STANDARDISATION OF NETWORK TECHNOLOGIES: MARKET PROCESSES OR THE RESULT OF INTER-FIRM CO-OPERATION?

Bertrand V. Quélin
HEC Paris

Tamym Abdessemed
AUDENCIA-Nantes

Jean-Philippe Bonardi
University of Western Ontario

Rodolphe Durand
EM-Lyon

Abstract. As recent studies on the evolution of a technology indicate, the role of a standard, or dominant design, is highly significant in a number of contemporary industries such as computer, telecommunications and consumer electronics. Following Katz' and Shapiro's pioneering works (1985), our paper rationally evaluates the concepts and results developed over the past ten years in this field. It is grounded on a typology of two types of models: the first is based on users' anticipatory behaviour, and the second, on the collaborative behaviour of existing firms. The article initially discusses the specificity of network technologies, then analyses market standardisation models, and finally, studies the different actors models. Our conclusion builds upon existing works in network technologies. We next propose a research agenda.

Keywords. Network; externalities; compatibility; cooperation

1. Introduction

Schumpeter (1942) suggested that technological innovation should be viewed as the key driving force behind economic change. Particularly useful in elucidating the development of state-of-the-art technologies, this perspective has attracted a number of adherents over the years.

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Previous research in this area has revealed that one of the main stages in the evolution of a technology is the emergence of a standard or dominant design (Tushman and Anderson, 1986; Gabel, 1991). The role of standards is especially important in a number of contemporary industries such as computer, telecommunications and consumer electronics.[1]

Following Katz' and Shapiro's pioneering works (1985), this paper rationally evaluates the concepts and results that have developed and evolved over the past ten years in the field of network technologies and the emergence of standards. The assessment is grounded on a typology of models elaborated in this newly developed field in literature. These models are grouped into two categories:

- a focus on the anticipated behaviour of users in view of the emergence of the standards: here, it is essential to understand the dynamics underlying users' adoption of the standards and the influence of these dynamics on the standard that ultimately prevails;
- a focus on the behaviour of the supply, and on the collaborative behaviour of existing firms during the emergence of standards. The issues in this category pertain to institutions, market configurations and the forms of competition specific to network technologies.

While all these models may aim to clarify the strategies that firms pursue in the presence of network externalities, they nonetheless apply different methods and tools in their scientific processes. Arthur, Ermoliev and Kaniovski (1987) and Filippi, Pierre and Torre (1996) had indicated that the first category of models refers significantly to methods and tools deriving from chemistry or physics. It is directed toward stochastic models elaborated from market standard emergence processes (Arthur, 1989; David, 1985; Foray, 1994). The second category of models emphasises the firm's strategies in the presence of network externalities, the importance of compatibility in the diffusion of network innovations, and the strategic and organisational conditions required in these situations (Antonelli, 1994; Besen and Farrell, 1994; Economides, 1996).

The next section in this document discusses the specificity of network technologies (part 2). Thereafter, we analyse market standardisation models (part 3) and actors' models (part 4). The conclusion drawn from these analyses builds on existing studies in network technologies. We ultimately propose a research agenda.

2. Standardisation of network technologies

Network externalities were first discussed in Rohlfs' seminal article (1974), then Katz and Shapiro (1985) highlighted their importance for a firm's strategy, and Farrell and Saloner (1986) explored the dynamics of installed base competition. Arthur (1989, 1994) recognised the economic role of positive feedback. David (1987) primarily reviewed the normative literature on the economics of standardisation.

2.1. *Network externalities and technologies: economic aspects*

Literature on the economics of compatible standards initially focused on elaborating the properties of network-based markets. A prominent feature of these markets is the existence of network externalities (Katz and Shapiro, 1985; Farrell and Saloner, 1986). Network externalities describe the phenomenon that a good becomes more valuable to each consumer the more other consumers use the same or a compatible product. Users seek to participate in networks that enable them to share resources, communicate with each other and mix and match products. In turn, the utility of such networks is dependent on the extent to which the various components are compatible with each other. Therefore, whether directly or indirectly, a user's ultimate utility is linked to those of other users. Their utility functions are interdependent.

Network externalities can arise in a number of different ways, one of which is through network technologies. Due to certain characteristics linked to the technology and to its use, the consummation, which is linked to the users' participation to a group, is based on a technological choice that eliminates all other choices. Accordingly, Katz and Shapiro noted: 'Any technology requiring specific training is subject to network externalities; the training is more valuable if the associated technology is more widely adopted' (1986: 823). Externalities express, then, the growing value of a product or service for all new clients or subscribers. Demand is a function that increases with demand.

Network externalities have critical strategic implications on the actors involved (producers and clients); consequently, economic analyses must take this into account. For instance, in the telecommunications sector, a person's willingness to subscribe to a telephone service is directly linked to the number of people that he can contact. The more users adopt a particular system and its associated standard, the more attractive this system becomes to potential adapters. If the user is given two distinct and incompatible networks, in order to choose the one that will maximise his utility, he must make concessions by anticipating the standard that will eventually become the most widespread on the market (Besen and Saloner, 1989). The entire difficulty is that, at the time when he chooses, the user cannot be certain that he is making the best choice because his own choice determines the standard that will thereafter become pervasive. What are the user's decision criteria, then, knowing that if he makes a bad choice, he will need to pay transfer costs (costs of subscribing to another network)? If he does not make a choice at all, the risk is that the innovation will disappear. Firms with two incompatible technologies must act in such a manner as to take into account the potential user's expectations, which include standardisation, ex-post compatibility of technologies, and intense competition between standards. What are the most appropriate strategies and their implications? What are the benefits and the risks?

Network technologies create a diffusion logic where the subscription risk for users and existing firms is a determining factor. How will these conditions define the establishment of the standard and what will be the degree of irreversibility of the standard that is collectively chosen, and not necessarily individually adopted?

The standardisation problem cannot be considered in the same light for new products (VCRs in the 70s[2]) as for technology upgrades (recent example of the APS film). The installed bases,[3] the resources to invest, and the profit sharing structure are different in each one of these situations, and vary according to the compatibility and complementarity of the products. As a result, the irreversibility mechanisms change accordingly (Willinger and Zuscovitch, 1993).

