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Abstract:

A crucial question at the center of corporate governance theories and of the literature on social networks alike is the sense of empower of prestige, or influence on the actors of a social network. This paper approaches the possibility of measuring this influence by detecting key individuals who support network dynamics. By means of a study conducted on a sample of CAC 40 directors, it will be shown that the most influential elements are not necessarily the best placed at the beginning. Contrary to all expectations, a dynamics of influence is based on criteria of indispensability to the network that will be presented as an example.

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INTRODUCTION

The recent bankruptcy of the great flagships of American capitalism (Enron, Lehman Brothers, AIG), indeed the present financial crisis, cannot be considered as mere deviations, or accidents of history; they all question governance under all its guises. In a broader sense, these dysfunctions shed new light upon modes of governance, notably on the Anglo-Saxon model and its *shareholder* approach at the very moment when it seemed to have imposed its supremacy in Europe to the detriment of the *stakeholder* model (Cohen (2005), Peyrelevedere (2005), Streeck and Höpner (2003)). If one is to consider corporate governance (CG) as a set of regulatory practices which govern the relations between directors (the management power) and company shareholders (those who own the capital), as well as other stakeholders of the company (employees, creditors, suppliers, clients) (Pastré 1994), it will be immediately apparent that there is no single CG model. This set of rules is in fact rooted in and evolves within traditions, within legal and institutional frameworks that vary from one country to another, from one geographical and cultural area to another (OECD 2004). Nevertheless, it is commonly admitted that a director would not be able to really fulfill his/her role beyond a certain number of directorships². Thus, the AFG-ASFFI report on “corporate governance” (2012) advocates the limit of three directorships, whereas the French law on New Economic Regulations (NRE) authorizes up to 5 directorships.

Nevertheless, this quantitative approach should not conceal the difficulty of choosing a director: should one prefer a director with only one directorship, who consequently has little influence, in the sense of traditional measures of influence within a network (as it will be shown, he would potentially be a *weak* link in the sense of Granovetter (1973)), or an influential director already holding a directorship elsewhere (potentially a *strong* link). This

² This limitation of directorships is placed within a broader political and historical context, unfavourable to the accumulation of directorships.

issue arises regardless of the qualitative nature of the director, whether he/she is declared to be independent or not³. In fact, the appointment of a director cannot simply be made at random. Behind this promoted candidate lies possible access to a network, to information/expertise, to mutual influences, which takes us back to the matter of the importance of maintaining a director or of his/her appointment for the influence of a particular director, a network of directors (a community) or even a company. The literature on partner selection is an important one, and many factors that affect partner selection have been identified. Most of them assume that the main motivation is to enforce some of the firm's network characteristics: market uncertainty, alliance, learning of new practices, and the diffusion of new management strategy (see Burt (1993), Gulati (1995), Powel *et al.* (1996), Beckman *et al.* (2002, 2004) and Connelly *et al.* (2011)).

This article seeks to explore the dynamics of network building in the specific case of the appointment to the boards of directors. Unless the appointment of a certain individual in the position of director of a particular company, part of a corporate network, can be reduced to a single motivation⁴, it would grant that person a quality of *indispensability*, a criterion which is yet to be detailed. Our essentially theoretical study seeks to define this *indispensability* criterion on the basis of a special motivation: that of strengthening the power of influence of the co-opting members, or of the business, within their respective networks. This is part of the literature on the analysis of business networks and, more specifically, of director interlocks. For Dudouet *et al.* (2009), the choice of a specific director aims to strengthen the national influence of the company, while from an international perspective, the choice of a director

³ This is because nothing prevents a director holding several directorships to be declared independent within certain boards and non-independent within others.

