its coherence ?

As argued in preceding chapters, the literature on open source communities (e.g. Kogut and Metiu, 2001) has pinpointed the coexistence of different types of governance: the structure of the community may be either very centralized (as in the case of linux), few leaders possessing the ability to influence the whole community, or more distributed structures (as in the case of Apache) in which a significant share of the community has the ability to direct behaviors. Tackling those two questions, the parameters we vary are therefore two. First, the level of specialization, φ, takes three values. 0.3 refers to a high level of specialization: only individuals having a behavior distant of less than 0.3 to a member's behavior being able to communicate with him. The other values are 0.325, indicating an average level of specialization, and 0.35, corresponding to a low level of specialization. Second, community structure is controlled by the share of individuals enjoying high reputation levels. As previously discussed, reputation, since it constitutes a prerequisite for leadership, forms an approximation of it. Thus, the second parameter we vary is the proportion π of individuals enjoying high reputation levels: $\pi = 0.1$ corresponds to the case of a centralised structure similar to Linux, few members of the community enjoying a leadership status. $\pi = 0.3$ corresponds to the case of a distributed structure similar to Apache, a significant share of the community enjoying an enhanced ability to direct the individuals' behaviors. Finally, the reputation value of leaders, R^{Max}, is set to 5 whereas the reputation R^{Min} of other members of the community is set to 2.

III. 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 positions of community leaders have been restricted to intervals X_{Max} = [0;0.7], [0;0.8], [0;0.9] and [0;1], this latter interval corresponding to the situation in which community leaders are uniformly distributed in the behavior spectrum X. Moreover, we are also interested in assessing the consequences of disagreements among community leaders[3]. In this case, community leaders are equally split between two intervals and the values of X_{Max} become $[0;0.35]\cup[0.65;1]$, $[0;0.4]\cup[0.6;1]$, $[0;0.45]\cup[0.55;1]$. 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.

III.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.

[3] In the open source literature, a famous instance of a strong disagreement between community leaders is found in the definition of ownership regimes. Historically, the birth of open source software corresponds to the settling of the GPL licence during the early 80's which notably states that any software using parts of code of a software under GPL licence has to disclose its source code. In the mid 90's, the Debian license has been introduced in order to soften some of the conditions imposed by the GPL (particularly on the regime of code disclosure). Now, those two ownership regimes are coexisting.

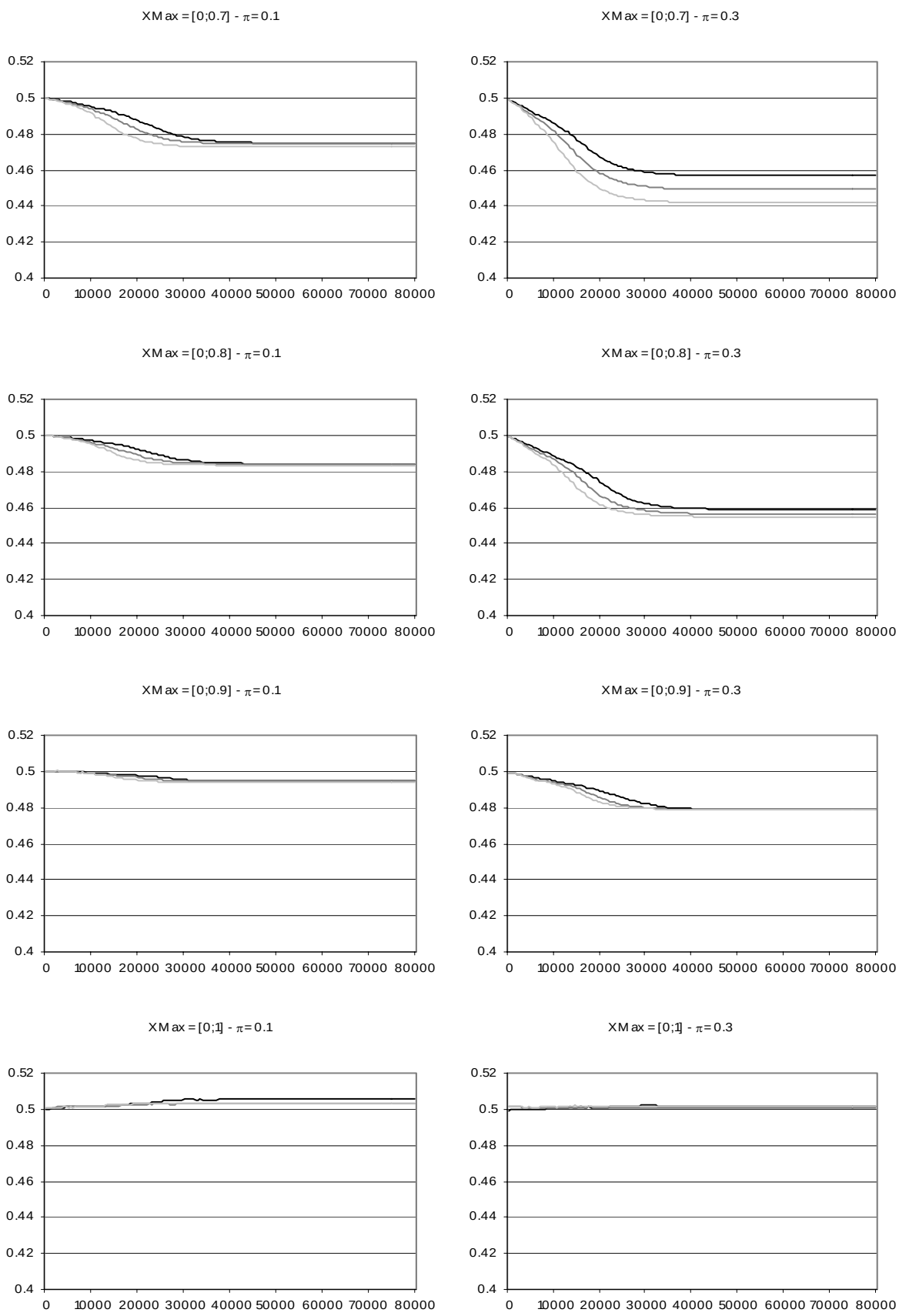

Figure VI-1a : Average behavior for R_{Min} individuals: φ = 0.3, black curve; φ = 0.325, dark grey curve; φ = 0.35, light grey curve