2.2. *Key concepts in the network economy*

The study of standardisation processes in network technologies has brought to light three main concepts that have since become common knowledge (Foray, 1989):

- *the existence of increasing returns*: the utility of a product or service will be greater for the n^{th} user than for the $(n-1)^{th}$ user. In markets characterised by network externalities, the benefit a consumer derives from a good often depends on the number of other consumers purchasing similar items (Katz and Shapiro, 1986, 1992; Choi, 1994a). Not only does the n^{th} user pay a lesser price for the good or service than his predecessor does, but in addition, the potential use and satisfaction that the n^{th} user can derive from his purchase are greater. Therefore, as the product becomes increasingly adopted, the chances are that it will become even more widely adopted, and the network of subscribers expands. Increasing returns are deeply rooted in hands-on learning, network externalities, economies of scale, increasing returns of information and technological inter-relations (David, 1985; Arthur, 1989).
- *path dependence*: for the user, the choice of one technology over another depends on the history of the standard's diffusion process in the competitive environment. This means that for the user, the act of purchasing is a part of a temporal process. As this temporal dimension has an impact on the successful diffusion of a product or service, time is not a neutral component in a network-based market. For instance, the loss of market share on Sony Betamax videocassettes does not encourage a user to buy one. The purchase of a VHS cassette reinforces, in turn, Betamax's decrease in market share (Cusumano, Mylonadis and Rosenbloom, 1992). A combination of early determining events and the absence of countervailing factors to offset the increasing returns effect can lead to a converging point in the market, which ultimately gives rise to a single technological option that becomes the 'standard'. If there are significant switching costs, it is likely that a selected technological option will persist over a long period of time.
- *irreversibility*: there are inflexion points for technology diffusion from which it is impossible to turn back, as the costs of changing from one standard to another become prohibitive (Choi, 1994b). Irreversibility is one of the characteristics of diffusion trajectories. According to some authors, despite the availability of alternatives, it is even possible that the ultimately adopted standard is not the best in absolute terms. This lock-in effect (David, 1985;

Arthur, 1989) supposes that as soon as the critical size is attained, a standard clearly becomes the most attractive on the market. David (1985) provided empirical evidence of the lock-in effect for the QWERTY keyboard dominance despite Liebovitz's and Margolis's (1990) contrary viewpoint.

These properties accentuate the importance of the irreversibility logic associated with the adoption of network technologies. This possibility represents both a threat and an opportunity for the actors involved in the process, from the firms' as well as the users' points of view (Besen and Farrell, 1994). The firms must find the right standard, which is affirmed through auto-reinforcement dynamics. Otherwise, they will find themselves with the 'weak' standard and will be forced to either disappear or to adopt the 'dominant' standard. Strategically, such a scheme is risky because it is founded on an 'all or nothing' logic, which, because of its very nature, is much dreaded by entrepreneurs. The lock-in notion suggests that networks fundamentally bestow a strategic advantage onto the first mover (as defined by Lieberman and Montgomery, 1988), and in this case, also onto the first actor that has attained a critical size.

As we will show later in the article, however, the lock-in phenomenon is not automatic. Lock-in occurs in cases where technologies compete to dominate a market. The question is whether or not the dominating technology is the most efficient technology (technically or otherwise). Many authors have demonstrated that lock-in is likely to occur only when many standards can be the dominant configuration in the presence of network technologies. In a number of situations, several standards may survive simultaneously, so competition between different standards exists (Liebowitz and Margolis, 1995; Steyer and Zimmermann, 1996). In other words, the market structure may ultimately be a monopoly, but this is not a systematic result. Furthermore, the introduction of a new technology is possible under certain conditions (Katz and Shapiro, 1991). Existing literature (Klemperer, 1987, 1989; Farrell and Shapiro, 1988) propose many formal economic models of competition for consumers with switching costs. Klemperer's works (1995) provide an overview of literature on switching costs.

2.3. *Network technologies and market structures*

In view of the properties elaborated above and their implications on the behaviour of users and firms, two sequences can be considered for the emergence of a standard. The first is where users' expectations determine the technology that will be selected through market processes. Competing technologies are then driven out, due to the growth of the installed base and the increasing returns. Here, the problem is to choose the strategies that would enable a firm to orient the adoption process in its favour. Each firm chooses to adopt a *laisser faire* attitude and incurs the risk that a de facto standardisation will ratify the first standard to attain the critical size.

In the second possible sequence, in order to prevent the market from determining a standard, which is too dangerous, firms choose co-operative efforts

as a means to establish a standard. For instance, firms can make their technologies compatible or choose a single co-standard. In this case, scholars address the strategic organisational issues of how the standards themselves are determined by the actors.

The purpose of this paper, which goes beyond explaining each of these dynamics, is to identify the theoretical determinants of either of the sequences. In other words, it aims to help practitioners and theoreticians alike by clarifying the reasons behind the choices of the different forms of co-operation and of the most adapted institutions in markets where network technologies are involved. The operational decisions to make are thus the following: must the firms share network externalities resulting from increasing returns, that is, must they choose to pursue a common standard? When can a situation be shifted ('tipping point' problem)? How should irreversibility effects be managed, independently or with others? The following sections focus on the answers to these questions for the two types of standardisation dynamics described above.

3. Market standardisation models or adoption models

3.1. *The determinism inherent in the first adoption normative models*

Prior to Katz and Shapiro, the first authors to model standardisation processes (1985), monopolists' internalisation of the positive network effects eliminated the compatibility problem that industrials had inherited. Katz and Shapiro analysed network externality effects on oligopolistic competition and on market equilibrium, then studied the motivations behind inter-firm compatibility.

Users' decisions to purchase a product or service are based on foresight on the potential size of the networks. In other words, consumers must make their choice before the actual size of the network is known: based on their assessment of the externalities, they determine their reservation price, then compare it to prices set by the different suppliers. Users' expectations on the relative positions of the different networks determine the effective networks. The establishment of the networks refers to a probabilistic approach of the expectations. The compatibility decision between the networks is considered only once the networks are established, following a cost and profit analysis of the inter-connection.

The first Katz and Shapiro model (1975) illustrates three properties: the presence of positive externalities, increasing returns and non co-operative behaviour between firms. These effects make it a deterministic market model where the advantages for firms to pursue technological compatibility can only be deduced retroactively.

Other studies had aimed to more precisely model the influence of users' expectations and their implications on adoption decisions and consequently, on the establishment of the networks. The path dependence and irreversibility properties, neither of which was considered in the Katz and Shapiro model (1985), were defined. They can lead to lock-in situations. David (1985) illustrated the lock-in characteristic in the QWERTY keyboard case, which has since become

well known. Here, QWERTY was successful despite the existence of a superior keyboard because of the importance of consumers' expectations and because of the firm's telling reputation. Bunn and David (1988) provide another historical example on electricity power, about the compatibility of different competing networks and the specific role of converters.