⁴ A traditional approach, inspired by the works Bourdieu, is based on the assumption of the replication of an elite that shares a common denominator, be it cultural, educational (major schools), economic or simply based on "filiation" (Dudouet *et al.* (2007), Kramarz *et al.* (2006), Massol, *et al.* (2009b)). But motivations can be much more pragmatic, as it is emphasized by Mizruchi (2003): having been recruited by someone who could be a friend, can scarcely lead to asking difficult questions or result in confrontations.

aims to fill structural gaps⁵. In the French case, Pichard-Stanford (2000) examines how leaders leverage these relationships to acquire new directorships and thus gain access to sources of information allowing them to specialize in the management of the company while strengthening their specific capital. According to this author, business growth and, therefore, the compensation of managing staff, can hypothetically be related positively to the company's capacity to exert influence: for instance, using a criterion of centrality degree (the number of links established between the company and the other companies via its directors holding several directorships); Hence the temptation to appoint directors with several directorships who already have a high degree of centrality within the board. We do not deny that such a strategy can exist (namely an objective to increase the level of influence of the company), but the individual interests of different board members remain to be analyzed. The assumption is that the more indispensable or desirable an individual, the more he/she enhances the influence of appointed directors within their respective networks (i.e. egocentric network), which can result in an increase in the income of the leader (Vigliano (2009), but also in a relaxation in his/her discipline (Charreaux 2003).

Our research is divided into three sections. The first section provides a critical survey of the concepts of centrality and introduces the concept of *Key Player*. The second section discusses the dynamics of building a network around these notions of centrality and *Key Player* and the impact of this dynamics on the existence of communities within a network. Section 3 empirically illustrates the need to develop a robust indispensability criterion using a CAC 40 network of directors. This criterion measures the changes induced by the introduction of an individual or by his/her removal on the power-sharing within the network. Finally, we reach our conclusions.

⁵According to Vigliano (2009), structural holes provide “business opportunities” to position oneself as a “bridge” or middle-man and thus, would bring a competitive edge to those who have a bridge position.

1. Who is central to whom?

Since the publication of Freeman's article (1979), these notions of power or influence have traditionally been observed through the prism of the use of centrality measures such as betweenness or closeness. Betweenness measures the number of times a node is placed in the path between two other nodes that are not interrelated. An individual may be weakly connected to the others and yet prove to be an essential intermediary for exchanges, or else, a mandatory path. Obviously, a high degree of betweenness is synonymous with the ability to influence and/or coordinate the network. Closeness measures the ability to reach all the other nodes in the network via the shortest paths (i.e. geodesic distances). In other words, it indicates the possibility of accessing the source of information in the social network. Needless to say, this indicator cannot be calculated unless all nodes are interconnected (i.e. there is always a way to reach everyone). Although these measures are widely accepted, they are nevertheless subject of criticism. Undoubtedly, the main objection is that of Borgatti (2005): betweenness or closeness measures assume that information flows only pass through the shortest paths, and that these flows cannot be divided.

The use of the shortest paths to transmit information, between two individuals for example, presupposes that the sender knows the entire network in advance, that is his/her network, but also the network of his/her direct friends, then the network of the networks of his/her friends, etc. However, in the absence of such information, the *small-world* effect tells a different story. The sender will choose the person whose network has the highest probability to connect indirectly to the recipient. Then, how does one choose the best person? Assuming that each sender knows their network perfectly and therefore implicitly knows if the members of the network have a network close to him/her or not, Granovetter (1973) has demonstrated that they often needed to focus on weak links. If one assumes that the strength of the relationship

between two individuals is proportional to the equivalence of their relationship, that is, to the “structural equivalence” (Lorraine and White (1971) and Burt (1976)), the search of the weak link will favor the choice of a person whose network is sufficiently different from his/her own in the hope that this person has an acquaintance who has an acquaintance, etc., who is in a better position to share the information. In the next section, it will be shown that to challenge the assumption of perfect and, above all, complete information amounts to questioning the very dynamics of networking. As far as the division of flows is concerned and in the context of influence, a person may be interested in increasing the number of transmission channels for the same information (i.e. this is the buzz strategy). Or else, the betweenness measure⁶ does not allow an increased number of paths. In fact, this measure is defined by:

$$bet(v) = \sum_{v \in V, \forall u, x \in V, v \neq x \neq u} \frac{\neq \text{ of shortest paths from node } u \text{ to node } x \text{ that pass through } v}{\neq \text{ of shortest paths from node } u \text{ to node } x}.$$