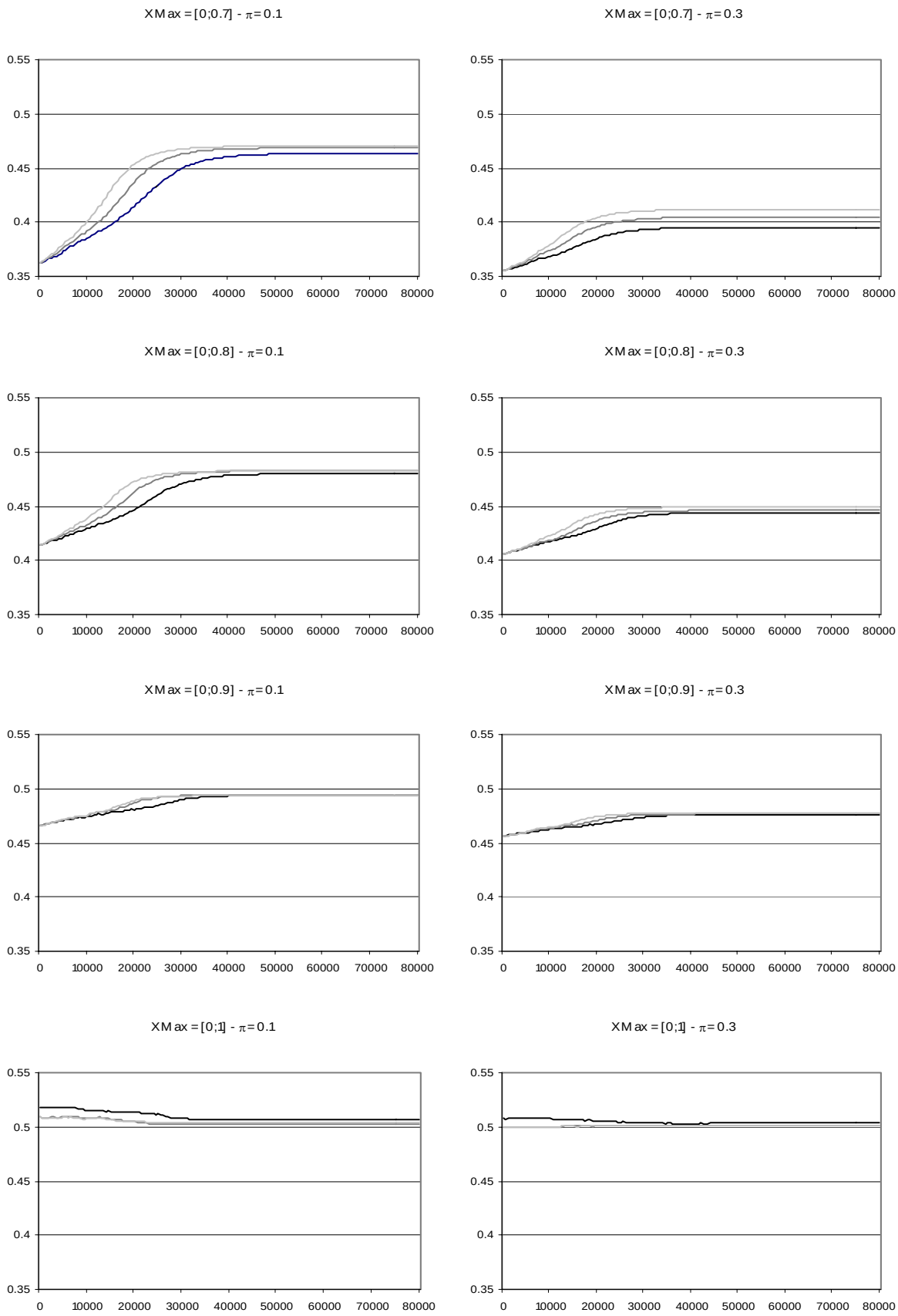

Figure VI-1b : Average behavior for R_{Max} individuals: φ = 0.3, black curve; φ = 0.325, dark grey curve; φ = 0.35, light grey curve.

Figures VI-1a and VI-1b display the evolution of average behavior for both individuals endowed with low and high reputation respectively. 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 (φ = 0.3), average specialization (φ = 0.325) and low specialization levels (φ = 0.35).

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 VI-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 VI-1a, by 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. This higher degree of coherence enhances the effectiveness of their influence on their community.

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 VI-1a, evolutions in the behaviors become more spectacular as the proportion of individuals enjoying high reputation degrees is increasing. As this proportion increases, the likelihood of individuals to be subject to the influence of community leaders increases. Finally, as shown in the bottom panels of Figure VI-1a, when leaders are uniformly distributed within the spectrum of behaviors, the behavior dynamics is similar to that in the model of Weisbuch *et al*. (2002) with average behaviors sticking to 0.5.

Figure VI-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.