Arthur (1989) was interested in the focalisation phenomenon on a given technology and searched for the reasons behind the blockage in the adopters' choice sequence. He notes: 'when two or more increasing-return technologies 'compete' then, for a 'market' of potential adopters, insignificant events may by chance give one of them an initial advantage in adoptions' (1989: 116). He shows that network externalities are originally self-reinforcement and path dependence phenomena, that competition between two technologies refers back to the decisions made by the first users, whose choice of one network over another is in fact quite random. The first users determine the increase in returns associated with the chosen technology and therefore directly influence the choice of subsequent adopters (Mangematin and Callon, 1995). Likewise, discussions on the critical size, that is, the size that enables self-reinforcement mechanisms to begin effectively and that makes the attractiveness of the firm dependent on its installed base, introduces the temporal dimension insofar as the standardisation phenomenon is concerned. Other studies also emphasise this temporal dimension.

3.2. *Market processes and heterogeneity of adopters*

3.2.1. *A market process*

In their paper on the preconditions required to introduce a new standard, Katz and Shapiro (1986) conceived a game played in two periods. The authors' core theme is that the firm that will dominate in the second period will be the one that had sponsored its technology to potential users in the first period. In this model, consumers' expectations remain uniform. 'To sponsor' means to maintain a very attractive pricing policy during the first period that becomes a competitive advantage in the second period by favourably directing the behaviour of the first adopters. Video game manufacturers pursue this strategy by selling their consoles (hardware) at nearly marginal costs, then by selling the software at a price that enables them to reap significant returns.

Due to the process' irreversible nature, the technology that is the least attractive qualitatively can be the one that is the most widely adopted if the firm that controls it accepts to sponsor it during the first period and assumes the financial risks associated with the possibility of failure. The lock-in effect is integrated, then, even if the path dependence applies to only two periods by means of the pre-emptive effect through sponsoring on the users.

Katz and Shapiro (1992) thereafter dedicated their efforts to evaluating the launch of new products when the installed base is critically significant in size. In this study, they focus on the case where users are receptive to a new entrance's technology, at the expense of old technologies, and even when this is not socially

beneficial. The authors show that if users' expectations can be dislodged or influenced in the presence of network externalities, it is possible to resist irreversibility effects. Hence, while these effects may be the driving factors in determining the dominating standard, they are still very much influenced by firms' strategies.

3.2.2. *The logic behind users' adoption decision*

These preliminary studies considered technological standardisation to be a market process. The consumer is viewed as part of the network, which interprets the adoption process in both its temporal (its adoption probability is a function of previous choices made and resulting payoffs) and spatial (the consumer is geographically positioned in terms of the network of products and services) dimensions. It seems, therefore, that standardisation results in a concurrent phenomenon: a type of temporal and/or spatial interdependence between the utilities of the producers and consumers develop, and utility functions are modified as the process is established.

More recent studies attempt to further refine the understanding of the market standardisation phenomena by focusing on the characteristics of the adopter. Steyer and Zimmermann (1996) affirm that there is a need to improve the user adoption model in the presence of network externalities. To the global temporal (all users share the same knowledge of the global context, that is, of the behaviour of all other users) and spatio-temporal (local knowledge because of the limited rationality of the agent's horizon) approaches, they add a 'resilience' approach that subjects the agent's knowledge to the social topography. The authors observed consequences on the diffusion (local or global) and show the validity of their results through the example of the facsimile where the distribution of the adoption behaviour responds to this resilience approach.

Similarly, and following the works and studies undertaken by Arthur (1988; 1989), Gaios and Zaninotto (1997), we analyse the implications of the fact that users are not entirely sensitive to the behaviour of other users (local externalities). While the behaviour of the first adopter is crucial, externalities with but a moderate impact can ultimately lead to the coexistence of several standards. Thus, the irreversibility concept is challenged by these new approaches and the technical variety that Kirman (1992) had highlighted is possible. In this same perspective on user behaviour, Dalle (1995) reconsiders the case where random adoption necessarily leads to the domination by a single standard, by raising the issue of representative, or average, individuals. In some cases, individuals with extreme choices can have a significant influence on the market, so standards coexist. In Dalle's example, extreme or atypical behaviour is a main reason behind the co-existence of technologies. The behaviour of certain consumers can be a source of differentiation, and not that of imitation. This is also the case in Narduzzo and Warglien's (1996) studies that focus on situations in which the agents base their adoption decisions on the experience of other agents, thereby eliciting the information contagion problem. Detailing the traditional amplification properties

of initial asymmetries in firms' market shares (path dependence and lock-in phenomenon), the authors showed that the final adoption result is even more uncertain than what earlier works had predicted.

In all these models that consider the adoption and positive retroaction phenomenon,[4] it is essential to model successfully the complex behaviour of agents' involuntary co-ordinated actions. The final result may be collective but the decisions are individual. These analyses are often applied to financial markets, where the role of contagion is particularly meaningful, even outside of network externalities, that is, beyond the scope of real interdependencies.[5] In this perspective, Umbauher (1997) notes that game theory provides an interesting framework. The author focused on the behaviour of agents in an economic game, comparing this behaviour in two game theory approaches (projective induction, that is, a bias by which all actions undertaken are rational and follow a discrete evolutionary process). The agent's behaviour emerges to be as much a function of what he knows (actions undertaken) as it is of his beliefs and expectations (actions not undertaken).

3.3. *Main limits of market models*

Diffusion, or epidemic, models that use the three combined properties (increasing returns, path dependence and irreversibility) are noteworthy because they refer to an analysis of adoption dynamics in the presence of network externalities. However, generally speaking, these models are limited, both in terms of their internal consistency and in their explicative capacities. These limits can be grouped into two categories: 1) the existence of an internal paradox in the theoretical construction of the research paradigm itself (agents' rationality and expectations); 2) the ex-post compatibility problem and the lack of a strategic dimension in the firms' behaviour. We analyse the first two limits as two paradoxes. Thereafter, we illustrate the lack of a real strategic dimension in these models.

3.3.1. *The paradox of market standardisation models: the rationality of agents*

Research on market standardisation of network technologies are conditioned, first by the behaviour of potential adopters, and second, by the properties of path dependence and irreversibility. Each of these two key elements has its limits. We will first consider those related to the hypotheses on the rationality of consumers.