The calculation of this measure for network nodes B and C, described in Figure 1, gives $bet(B) = bet(C) = 1/2$. Taking the B node as reference node, B is found to be a mandatory path only between A and D. However, C is also a possibility of linking A and D. So the intermediacy value is 1/2 because it implicitly assigns a 50% probability that the information passes through B rather than C between A and D⁷.

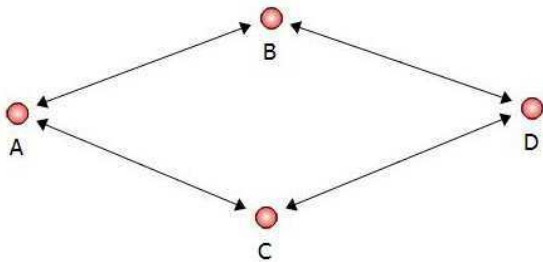


Figure 1 – B and C mandatory paths between A and D

⁶ See Appendix A.3 for a definition.

⁷ Proportionally, we have $bet(B)=1/6$, with the rescaled formula (should we consider path AD and AD as equivalent): $bet(B) = \frac{bet(B)}{(n-1)(n-2)/2}$.

It is likely that if A wanted to influence D, he/she would seek to do so through B and C. Why deprive oneself of a means of influence?

In reality, the choice of the optimal path to reach a particular director is complex. In fact, the link created by such a choice can only be temporary: the network of CAC 40 directors is constantly changing. Directors are generally appointed for only 4 or 5 years and each of them may terminate their mandate when they see fit. Furthermore, choosing one new director over another, can lead to two opposing strategies. A new director can strengthen the corporate network (providing resources, market knowledge, know-how) and thus improve the overall performance of the company. But the choice to integrate a new director can also stem from an opportunistic strategy employed to strengthen the staff egocentric network of prescribers, even at the expense of the company. Hence, we gather that the construction of a network, including that of an egocentric network, is generally not a coincidence.

The traditional approach based on the graph theory analyses this kind of construction dynamics by means of the correct setting and use of a random network (Newman 2003). Because this approach does not allow a consideration of the “small-world” characteristics of social networks, a more recent, alternative approach was proposed by Jackson and Rogers (2007), one based on the use of tools from statistical physics. Even if this approach can track the *small-world* characteristics, it fails however to provide an endogenous understanding of the network’s dynamics. Deng, Heping and Dejun (2007) studied the impact of the removal of a link within the dynamics of building a network as defined by Barabási and Albert (1999). They show that certain structural properties such as the small-world effect may be modified by the removal of an individual. There are thus people who are *essential* to the network and others that are not, in the sense of the existence of a *small-world* effect. But the matter of

identifying these indispensable individuals remains without a satisfactory (or complete) solution.

Borgatti (2003, 2006) suggested an alternative to the use of too simple measures of betweenness and closeness to identify such individuals. This alternative relies on the definition of a *Key Player*. Two readings of the Key Player Problem are possible:

- a) The “Key Player Problem Positive” (*KPP-Pos*), which means to select a subnet for the rapid dissemination of information/practice throughout the network.
- b) The “Key Player Problem Negative” (*KPP-Neg*), which determines the essential subnet to the functioning of the system. It is self-evident that if this subnet is removed, the network loses its fundamental properties.

Within a social network, and in order to optimize its individual network, these *KPP-Pos* and *KPP-Neg* notions are directly related to the research of a key individual: adding this individual means reaching new people quickly (*KPP-Pos*) and their removal destabilizes the network (*KPP-Neg*).