Leaders are in fact confronted to two opposite effects. The first effect is applying when leaders influence each other and directs their respective behaviors towards their own average. This effect, internal to the "cast" of community leaders, is stabilizing. The second effect is occurring when a leader is subject to the influence of other members. In this case, their behavior is likely to be influenced in direction to the R^{Min} individuals' average behavior. This latter effect, external to the "cast" of community leaders, increases the current dispersion in their behavior. 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 theoretical challenge might be tackled by the study of the evolution of behavior dispersion for R^{Max} individuals and R^{Min} individuals.

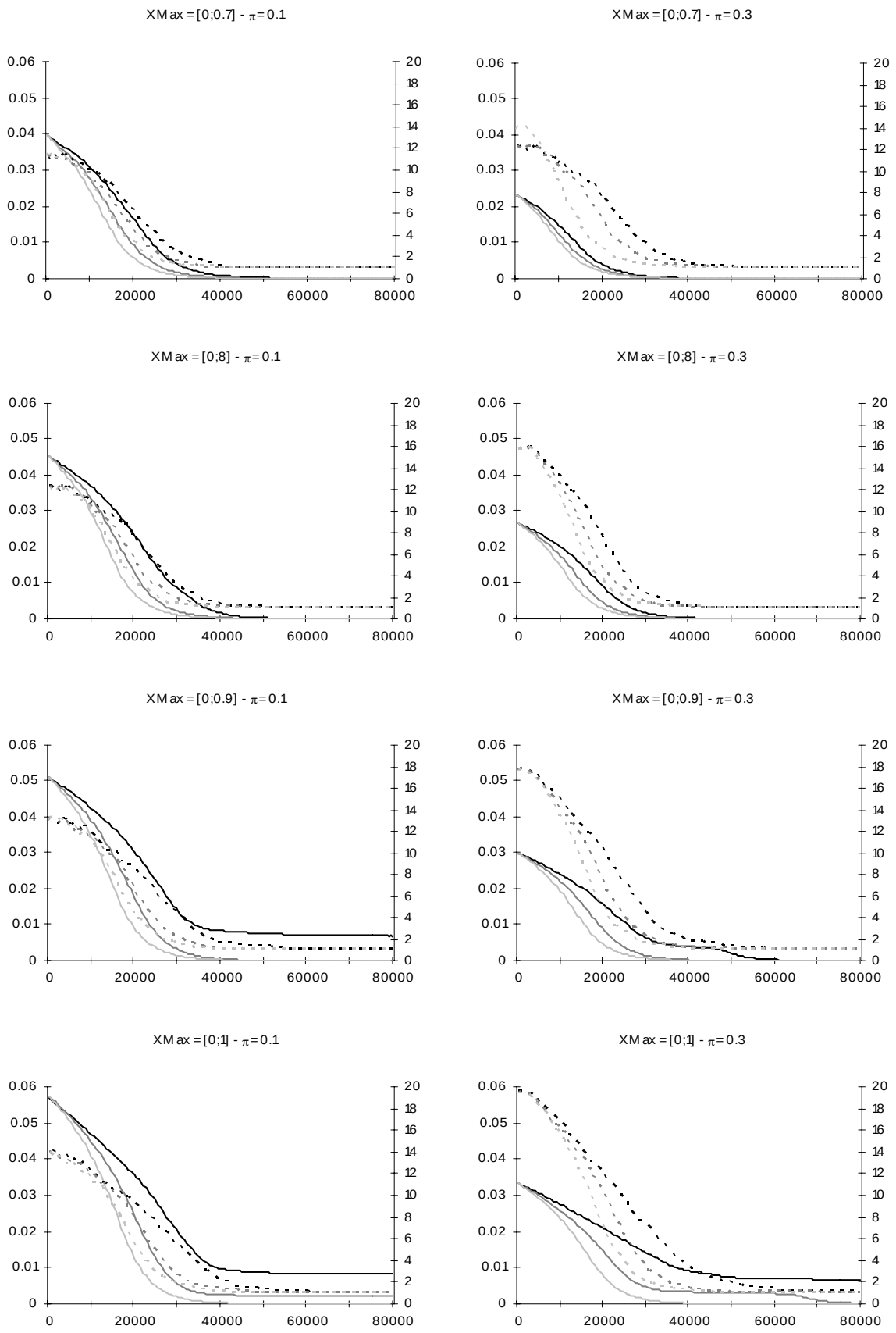

Figure VI-2a : behavior standard deviation (solid lines, left axis) and number of clusters (dotted lines, right axis) for R_{Max} individuals with no disagreement among leaders: φ = 0.3, black curve; φ = 0.325, dark grey curve; φ = 0.35, light grey curve.

Figure VI-2a displays the evolution of behavior dispersion for R^{Max} individuals. 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 VI-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. This is due to the fact that community leaders are more likely to be influenced by other leaders, thus contributing to reduce the gap between them. Moreover, in the context of distributed leadership, leaders are less exposed to the influence of R^{Min} individuals whose trajectories are more uncertain and which may contribute to increases in leaders' behaviors discrepancies. 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.