Consumers in dynamic economic models are depicted as being capable of making judgements. They are inclined to favour one technology over another, because of certain determined variables and because of their knowledge of the market at a specific point in time. Moreover, one supposes that they are capable of evaluating the respective properties of competing standards, as well as the associated costs eventually incurred. For these reasons, the individuals can be qualified as being completely informed and perfectly rational: 'The individual agent loses his active rationality attributes and becomes a sort of robot reacting

(and reinforcing) to the collective dynamics of a local system, according to a maximisation behaviour' (David and Foray, 1995). Individuals, then, can be considered as being purely reactive, and therefore rationally passive, or anticipating and proactive.

However, provided that one considers information and rationality to be the necessary and sufficient preconditions for diffusion, one is confronted with a paradox. Indeed, one makes the hypothesis that, while choosing a standard, the adopter knows the actual or final percentage of adopters (actual or potential) in the population. However, so as to limit their uncertainties, why do these rational users not wait before making their choice? How can one suppose that, on the one hand, the adopters have a certain knowledge of the relative installed bases and an aptitude to foresee the advantages gained if the standard is adopted and, on the other hand, affirm that they make a choice when the cost of waiting seems to be largely compensated by the reduced uncertainty and the enhanced product's attractiveness (price reductions and increase in services offered)?

3.3.2. *Agents' expectations and the irreversibility problem inherent in the process*

Likewise, one can question the limits specific to users' expectations on irreversibility. Liebowitz and Margolis (1994; 1995) had meticulously studied hypotheses on sub-optimisation resulting from technological lock-in situations. They supposed that one could never determine, at the time that the choice is made, whether or not the consumer has chosen a sub-optimal standard. It is only over time that a standard's sub-optimisation can be recognised. Liebowitz and Margolis' (1995) criticism brings to light a second paradox in market standardisation models — the emphasis made on the importance of consumers' expectations at the expense of information access structures (Shapiro and Varian, 1999).

In the majority of models, when consumers estimate the relative value of current standards at a certain time t_i, two cases are possible: 1) either the estimated value depends on the total number of adopters at a point in time t_n, or 2) it depends on the first adopters during the period t_0 to t_i, n being the final state that actually occurs. In the first case, lock-in is indeed impossible and the hypothesis that the consumers — or the firms — know the total number of final adopters is unrealistic. They can only estimate this number. One falls into the paradox described above about the rationality of economic agents (see infra) and lock-in is impossible, but because of unrealistic hypotheses. In this context, identifying when lock-in and technological lockout take place could be an interesting research question (Schilling, 1998).

In the second case, for a sub-optimal standard to be adopted, it suffices that the information provided to consumers be incomplete or unequally diffused. A paradox results because the quality of the possible expectations, and the possibility of lock-in, needs to be challenged. Even if adopters had perfect foresight of the updated value of the standard, it is the diffusion of and access to information related to the historical condition of the market that determines the

result of the processes. Yet, information diffusion is described in a but cursory manner in market standardisation models while the estimations of expectations are greatly detailed.

Hence, the dynamic market models are based on a theoretical construction that, on certain points, presents difficulties. These are in part due to the models' exclusive focus on the behaviour of consumers. They have neglected the role of the firms themselves and the interaction between the firms' strategies and the consumers: nothing leads one to suppose that this interaction is global and that firms only confirm users' choices once they have been collectively made. On the contrary, everything leads one to believe that global interaction is a succession of local interactions between a user and one or several technologies sponsored by competing firms. Consequently, it appears difficult to discuss technology diffusion and firms' strategies successively as the two phenomena are interdependent.

3.3.3. *Absence of a real strategic dimension in the models*

The absence of a strategic dimension is made evident in the discussion on compatibility in the market models. The models previously analysed (not considering the hypothesis of non sponsored technologies in Katz and Shapiro's models) use the theoretical results from the David and Arthur models, which stress the influence of successive users' choices on the results of the technological competition. However, while these results were elaborated, the strategies of firms were not considered. This leads to a new paradox. If a path dependence effect such as that David and Steinmueller (1994) had described truly exists, then a technological monopoly inevitably emerges: as soon as it develops beyond the critical size, a network becomes dominant. The compatibility question is thus considered in relation with the networks that have successfully co-existed. Consequently, it is possible for several firms to attain the critical size separately. The problem becomes, then, that of knowing if the existence of several networks is economically efficient. Two perspectives are lacking in this analysis:

- the growth of competing networks beyond the critical size has not been taken into account: if attaining the critical size does not imply absolute competitive advantage and the elimination of other networks, the confrontation between technologies persists. Each network continues to possess its own attractive potential and attempts to draw in subsequent users. In winning over new users, the compatibility question, and thus the attractiveness of the networks, cannot be ignored and must be considered on the strategic level, especially in view of the strategic importance of network externalities. Furthermore, the idea that a user is a prisoner of his network is only relative: there comes a moment when investing in a new product can be more profitable than possessing a product that is becoming increasingly useless, especially since these markets are obliged to systematically renew their technologies. In short, market confrontation raises an oligopolistic issue, which poses questions on ex-post strategies that cannot be neglected.

- ex-ante compatibility: the risk of several technologies competing so intensely against each other that none can attain a critical size still needs to be measured. In this case, there is a genuine interest in forecasting the ex-ante compatibility. If no network attains the critical size, this implies that market efficiency must be challenged, since the uncertainty dissuades users from subscribing to alternative networks. This problem leads to a strategic interest in compatibility as a means to consolidate the market.

The risk of a technological confrontation, whether this occurs prior or subsequent to the attainment of the critical size, appears, then, to be largely underestimated by market standardisation models. An analysis of the weaknesses of these models, strongly focused on users' expectations, reveals that a major problem of activities with network externalities is also the difficulty of co-ordinating the suppliers. More generally, what should be subject to criticism is the idea that a confrontation between standards is the only possible competitive option. The concepts underlying the economics of networks appear to be relevant, but this does not suppose that the firms must necessarily conform to them. The risks linked to the involvement and standardisation processes should argue, not for an avoidance strategy, which can be potentially detrimental to innovation, but for the definition of a common competitive environment.

In conclusion, while firms' strategies are certainly not entirely neglected in the models considered thus far, they appear to be all alike and are mechanically determined by users' expectations. It is also very clear that the more methodologically refined the dynamic models, the less important the firm's strategic role becomes in the standardisation process. Although one of the critical dimensions that the market models bring to evidence is the great uncertainty that characterises network industries, there is no discussion on the how firms can limit this uncertainty. A second research domain to pursue consists in demonstrating that firms can succeed in collaborating on the standards. It is this co-operation, and not only the market processes that firms do not control, that will lead to the adoption of a standard.