2. Network Dynamics

2.1. *Adding Friends and KPP-Pos*

The notion of *KPP-Pos* questions the choice of the individual to add to one’s network. We know, using the shortest paths requires a perfect knowledge of the network. If such knowledge is not available, how could someone find such path? By groping around, through a process of trial and error? If we accept the impossibility of knowing the network to perfection, notably from an egocentric point of view, then the preferred choice of individuals to form or, especially, to reconstruct one’s network is problematic. It can be easily admitted that an individual knows his/her closest friends/acquaintances (to one link) and even friends of

friends (two links). Whenever an individual is brought into one’s inner circle of friends/acquaintances (one link), this friend’s network gets to be known too. Based on Borgatti (2003,2006), the figure 2 below illustrates this problem. If A can integrate E or F into his network, depending on his purpose he will have to prioritize the individual F, if he seeks to increase the size of his indirect network, and, the individual E, assuming that he is a friend, if he seeks to strengthen his influence on B, C and D.

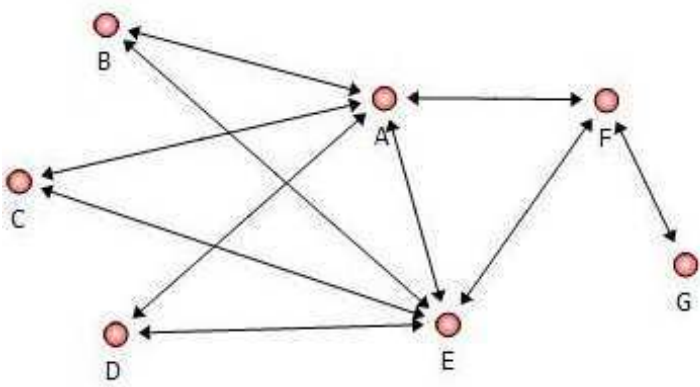


Figure 2 - Adding a link starting with A: E or F

The quest for an important individual within the meaning of the *KPP-Pos* can be operated by the notion of “structural equivalence” (Lorraine and White (1971) and Burt (1976)): two individuals are structurally equivalent if they have the same relations (overlapping neighborhoods). The pair of individuals {A, F} will be preferred to the pair {A, E} if it is less structurally equivalent. Indeed, if A and E are central, particularly with regard to the closeness centrality⁸, but have exactly the same neighborhoods/relationships, then linking A individuals to an F individual will render the whole more efficient (particularly in terms of number of nodes connected to A’s network).

2.2. Deleting Friends and KPP-Neg

⁸ This indicator measures the ability of joining all of the other nodes of the network using the shortest paths (i.e. geodetic distances).

A social network of the directors of large companies type is by definition constantly evolving. One director is appointed, another one is let go. If the networks of these two directors are not structurally equivalent, then these changes can have a significant impact on the structural properties of the network as a whole and/or the network efficiency of a particular director. The *KPP-Neg* notion is directly related to the structural impact of a dismissal.

According to Borgatti (2006), the measure that one would naturally think of for studying the *KPP-Neg* would be that of Freeman’s betweenness centrality (1979) which measure the number of times a node is positioned in the path between two other nodes that are not interrelated. An individual may be weakly connected to the others and yet prove to be an indispensable intermediary during the exchanges. In theory, a high degree of betweenness is synonymous with the ability to influence and/or coordinate the network.

As previously stated, the notion of *KPP-Neg* indicates who is important in relation to a given network characteristic. However, as Borgatti (2006) demonstrates, this characteristic can only be slightly affected by the disappearance of a central individual in the sense of betweenness. Consider the network describes below.