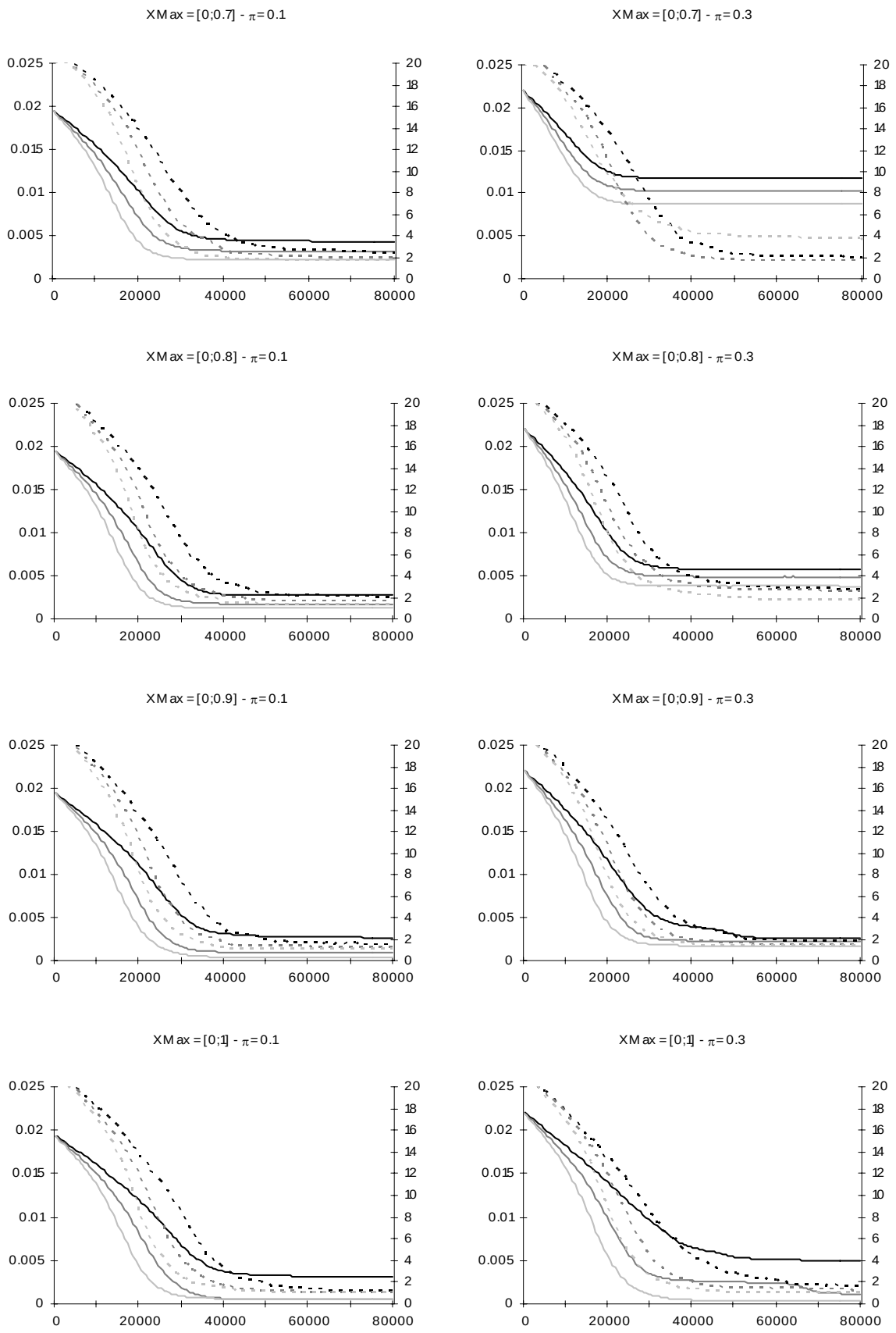

Figure VI-2b : behavior standard deviation (solid lines, left axis) and number of clusters (dotted lines, right axis) for R_{Min} individuals with no disagreement among leaders: φ = 0.3, black curve; φ = 0.325, dark grey curve; φ = 0.35, light grey curve.

Figure VI-2b shows the evolution of behavior dispersion for R^{Min} individuals. As in the case of community leaders, the decreasing shape of the curves indicate a reduction in behavior discrepancies. The emergence of consensus among R^{Min} individuals is conditioned by different factors: the degree of specialization, the position of community leaders and the structure of governance.

As in the case of leaders, decreases in the degree of specialization have a positive impact on the convergence of community members' behaviors. Moreover, increases in the dispersion of leaders within the behavior spectrum have a positive effect on the convergence of community members' behaviors. This is due to the fact that such dispersion increases the leaders' ability to communicate and influence other members of the community.

Interestingly, convergence in R^{Min} individuals' behaviors is favoured by a centralized structure of leadership. One may therefore strikingly 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 $\pi = 0.3$).

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.

III.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 VI-3a and VI-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. Simulation runs were performed with different sizes for $X_{Max} = [0;0.35] \cup [0.65;1]$; $[0;0.4] \cup [0.6;1]$; $[0;0.45] \cup [0.55;1]$. Finally, the case of $X_{Max} = [0;1]$ in which leaders are uniformly distributed across X has been included. 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.