4. Actors models

Recently, in parallel with market models, literature on network technologies have been developing a different research program centred on the study of firms' strategies and on the voluntary standardisation process (Hill, 1992). Standardisation emerges as the result of an inter-firm co-operation strategy. In fact, it appears that on numerous markets, the standard is the outcome of inter-firm co-operation rather than that of an irreversibility or lock-in process (CD-video, APS film). How can one understand this strategic choice that firms make? What motivates them, individually, to co-operate rather than to compete? How can a collective action be established to define a standard? These are the questions to which the new models attempt to respond. Hereafter, we will address each of these questions successively. We first note that the new models do not entirely reject the models

described in the previous section, but rather, propose another type of simultaneous explanation.

4.1. *Compatibility: a crucial strategic choice in network technologies*

Besen and Farrell (1994) clearly expose the strategic dimension inherent in standardisation. While the authors do not propose formal models, they do build an analytical framework that integrates the fundamental principles of markets with network externalities to the strategic discussion on competing firms.

The fundamental choice is the result of compatibility: either the firms choose to not co-operate, attempting instead to impose their own technologies, and thereby depending on the capacity of these technologies to attract adopters, or they opt for compatibility between technologies, competing only on traditional elements unrelated to the characteristics of network technologies (price, quality, performance, reputation, etc.). Besen and Farrell (1994) refer to the first case as inter-standard competition and to the second as intra-standard competition. The dilemma that firms face is the choice between inter- and intra-standard competition.

Inter-standard competition implies a *laisser faire* attitude toward the market and toward expectations, which results in dynamics that market models have already examined. In contrast, in intra-standard competition, firms co-operate on a co-standard and continue to compete on derivative products of the technology at hand. The choice of one form of competition over another requires firms to use different resources. Intra-standard competition seems to be more traditional, focused on products, prices, quality, etc. Consumers' expectations become secondary in the sense that if a firm no longer exists, users still have access to technologies compatible with the products that they have acquired. On the contrary, in inter-standard competition, the issue is the firms' capacity to inform (and to reassure) the consumers who have become particularly cautious due to the uncertainty that characterises the network markets. In short, the difficulty is to favourably direct users' expectations. It is therefore necessary to build a reputation in the eyes of the consumers. Strategies to sponsor a technology during the first period of its distribution (Katz and Shapiro, 1986) can play a similar role by reducing, not the uncertainty itself, but the cost linked to the uncertainty.

De Palma, LeRuth and Regibeau (1993) propose, as a result of their studies on bankcards, a complementary clarification of the strategic consequences of compatibility. The authors demonstrate that the choice for compatibility between two technologies has two main effects on the competition, one with a potentially positive implication for firms, the other, a negative one:

- a collusive effect (positive): a firm's growth directly benefits others. This effect results from technological compatibility, and produces an inverse effect on firms that occurs in inter-standard competition when the growth of a firm increasingly penalises its competitor by causing adopters' expectations

to evolve (Katz and Shapiro, 1985). Co-operation thus enables a technology to sustain over time, which is advantageous to all firms that have decided to collaborate.

- a competitive effect (negative): by making their technologies compatible, firms lose an essential part of their differentiation. Certainly, the transition to intra-standard competition weakens the captive link that exists between firms and consumers in inter-standard competition. Compatibility considerably reduces consumers' captivity and the firm is thus forced to search for other sources of differentiation.

The two alternative strategic branches are clearly stated here. By choosing intra-standard competition, the firm loses its most powerful strategic mechanisms, that is, those which can enable it to become a monopoly (if the technology stands out among all others in the market processes), or at least those which help it to efficiently differentiate itself due to the captivity of its consumers. Yet, this intra-standard competition at the same time limits the uncertainty linked to market adoption mechanisms of network technologies.

Consequently, it is this reduced uncertainty that, in co-operation models, constitutes the principal motivation for firms to opt for intra-standard competition. We will now further develop the characteristics of this uncertainty.

4.2. *Incentives to technological compatibility*

As it is still in the process of being developed, existing literature has but a fragmented vision of incentives to creating a single standard through collaboration. We have chosen to organise this sub-section by theme, addressing the arguments of different authors.

4.2.1. *Uncertainty linked to the existence and size of the market*

The analysis of uncertainty can be broken down into three distinct dimensions: the existence of the market, its size and the cost to develop it. The first source of uncertainty inciting firms to turn toward intra-standard competition involves the existence of the market itself. De Palma, LeRuth and Régibeau (1993) showed that when a market emerges, technological compatibility reduces the risks that the market may not exist at all. As Besen and Farrell (1994) had indicated, the uncertainty here concerns the market size, which must be compared to the critical size that firms need to attain in order to build an installed base and to benefit from network externalities.

In addition, Besen and Farrell (1994) emphasise the temporal dimension of the standardisation phenomenon. Collaboration prevents users from postponing their adoption decision until a standard actually dominates the market; this would be detrimental to the technologies due to the length of time that it would take to yield returns on investments. Moreover, the uncertainty is magnified because inter-standard competition requires substantial investments to build up the firm's

reputation, which implies that the time needed to make an investment profitable is lengthened.

Furthermore, once the firms become established in the market, compatibility expands this market (Economides, 1989), giving rise to a better appreciation of externalities and creating more value for the product or service offered (De Palma, LeRuth and Régibeau, 1993). When the networks are compatible, consumers benefit from the combined size of the competing firms and gain from the resulting surplus (Garud and Kumaraswamy, 1993). Consequently, the market becomes more attractive and the risks associated with the existence of the market are reduced.

Likewise, Economides and Woroch (1992) demonstrated that co-operative efforts might be preferable to market forces in the interconnection of physical networks. They specify the case of a network providing a comprehensive service that is challenged by another service, which offers only a part of that service and is dependent on the connection to the first network. The authors varied the degree of integration of the two networks: for each configuration, they calculated the endogenous variables (price, volume, and economic surplus) and assessed the diverse configurations in the objective of determining the level of integration and co-operation desired. They reached the conclusion that the network that has the possibility of offering all of the services will prefer to connect the competing network. The strategy to exclude the competitor from the network appears undesirable, as the sale of components to this network will decrease and will not be sufficiently compensated by the increase in the sale of end products on the main network. Once again, it is precisely the desire to increase the size of the main network that encourages firms to collaborate (David and Greenstein, 1990).