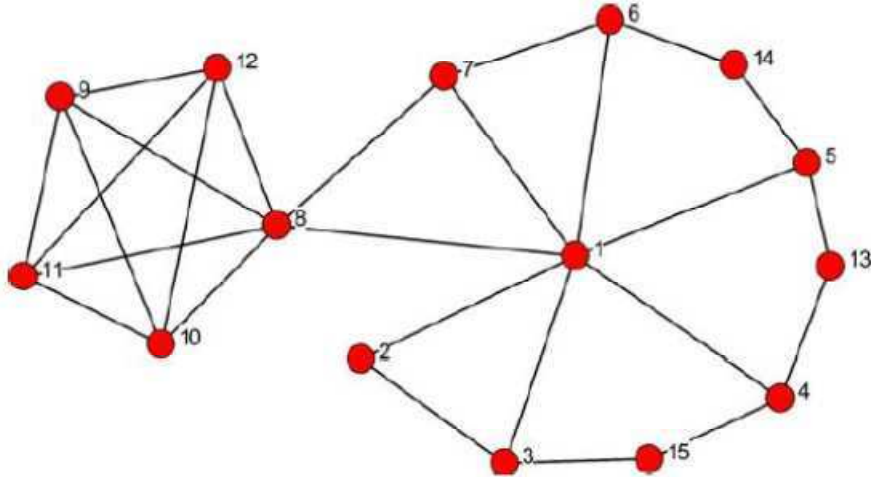


Figure 3 - Example of a network wherein the deletion of a central node (1) is not a source of discontinuity (Source: Borgatti 2006)

Within this network, according to different traditional measures of centrality, node 1 appears to be each time as the most central. Or, if the important notion is that of network cohesion in the sense of continuity (and not fragmentation), then removing node 1 is inconsequential, whereas removing node 8, which is situated on a lower centrality level, regardless of what the measure of centrality is, would trigger a genuine discontinuity.

Thus, measuring the effectiveness of a network implies a clearly defined criterion of underlying efficiency. However, efficiency can be a network's outer, *a priori* aspect, such as the network's ability to generate pricing agreements. Highlighting the "efficiency-structure" correlation raises empirical difficulties. Thus, traditionally, we aim to test whether a more connected network has an impact on the distribution of dividends, on the income of executives, and on the performance of the company (Pichard-Stanford (2000), Vigliano (2009)). Naturally, it follows that an individual is *essential* if effective, and, if the contrary, he is useless. But does one need to be influential in the sense of a classification and according to a given network criterion in order to be indispensable?

2.3. Communities, Weak Links and Egocentric Networks

The network described in Figure 3 clearly shows two communities. As it was pinpointed by Pons (2005) and Pons and Latapy (2006), the concept of community within graph theory is not clearly defined. However, it is possible to define a community as a set of vertices whose density of internal connections is greater than the density of connections to the outside (Pons, 2005). Assuming a network whose number of communities decreases is a more cohesive network, we can therefore define an individual "indispensable" to the network as an individual for whom:

- the disappearance of links within the network increases the number of communities;
- conversely, his/her presence in the network reduces the number of communities.

The first definition refers to a *KPP-Neg* type of reading, the second to a *KPP-Pos* one. In Figure 3, node 8 is essential; without it, the community formed of nodes {9;10;11;12} is isolated from the rest of the network⁹. Or, as previously stated, node 8 is not the most central, and therefore, according to this criterion, the most influential. Furthermore, it seems legitimate to redefine the {9, 10, 11, 12} community as 8's community. This brings us to an egocentric reading of the network. But the *KPP* notions use a global reading of the network. This becomes a matter of reconsidering these concepts from an egocentric perspective. Within a closed social network, where admission is made by appointment, for instance, it is not uncommon for someone's inclusion to only be the result of someone else's choice. The latter can include the candidate for a macro reason or for a micro reason. The macro reason is based on the assumption that the candidate will benefit the whole network or the entire community. When defining an efficiency criterion, the notion of *KPP-Neg* shows its relevance. More selfish, the micro reason postulates only that a candidate will strengthen a feature of the sponsor's network/community. It is the sponsor's opportunism against the potential efficiency of the network.