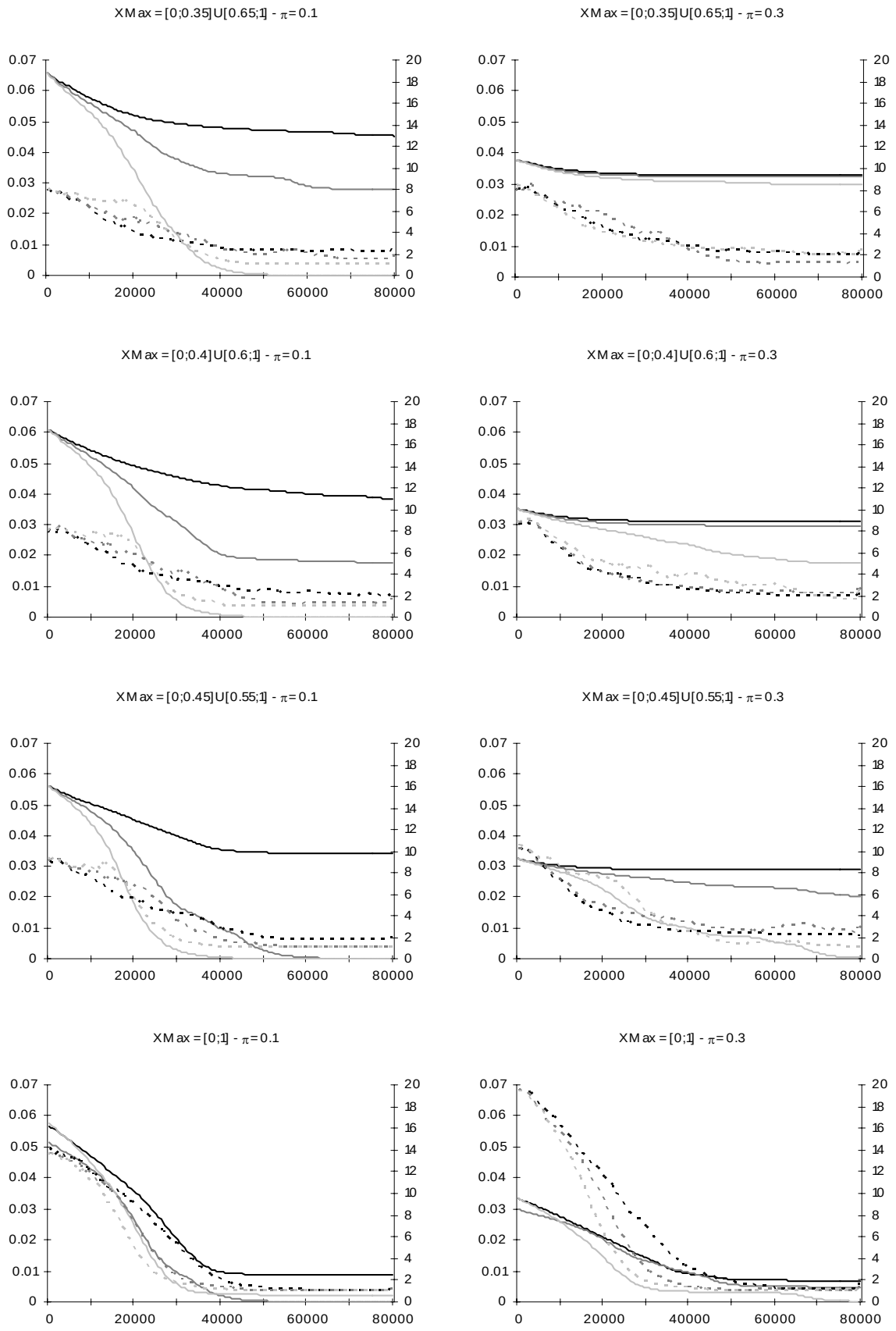

Figure VI-3a: behavior standard deviation (solid lines, left axis) and number of clusters (dotted lines, right axis) for R_{Max} individuals with disagreement among leaders: φ = 0.3, black curve; φ = 0.325, dark grey curve; φ = 0.35, light grey curve.