4.2.2. *Uncertainty linked to competitors*

The second form of uncertainty that can limit a co-operation strategy involves the competition. Co-operation can be a means to reduce the competitive intensity that inter-standard competition can cause. Here, the authors focus on the difference in the size of firms. Besen and Farrell (1994) explain that small firms will experience more difficulty in establishing a reputation that is sufficiently strong to be efficient in inter-standard competition. Since one key element of this form of competition is, as we have seen, firms' capacity to reassure consumers of the viability and the superiority of their technology, it is often to the advantage of small firms to co-operate when they are confronted with large competitors.

Likewise, De Palma, LeRuth and Regibeau (1993) elicit the equaliser effect that is triggered by intra-standard competition. While the networks do not necessarily have the same size at the outset, compatibility makes them equally attractive since the users of one network can benefit from the size of another. The equaliser effect is at the centre of negotiations on rules applicable between firms in a co-operative network.

De Bondt (1996) nevertheless rejects this analysis insofar as R&D co-operations are concerned. He notes that the asymmetries between the suppliers on the

expected returns harm the co-operation. Often, these asymmetries are due to size differences between the actors. Consequently, Perrot (1995) posits that, for network operators in regulated activities, 'the strongest operators, in terms of market share or technological advantage, are encouraged to refuse product compatibility, while the least advantaged actively seek to establish' it (Perrot, 1995: 62). However, according to the characteristics of markets with network externalities, compatibility between large and small companies can help to reach a better coverage of market (e.g. residual demand, or local customers with specificity). In this case, we can add here that compatibility can also reduce price wars, thereby making room in the market for firms with the highest production costs (that is, small firms in markets such as transportation or airline activities where economies of scale and scope play crucial roles) (Perrot, 1996).

Kogut, Walker and Kim (1995) digress from the only discussion on the size of competitors to turn toward questions on the structures of co-operating firms. They illustrate that small, innovative 'start-up' firms tend to favour co-operation with networks organised around a dominating firm, because this ensures them of a reputation and an installed base, rather than with networks of small firms, even ones with many members. Therefore, while the size of potential competitors has here a determining impact on the strategic decision of the partner, the centralised nature of the structure itself also plays a significant motivating role. This is what the authors refer to as supplier network 'centrality'.[6] The greater this centrality, the more the start-up firms are incited to collaborate. In exchange for the large firm's reputation and installed base, small firms contribute technological innovation that they have developed and make them compatible to all suppliers in the network. Even if these firms lose profits in the process, they nevertheless considerably increase the chances of making their technology the market standard.

The uncertainty that firms attempt to limit by choosing intra-standard competition thus takes on diverse forms, linked either to market characteristics or to those of the competitors. While these co-operation incentives have been clarified, they are nonetheless insufficient to explain the reasons behind the decision to co-operate, which is collectively, and not merely individually, made. Intended for all actors on a market, a standard has an institutional dimension (Garud and Kumaraswamy, 1993). The question is, therefore, to determine, in view of the incentives that we have just seen, how a standard (collective decision) can emerge.

4.3. *The institutional dimension of a standard, or co-ordination mechanisms leading to the collective adoption of a standard*

Scholars of technological change have recognised the collective nature of organisational action in the emergence of standards (Van de Ven and Garud, 1989; Tushman and Rosenkopf, 1992). Technology standards can be seen as the 'rules' that enable compatibility between products or networks. In view of their significance, the establishment of a technology as the dominant standard has

become a key strategic issue in network-based industries. Indeed, the battle between alternative technologies to become the market standard can be conceptualised as the interaction between various organisational actors 'to set the rules of the game' (Hamel and Prahalad, 1994). Two main types of studies, both of which highlight different institutional forms, respond to this question in the field of network technologies.

4.3.1. *Standardisation committees*

In many cases, firms recognise the need to explicitly co-ordinate their actions in order for their technology to become the market standard. Standardisation committees constitute an intermediary process leading to the institutionalisation of the standard (Farrell and Saloner, 1988). Such governance structures expressly promote collective action between firms involved in establishing a standard. The firms decide on the collaboration at these committees, thereby giving them a spontaneous characteristic. However, this collaboration is also based on an organisation that already exists — the standardisation committee, which was created prior to the decision to collaborate (Foray, 1994).

The starting point of models introducing standardisation committees is the avoidance of both the sub-optimisations linked to lock-in and the two types of uncertainties mentioned above. Thanks to these committees, firms are able to rely on an existing institutional structure in order to collaborate, thereby reducing costs linked to the collaboration (Farrell and Saloner, 1985). The committees also have the virtue of reassuring consumers, so much so that they can help firms to reduce costs linked to the development of a reputation and of their credibility.

However, certain authors question the quality of the collaboration resulting from negotiations in standardisation committees. They consider that, at the core of formal standardisation processes, the problem of installed bases and the technological confrontation remain completely unchanged (Foray, 1994). Indeed, it seems that the committee, as long as it is created prior to the competition between technologies, does not play a role other than that of recording market decisions. For the firms, then, it does not provide satisfying solutions to the strategic problem posed by inter-standard competition. Compatibility remains an ex-post and not an ex-ante decision as it should be in the case of collaboration (Postrel, 1990).

One can thus consider that the standardisation committee is a hybrid organisational form that is hardly innovative because its ultimate task is but to preserve existing networks, the decisions that it makes being irreversible due to each firm's installed base (Williamson, 1985). On the theoretical level, we must refer back to the first models, which are based on increasing returns and on consumers' expectations.

The reason why standardisation committees are not an efficient incentive structure for standardisation is undoubtedly because only the organisation associated with the collaboration (the standardisation committee), and not the decision itself to collaborate, is institutionalised. First, the standardisation

committee does not necessarily provide an incentive structure that is adapted to the problem posed by the technological competition between firms. In certain competitive situations, this structure must be very rigid; in others, much less so. Here, there can be no predefined structure. Second, the standardisation committee does not give rise to behavioural norms that are adopted by all and that guarantee a standardisation process differing from that which the market generates. The case is different altogether when it is the decision to collaborate itself that is institutionalised, as this results in an adequate incentive structure (Krauss, 1994).

4.3.2. *The spontaneous emergence of collaborative institutional forms*

Since a predefined organisation hardly appears to be an efficient incentive structure for standardisation through collaboration, another theoretical line of thought develops, addressing the spontaneous emergence of organisational forms that guarantee collaboration. Here, it is the decision to collaborate that is institutionalised, and not only the organisation associated with the collaboration.