An individual may seek to strengthen his weak links while ignoring whether this will or will not improve the cohesion of the entire network. In fact, within an egocentric network there is a possible relationship between the concepts of *KPP* and that of Granovetter's (1973) strength of weak links. The impact of these weak links on the communities they originated in or on any other term of comparison has yet to be seen/discovered or identified. Based on the criterion of betweenness centrality and on a criterion of network cohesion measured using the number and size of communities, the following section of the paper will emphasize the distinction between *influential* and *indispensable* within a network of directors.

⁹ Node 8 can also be interpreted as a cut-point (i.e. node of an initial component without which this component would break into several elements).

3. Empirical Analyses and Robustness within CAC 40

From all the mechanisms of corporate governance that aim to “delineate the powers and influence the decisions of leaders” of large managerial companies (Charreaux, 1997), the Board of Directors (BOD) occupies a central place, regardless of the outlook adopted. Within the disciplinary or financial approach of corporate governance, the Board is primarily designed as the main instrument for monitoring managers so that they maximize shareholder value. From this point of view, the directors are characterized by their independence in what concerns the management, their expertise, their ability to control and implement mechanisms that encourage managers to be effective and less opportunistic. Within the partnership approach, and even more so in the case of the strategic or cognitive approaches of governance (Charreaux 2000, Gomez 1996), there is an emphasis on the ability of the Board to participate in the creation of sustainable value by contributing, for example, to the choice of optimal strategies, helping management to identify and build new opportunities for development, or even by promoting innovation (Prahalad 1994). As well as the aforementioned oversight role of directors, there are other functions and skills, such as the ability to provide resources, that enrich the human capital, build relationships with other companies. It is the cognitive and interpersonal contribution of directors that is sought after, the objective being to increase the competitiveness of the company.

Choosing a director is without doubt strategically important. According to Guieu and Meschi (2008), “between 2000 and 2003, there have been significant changes in the number and composition of network administrators in Europe. [...] many networks have disappeared; entirely new ones have been created. Subsequently, a big replacement of directors could be observed during this period: two thirds of directors belonging to a network in 2003 did not belong to a network in 2000. Out of the 95 that belonged to a network in 2000, only 45 are

still within a network three years later.” Thus, a company, a director or board of directors, needs to constantly consider the renewal of a mandate or the appointment of a new member.

For the remainder of the analysis we contend that the appointment of an X individual must have the effect of increasing the Board’s efficiency or, from a more egocentric perspective, of strengthening the network of the individual Z, a current member of the Board. But that leaves us again with the delicate question of measuring the importance or indispensability of appointing X or getting Y to stay. To this end, we propose the use of a criterion of indispensability, closely related after all to the notions of *KPP-Pos* and *KPP-Neg*. The empirical application of our approach relies on a database which consists of the directors of CAC 40 companies in 2004¹⁰. By definition, there is a link (within the Board) whenever two directors have the same BOD in common and there is a link (between Boards) between companies whenever a director holds multiple directorships. In our database, the average size of boards is of 14.205 directors and the average number of direct links between companies (through a director holding several directorships) is of 9.025. Similarly, out of the 429 directors listed in the database, the average number of directorships is of 1.2913, with a maximum of 5 directorships and 349 with only one directorship (about 79.6% of directors). This creates an average number of 18.1305 direct links between directors.

3.1. Foreword: What Makes a Good Criterion?

We made reference to a certain critique of the criteria of centrality according to Freeman (1979). These criticisms belong to network analysis as a whole. By focusing on individual networks (egocentric), we can formulate criticism directly inspired from decision theory. By analogy to the *row adjunction* criterion used by Milnor (1954), a robust classification criterion should be such that the result of ranking 2 individuals would not have to be changed by

¹⁰The methodology of putting together the database is described in Appendix A.1.

adding an individual who ranks lower than the first 2 within the network. Or, centrality criteria are generally not robust. Certainly, the measurement of the centrality degree is certainly too rough to fulfill this robustness condition. Nevertheless, it serves to illustrate that the influence of directors is not homogeneous. Some have more influence than others. Therefore, within a network of CAC 40 directors, there is in fact no causal link between the size of boards (i.e. the number of directors) and the ability of the company to create links with other companies (see Figure A.1., Appendix A).