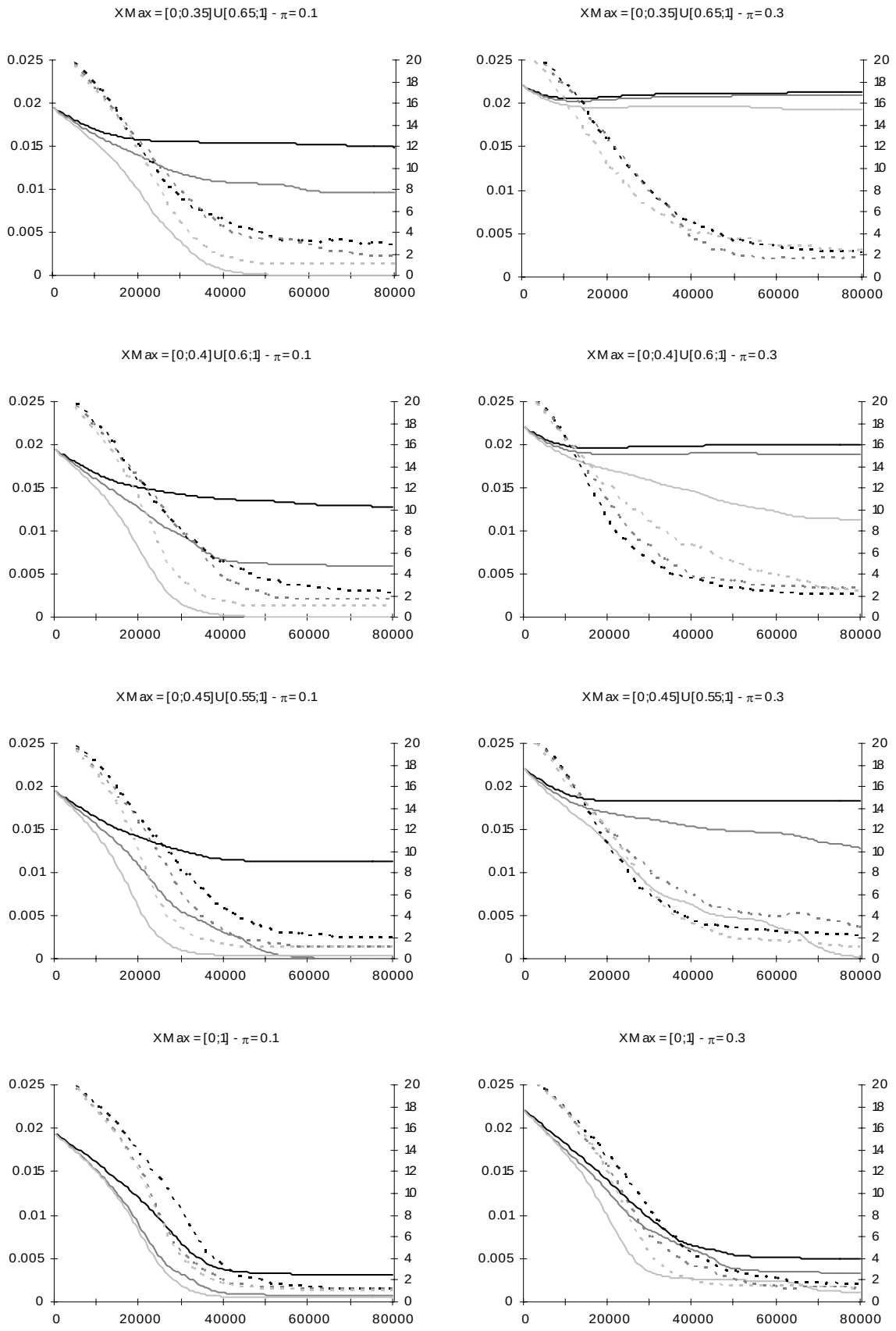

Figure VI-3b : behavior standard deviation (solid lines, left axis) and number of clusters (dotted lines, right axis) for R_{Min} individuals with disagreement among leaders: φ = 0.3, black curve; φ = 0.325, dark grey curve; φ = 0.35, light grey curve.

The comparison between Figures VI-3a and VI-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. Contrary to the preceding results, the existence of similarities in behavior evolutions allows to draw some conclusion which apply to the whole community. In both Figures VI-3a and VI-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 standard deviation values for R^{Max} and R^{Min} individuals which are much higher than 0 while, in the long run, a small number of behavior clusters remains. This constitutes a strong evidence of community forking for 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.

Differences in the levels of specialization within the community have a strong influence on forking. As shown in Figures VI-3a and VI-3b, a strong disagreement among community leaders ($X_{Max} = [0;0.35]\cup[0.65;1]$) for centralized leadership ($\pi = 0.1$), low levels of specialization ($\varphi = 0.35$) allow influence relationships to stretch over a wider share of acceptable behaviors. This ends up in achieving consensus among community leaders and, in turn, to prevent forking. As the level of disagreement among leaders decreases, higher levels of specialization are afforded while avoiding forking.

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 VI-3a and VI-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 be subject to 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, as found in Chapter V, in the case of a distributed leadership, it takes less time for members to be legitimized as community leaders. 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 chapter has been to study the role of leadership as a mechanism addressing the issue of the global coordination and cohesion of communities of practice. The motivation underlying this chapter has been the observation that trust only provides a local coordination mechanism since it only grounds on the existence of commonalities between partners. Thus, the global coordination of communities of practice may not be ensured by the sole recourse to trust.

This chapter 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. To this end, 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 chapter 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.

Conclusion.

This work has proposed a theoretical framework accounting for the coordination and motivation to contribute to communities of practice. The central hypothesis underlying this work is that, in a Knowledge Based Economy, a significant share of the processes of production, diffusion and storage of knowledge is hold by communities of practice. The study of those communities, which might be found in organizations (such as firms), public institutions (as in research laboratories) or that may even emerge in the absence of any institutional settings (as in the case of numerous open source projects) constitutes an important aspect for an understanding of economies grounded on innovation and technological change.

The motivation underlying this dissertation lies in the observation that community of practice still constitutes a rather ill-defined concept. More precisely, the coordination of communitarian work and the motivation of individuals for contributing to its advancement have been the object of little developments in the literature. The argument developed throughout this work is that an important mechanism underlying the activity and the development of communities of practice resides in the emergence of community leaders. Those leaders, due to their capacity to influence information and knowledge flows occurring within a community, significantly contribute to its internal coordination.

An important characteristic of community leaders is that their status rests on the accumulation of reputation and trust. Reputation provides individuals with the opportunity to bind numerous relationships with members of the community. In this respect, it constitutes a way for them to access information and knowledge they wouldn't access in the case of low reputation. Knowing this, other members of the community are likely to be more influenced by leaders' behaviors than by other, less reputed, members. However, in order to make actual those influence relationships, it is necessary for leaders to be credible in their role. A way to acquire this credibility lies in the high degree of trust they enjoy within the community. The problem of leadership in the internal coordination of communities of practice is important since it also influences the relative effectiveness of its members' activity. In turn, this

effectiveness conditions the internal cohesion of the community by partly determining members' interest in contributing to the common enterprise.

The discussion of the problems of reputation and trust as two basic conditions for the exercise of leadership in communities has also led us to provide new analytical insights concerning those two concepts. Their inspection has been motivated by the limitation they raise, when used in their classical sense. Indeed, the concept of reputation and trust have been principally discussed in the Economics of Information literature and have been approached from a game theoretic standing point. In this context, high degrees of reputation and of trust refer to the adoption of a cooperative behavior because this behavior represents an optimum and any deviation would yield future decreases in the gains. In the frame of knowledge asymmetries, the game theoretical approach to trust and reputation are irrelevant since, in a context of pervasive uncertainty, the very structure of the game is ill-defined.