Antonelli (1994) defines the emergence of standards as a part of a larger institutional process. The magnitude of the demand in the standardisation process is reflected by the capture of network externalities due to the co-operation of all types of organisations involved in the process. The standard becomes an economic 'institution', that is, an inter-firm interaction mechanism that does not exclusively generate price adjustments but also brings into action technological innovations, organisational arrangements and behavioural norms.

Antonelli proposes a model with a voluntary emergence of a standard through co-ordination efforts by two firms, each with a different technical process (niche). The emergence of the standard incurs adoption, sponsoring and competitor control costs. However, the co-operation also enables the firms to stabilise users' expectations by minimising their uncertainty and their potential dissatisfaction, and by reducing switching costs from one technological system to another. The Antonelli model, then, affirms the importance of the co-operative process between suppliers, by maintaining a classical vision of co-operation, inspired by the idea of cartels.

David and Steinmueller (1994) also focus on questions associated with co-ordination efforts to implement during the spontaneous emergence of a standard. The authors showed that the degree of co-operation depends on different levels of possible standards (common reference, interface, compatibility, and so forth). They illustrate that the standardisation's influence on the competition between actors is ambivalent: it generates an additional competitive pressure because of the information that it reveals but, in principle, reduces the competition by encouraging co-operation and by limiting the diversity of the offer (Foray, 1993; Metcalfe and Miles, 1994). In fact, the actual determining factors in the co-operation decision are just as strategic and organisational as they are economic in nature (David and Steinmueller, 1994). The co-operation becomes an organisational form in competition against the market with the objective of managing increasing returns, path dependence effects and irreversibility. One finds here an

approach valuable to transaction cost economics, where standardisation through collaboration appears to be a 'hybrid form' between the market and the hierarchy (Williamson, 1985).

Kavassalis, Salomon and Benghozi (1996) also evoke this new organisational approach, where co-operation is pursued in a spontaneous manner, in the area of telecommunications standards. According to the authors, these standards will evolve toward an Internet-type operation, based on interoperability, that is, a flexible and dynamic connection through gateways and appropriate software. A new standard will thus emerge, raising issues about the functioning of a system and no longer merely interconnection issues. In the same vein, McKnight, Bailey and Jacobson (1996) use digital television as an example of inter-operability standards.

4.4. *Ex-post compatibility through converters, add-ons or emulators*

Standardisation can be the result of many processes — independent actions of market participants, formal co-ordination activities of voluntary industry standard committees or government actions. However, since many proprietary standards can co-exist, it is also possible to achieve ex-post compatibility between technologies. This compatibility does not result uniquely from co-operation between firms, but can also be achieved through converters or emulators, also called gateway technologies. David and Bunn (1988) generally define a gateway technology as 'some means (a device, or a convention) for effectuating whatever technical connections between distinct production sub-systems' (1988: 170). Farrell and Saloner (1992) showed that this type of ex-post compatibility without standardisation does not reduce variety and innovation, which may be appealing. Yet, it is true that converters are seldom available when incompatible products are marketed, which means that market selection is generally the dominant process. Finally, the conversion process remains expensive and is not perfect, as dominant firms have incentives to manipulate converters to make them costly and ineffective. They also can create one-way converters so that users of rival technologies cannot capture network externalities (David and Bunn, 1988). All in all, the relationship between converters and social welfare is ambiguous, as attest the main results of Farrell's and Saloner's research.

4.5. *The limits of studies on voluntary compatibility between actors*

Although extremely promising, actors models also have limits, partly because they correspond to a research program that is still being developed. Indeed, one can note the extreme diversity of these approaches, inasmuch as the scope of knowledge and even the research program appear to be much less structured and elaborated than those of the market models. The authors do not quote each other, which indicates that there is yet no common reference in the field of standardisation through collaboration. The common references remain the market models described in the previous section and in which collaboration is

always presented as a solution enabling firms to protect themselves against irreversibility effects generated by markets with network externalities. Our article is a preliminary study for the implementation of an analytical framework which integrates and links together different studies on the planning of the method, all the while uncovering expressed links in the problems described in these studies.

Certain criticisms, besides those pertaining to the emerging character of the research, can be formulated about the competitive dynamics in the case of standardisation through collaboration. While all the details about intra-standard competition are beginning to become known, co-operation models respond but very moderately to the consequences of the compatibility decision on the competitive topography of the sector in consideration. Consequently, will a leading firm's exclusion from the process of establishing a joint standard in the sector ultimately ruin the chances of that firm's standard, or of those of competing firms', of being widely chosen? What alternative strategies do the firms with weaker market power conceive in order to avoid being excluded from asset coalitions organised by competitors? To which logic do the successive collaborative mechanisms of competing networks adhere? These questions are not explicitly discussed in the actors models.

Likewise, the implications of different forms of collaboration on competitive dynamics are not largely considered. De Palma, LeRuth and Regibeau (1993) had noted that the co-operation could only be partial, creating an intermediary form of competition between inter-standard and intra-standard competition. Moreover, should distinctions not be made depending on whether or not the collaboration aims to achieve technology compatibility once these technologies are developed? Should distinctions not also be made depending on whether or not the collaboration supposes that firms work together to pool their research projects?

However promising, the field the least explored remains that which addresses the institutional dimension of standardisation through collaboration (Van de Ven and Garud, 1994). While the spontaneous emergence of the standard is the keystone of the analysis, except in models introducing standardisation committees, the conditions leading to this emergence are never explicated. As for the economic analysis of the birth of institutions (Dupuy, 1989; Sugden, 1991), one can suppose that more dynamic outlooks, particularly based on game theory, will emerge to explore these dynamics involved in the creation of co-operative networks.