Rather than adopting what we could call a "default" conception (an individual enjoys high degrees of reputation and of trust because a cooperative behavior constitutes an intertemporal optimum) we propose a richer approach to those concept. In this perspective, reputation and trust refer not only to the nature of the agent's behavior (whether he has adopted a cooperative behavior or not) but provides indications of his competences too. Hence, reputation and trust, by building on information about an individual's past behaviour, give rise to rational expectations (without being calculative) about his competences and intentions. Finally, our discussion also led us to consider reputation and trust as two mechanisms acting as coordination and incentive devices.

This work has aimed at proposing some (we hope, interesting) insights into the coordination and the motivation of individuals in communities of practice. Apart from the numerous examples dealing with open source software development which have been introduced through this dissertation, we suspect that the theoretical framework sketched in this dissertation might apply to numerous cases. The apparently most direct application of the argument of this dissertation lies in the Economics of Science[1]. Several analytical questions raised in this field of enquiry might be addressed by making use of the theoretical insights

[1] Numerous insights reported in this thesis emerged from the literature related to scientific research, especially the well discussed Matthew Effect (see. Merton, 1968 and 1988, Carayol, 2003) and greatly benefited from the project BETA-GERSULP-LES « Économies fondées sur la connaissance et nouveaux espaces de négociation en matière d'expertise : le rôle et la place de l'université ».

provided by this research: e.g. how do new fields of enquiry emerge ? or why some scholars are more able to significantly influence further research trajectories in their field than others ?

Moreover, our work may contribute to the evolutionary literature by providing a new look at the question of incentives by overcoming the problems raised by routines as a truce mechanism (see Coriat and Weinstein, 1995). In fact, when we assume that organizations are composed of several communities (referring to the conception of firms as "Communities of communities" developed by Cohendet and Diani (2003)), the reasoning in terms of reputation, trust and leadership, provides a complement to routines in accounting for the coordination and the motivation of the members of an organization.

As an exploratory work, the main argument of this dissertation may significantly benefit from further theoretical and empirical developments. We would like to stress several lines for further enquiry which, to our knowledge, may appear as particularly beneficial for our work. Even though the principal methodology is numerical simulation, the theoretical argument put forward in this dissertation might be significantly reinforced by a recourse to statistical methods. To our knowledge, most of the empirical treatments of communities of practice have been made through case studies (e.g. Dupouët, 2003 or the studies of Lakhani and von Hippel (2003) or von Krogh *et al*. (2003) for case studies of open source communities). But, due to their informality, one can, at first sight, wonder about the problems of gathering data related to the work of communities. A promising area of research might be provided by some specific newsgroups and forums. For example, in a study of virtual forums, Guittard (2004) undertook a survey of a discussion forum dedicated to computer hardware, Hardware.fr[2]. In this study, he found evidence of the existence of a community of practice since the community was defined by a specific *domain of focus* (technical knowledge related to computer hardware), members *interacted* with each other through the forum and *developed a shared repertoire of resources* through the disclosure of advices and technical solutions related to hardware problems.

A second line of developments which might be more specific to the modelling of communities of practice would consist in the introduction of social norms and learning dynamics in simulation models. The importance of social norms as a coordinating device has been mentioned in Chapters I and VI. Social norms due to their capacity to delimit the set of

[2] http://www.hardware.fr/

possible behaviors, contributes to the internal coordination of communities of practice. In this way, further simulation models would explore the relationship between social norms, leadership and the dynamics of communities of practice mentioned in Chapter I.

Finally, the argument developed in this dissertation would greatly benefit from a consideration of the relationship between the environmental factors and the evolutions of the community (see e.g. Wenger and Snyder, 2000, Cohendet *et al*., 2004). We suspect a complex relationship between the environmental setting and the internal dynamics of communities: while external factors influence the internal dynamics, the latter may, in turn, contribute to modify the environment of communities. If we adopt a counterfactual mode of reasoning, one can wonder whether other open source communities would have adopted the same type of internal organization and follow the same learning trajectories as they actually do if the Linux community adopted a different type of organization ? In any case, as complex social system, we believe that the organizational dynamics of communities of practice and, *de facto*, coordination and motivation cannot be fully understood without considering their environment.

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Table of Content.

List of Figures.

List of Tables.

Résumé.

Dans le cadre d'une économie basée sur la connaissance, une part croissante des processus de production et de diffusion des connaissances est assurée par les communautés de pratique. Ces dernières, en fournissant des espaces intangibles propices à la circulation d'informations et de connaissances, jouent un rôle important dans les processus d'apprentissage collectifs. De telles communautés peuvent être définies de manière générales comme des structures d'interactions sociale ayant pour but la génération et la diffusion de connaissances. Plus précisément, de telles communautés représentent des groupes d'individus engagés dans une pratique commune et interagissant fréquemment en vue de développer leurs compétences dans le domaine considéré.

Du fait de l'absence de tout schéma contractuel en leur sein, un des traits fondamentaux des communautés correspond à la liberté laissée à leurs membres dans la détermination de leur trajectoire de spécialisation. En d'autres termes, il leur est possible de déterminer de manière décentralisée tant le volume que la nature de leur contribution à l'entreprise de développement d'une pratique commune. Une telle liberté laissée aux membres va néanmoins de pair avec certaines interrogations concernant l'efficacité du système. Plus précisément, se font jour deux catégories de problèmes. Sur le plan des incitation, l'absence de schémas contractuels peut donner l'opportunité aux membres de s'engager dans des comportements opportunistes du type passager clandestin. Sur le plan de la coordination, se pose un problème d'efficacité des activités des membres. En effet, en l'absence d'une division claire et imposée des tâches au sein de la communauté, les individus peuvent s'engager soit dans des activités disparates, donnant ainsi lieu à un problème de cohérence, soit dans des activités redondantes, conduisant à une sous-utilisation des capacités cognitives des agents.

Le but de ce travail de thèse est d'étudier certains des mécanismes présidant à la coordination et aux incitations des agents au sein des communautés de pratique. Dans cette optique il est proposé que celle-ci est soutenue par l'émergence d'individus jouissant d'un statut particulier au sein des communautés : les leaders communautaires. De manière très basique, le leadership est ici défini comme la capacité d'influencer les comportements individuels par une influence exercée sur les flux d'informations et de connaissances par l'adoption d'une position centrale au sein de la communauté. Une telle capacité est obtenue par la conjugaison de deux attributions complémentaires des leaders. Premièrement, la capacité de contraindre les flux de communication est issue de leur capacité de médiation, liant ainsi des parties éloignées de la communauté. Une telle capacité permet aux leaders, par le filtrage des flux de communication se produisant au sein de la communauté, d'apporter une cohérence dans la base de connaissances communes. Deuxièmement, les leaders bénéficient d'un accès privilégié aux informations et connaissances, issu de la multiplication des relations avec d'autres membres de la communauté. Sachant cela, les membres supposent que les leaders, confrontés à un niveau d'incertitude plus faible, sont en mesure de prendre de meilleures décisions. Ces derniers sont dès lors susceptibles de faire l'objet de comportements de mimétismes.

Le leadership constitue un phénomène émergent dans le sens où il est issu d'un processus d'auto-organisation. Dans cette optique, les leaders communautaires appuient leur statut sur la conjonction d'effets de réputation et de confiance. La réputation est ici entendue comme un ensemble d'informations concernant des éléments constants et récurrents dans le comportement passé d'un individus. Ces informations sont partagées par les membres de la communauté. Ainsi, la réputation, en réduisant l'incertitude associée au comportement de l'individu dans le cadre d'une première interaction, permet de faciliter son occurrence. De ce fait, des individus dotés d'une forte réputation tendent à bénéficier d'un plus grand nombre de relations au sein de la communauté, leur permettant ainsi d'obtenir une position centrale en leur sein. La confiance vient suppléer la réputation dans le cadre de relations répétées entre deux partenaires. Cette dernière correspond à l'anticipation d'un comportement coopératif. Elle se fonde sur l'accumulation de connaissances sur les comportements passés de l'individu. Ces connaissances, en étant accumulées lors d'interactions antérieures, sont ainsi spécifiques à relation considérée. Ainsi, se tresse un lien étroit entre réputation et confiance. Tandis que la réputation constitue une condition nécessaire à l'occurrence d'une première interaction entre deux individus, la confiance, en se substituant à cette dernière, permet de la faire perdurer.

Mots-clé: Communautés de pratique, coordination, incitation, leadership, réputation, confiance, simulation socials.

Summary.

In the frame of a knowledge based economy, a growing part of the processes of knowledge production and knowledge diffusion are hold by so-called communities of practice. Communities, by providing intangible spaces triggering the sharing of information and knowledge, play a paramount role in collective learning processes. Those communities may be broadly defined as specific social interaction structures aiming at the production and the diffusion of knowledge. More precisely, they correspond to groups of people engaged in a common practice and frequently interacting in order to develop their competences.

Due to the absence of any contractual scheme, one of the defining traits of communities of practice lies in the ability of the members to determine their specialization trajectories in a decentralized manner. To put it differently, they enjoy the ability to determine the extent and the nature of their contribution to the growth of the common practice. However, such a freedom left to the agents may raise some issues concerning the efficiency of this system. From the incentives point of view, the absence of any contractual scheme may give the agents the opportunity to engage in opportunistic behaviors, giving rise to a problem of prisoner dilemma. Moreover, the absence of any clear-cut division of labour may imply two possibilities: either the agents engage in too different tasks which may hinder the overall coherence of the common practice. Or the individuals engage in similar activities, leading to problems of redundancies in the common practice.

The goal of this thesis is to isolate some of the mechanisms governing the coordination of agents within communities of practice. It is proposed that coordination is supported by the emergence of individuals enjoying a specific status within the community: communitarian leaders.

Leadership is here defined as the ability to influence individual behaviors through an influence exercises on information and knowledge flows. This is due to the adoption by community leaders of a central position within the community. The leaders' ability to control knowledge flows arises out of the conjunction of two complementary features. First, the ability to constrain communication flows, which arises out of their ability to take on the role of mediators and to link distant parts of the community. This ability allows leaders to enhance the coherence of the common knowledge base by filtering communication flows. Second, due to their ability to accumulate relationships with other members of the community, leaders enjoy an enhanced access to information and knowledge. Knowing this, community members assume that leaders are facing lower levels of uncertainty, implying that they are able to take more adequate decisions. Community leaders are likely to be subject to mimesis behaviors.

Leadership constitutes an emergent phenomenon in the sense that it arises out of a process of self-organization. The conjunction of reputation and trust comes in support of the community leaders' specific status. Reputation is here defined as a set of information concerning constant and recurring evidences of an individual's past behavior. Those information are shared among community members. Reputation, by reducing the uncertainty associated with an individual's behaviour during a first interaction, eases its occurrence. Individuals endowed with high reputation levels benefit from a higher number of acquaintances within the community. This allows them to acquire a central position in the community.

Trust complements reputation in the frame of recurrent interactions among two partners. Trust corresponds to the expectation of a cooperative behavior and relies on the accumulation of knowledge arising out of preceding interactions. A strong relationship binds reputation and trust: while reputation constitutes a necessary condition for a first interaction to occur, trust allows perpetuating it.

Keywords: Community of practice, coordination, incentives, leadership, reputation, trust, social simulation.