On the other hand, one of the limits of these studies on the institutional dimension of the standard is their focus on the collaboration decision and their neglect to fully address the consequences of this decision. Indeed, co-ordination mechanisms applied at the time when these consequences occur are considered, since they reduce the costs linked to the collaboration, but they are never formally elucidated. What about, for instance, opportunity risks, or the difficulty in defining the objectives and the scope of the co-operation? How are the co-operation and the functioning of the inter-operability managed? What are, at the time of negotiations, the true strategic levers toward which gravitates the

co-operation agreement? Likewise, a question that is not widely considered is that of the division of tasks in the collaboration. A related point is the sharing of costs among partners. A firm can never be sure that an R&D co-operation will ensure an equitable sharing of costs associated with the improvement of a standard. This uncertainty can be the result of several factors. For instance, the value of a standard can be greater for one of the firms in the R&D co-operation than for another, so its involvement will be greater. Or a firm can be weary of becoming technologically dependent on its partner, so it will tend to duplicate its R&D efforts. Or competition between several technologies to become the dominant standard can cancel out the efforts of each consortium involved in the competition. Can the collaboration not create a runaway behaviour (Olson, 1965)? Can this behaviour not challenge the institutional nature of the collaboration? Is this perhaps because the role of the large firm, often evoked by authors as an incentive to collaboration, is to stop contradictory behaviour undermining the institutional logic of the collaboration?

One last comment is necessary about firms' incentives to co-operate, which are generally viewed as a completely endogenous process which is related to a strategic decision. It must be mentioned that public authorities may encourage compatibility decisions, for public goods such as telecommunications, and can even regulate monopolies (Gilbert, 1998). For telephone networks, the existence of network externalities have historically led to monopolies, whereas today oligopoly is encouraged since compatibility is already achieved between networks. Curien and Gensollen (1987) suggested different possible regulations for telecommunications, arguing that deregulation is desirable, provided that monopolies are characterised by contestability (no entry barriers, no sunk costs, hit and run strategies) (Baumol, Panzar and Willig, 1982). In this context, it seems that regulators aim at encouraging both the capture of externalities and the existence of competition (Benzoni and Rogy, 1993; Economides and White, 1994). Many institutions are possible, such as regulations, antitrust policies, incentives through associations, etc.

5. Conclusion and research agenda

Three key conclusions can be made from the analysis of literature on standardisation in network technologies. First, one can distinguish two types of models that analyse this process, each with its own methodologies, analytical tools, simplifications and conceptual limits: market, or adoption, models and actors models. The market models suffer from the problem of integrating the temporal dimension and the adopters' reasoning in the standardisation process. It also faces the difficulty of freeing itself from the irreversibility paradoxes implied by the properties of increasing returns, path dependence and irreversibility. The co-ordination models between producers illustrate that irreversibility can be managed at the producers' level, either ex-ante or ex-post, to the benefit of both firms and users in view of reduced uncertainty. Despite their different foci, these

contributions are complementary because the market models implicitly inform us of the consequences of a *laisser faire* strategic behaviour.

Second, irreversibility appears to be at the core of the standardisation process. Management of the standardisation is a management of irreversibility. Here, the role of information is crucial. The users modify their adoption behaviour in light of the information that they receive (installed base, software available or to be made available, competitive performance). The producers know the properties of the standardisation of network technologies (increasing returns of adoption, dependence and lock-in) and are aware of the strategic importance of information. When launching a product, they influence users' expectations (the case of market models); at one point in this process, firms can co-operate to share the investments and revenues associated with the standardisation (compatibility, interconnection, etc.).

This leads us to the third conclusion: firms do not merely have a reactive attitude. Their proactive behaviour can take upon several forms: sponsoring, purchase financing (the case of mobile phones in Great Britain) or, following a market approach, diffusion of information to influence the beginning of the process. If the compatibility choice is made, the determinants must be understood. In the spirit of co-operation, firms together gamble on increasing returns and on the irreversibility of the process. Inter-standard competition, in this case, is modified, but the scope of intra-standard competition expands, which poses a management problem for actors having invested in co-operative efforts. The co-operation, then, appears to be an equivocal action that requires real time management (procedures, rules, resource sharing).

The consequences of firms' proactive behaviour extend beyond the range of the economic framework, spilling over to the institutional framework. The standard itself earns the status of an economic institution with specific and endogenous operating and resource allocation rules.

These three findings show that the study of standardisation processes, at the very least on the strategic level, is still in progress and seriously needs to be further studied. Although market models continue to be improved (local externalities and percolation structures), one can suppose that the analyses of results obtained have reached a mature stage and that any further amelioration will be at the expense of exaggerated simplifications on firms' behaviour in the presence of network technologies. In contrast, it is this last question, that is, the behaviour of firms in interdependence situations, that must be further studied from several angles:

- on a strategic level, two main questions emerge: How can the determinants of the compatibility decision and the forms that it assumes (organisational modes, type of management) be understood? (Garud, Jain and Phelps, 1998); the second question pertains to the competitive dynamics induced by a compatibility decision (David and Greenstein, 1990). The development of appropriate responses provides a solid base to a strategic approach to management of compatibility (Durand *et al.*, 1998).

- on a more economic level, the question posed pertains to the modes of activity co-ordination: Why can the market not ensure the co-ordination of certain activities that involve an interdependence of economic actors, and what status does the inter-firm co-operation process assume from this point forward? How, more generally, can a connection between the innovation and co-operation between firms be made?

On both the macro- and micro-economic levels, interesting questions pertaining to the connection between the variety, the technological change and global performance emerge. According to Elliason (1995), 'the selection mechanism dominates long-term industrial development'. The management of interdependencies, an important field of thought for theoreticians and practitioners in economics and management, would benefit from more advanced modelling on these questions.

Standardisation, then, is an interesting issue because it evokes the question of co-ordination between economic actors and that of the types of framework they need to build to manage a balance between co-operation and competition. One must therefore bear in mind that the formation of standards is but one example of a larger process, which is the creation of endogenous institutions in the economic environment.

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Notes

1. This article draws heavily on literature in economics devoted to networks, standards, and switching costs. Three important on-line resources in this area contain a more extensive listing of works. They are at: *http://www.stern.nyu.edu/networks/*, at *http://www.sims.berkeley.edu/resources/infoecon* and at *http://wwwpub.utdallas.edu/~liebowit/*
2. For additional details on these examples, refer to studies conducted by Cusumano, Mylonadis and Rosenbloom (1992), Cawson (1994) and Krauss (1994).
3. It is important to note that the installed base does not equal market share unless the firm is the sole provider of a particular technology standard.
4. Cohendet (1995) groups these models into two categories: a defined population of agents and an evolutionary one, the adoption dynamics of which are grounded on the entry of new and non uniform agents. Concretely, this has resulted in studies based on Arthur's method (random selection from a Polya urn) or on works related to the percolation theory (Zuscovitch, 1986; David and Foray, 1994).
5. Indeed, more generally, the problem becomes that of the sensitivity of a user's decision to others': contagion, rumour phenomenon and mode effects are considered here.
6. The authors talk about the 'degree of centrality'.

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