An analysis based on the criterion of betweenness centrality (see Appendix A.3), demonstrates that the disappearance of F. Riboud's links brings great "benefits" to Marc Ladreit de Lacharrière and, to a lesser degree, to Thierry Breton, whereas it "harms" the positions of Lindsay Owen-Jones and Didier Lombard.

Proposition 1: The individuals indispensable to the network are not the same for all.

Proposition 1 is obvious. If keeping director F. Riboud proves to be indispensable to keeping the dominant position of Lindsay Owen-Jones (in the sense of a KPP-Neg criterion where efficiency is the ranking according to betweenness), his eviction (or his non-inclusion) appears as indispensable to Marc Ladreit de Lacharrière. Depending on the point of view adopted, we note here a contradiction.

How can this result be interpreted? Remember that this betweenness centrality somewhat measures the likelihood of a director or a company to be on a geodesic path (i.e. the smallest of path lengths connecting two nodes within a network) of different directors or companies of the network and therefore to be a mandatory path for connecting two directors or companies. The dismissal of F. Riboud will force some directors who used to pass by him, to turn towards

other directors (Marc Ladreit de Lacharrière) and indirectly not to go through to a close connection of F. Riboud's any longer (Lindsay Owen-Jones).

Noting that there are changes in the relative rankings of a centrality criterion, such as that of betweenness, following the inclusion or dismissal of the links of a given director, we propose to define the notion of indispensability.

3.2. Where Are the Strong Weak Links?

If we delete F. Riboud's links (initially 20th in terms of betweenness), Lindsay Owen-Jones drops one place. Let us assume that deleting the links of director who ranked 400th (from 429) led to the same result. Can we give the same power of influence or indispensability to these two directors within Lindsay Owen-Jones's network?

Clearly, influential individuals are more likely to change relative rankings than individuals with little influence. But if this were not the case, can we deduce that these individuals are indispensable weak links? Weak because they have little influence according to the centrality criterion applied, but indispensable to a given director because they are a means of deeply changing his influence. Thus, if we take Lindsay Owen-Jones as a reference point, who is the most central in terms of betweenness and if we eliminate Edouard de Royère's links (initially 6th) Lindsay Owen-Jones drops 4 places. Similarly, without René Carron (initially 11th) he drops 3 places. There are many directors who, despite having little or no influence in the sense of the betweenness criterion, make Lindsay Owen-Jones drop 2 places if their links are deleted from the network. Nevertheless, at a dynamic reading, their deletion could be easily replaced by the appearance of a director with similar characteristics.

In order to highlight this relationship between influence and indispensability, we use a calculus algorithm that measures the influence of a director j on a director i taking betweenness centrality as a reference criterion. The stages of the algorithm are as follows:

- Calculation of the measures of betweenness centrality for the overall network
- For each i reference director:
 - deletion of the links of director j;
 - calculation of the measures of betweenness centrality;
 - calculation of the matrix of positional variations: measure of the director's impact j for i in absolute (change of the place in the general ranking), in relative (change of the weighted place by the distance from j compared to its initial ranking).

If it can be assumed that the absolute place variations in a given classification allow for the measurement of the impact of an individual on another, it is more difficult to deduce from it a link with an indispensability criterion in the sense of Granovetter's weak links (1973). Admittedly imperfect, due to the methodological difficulty of measuring the "strength of weak links", the relative measure calculated by the algorithm is based on the following methodological hypotheses:

- Hypothesis 1: an individual more influential than myself in the overall network cannot be a weak link for me¹¹ ;
- Hypothesis 2: an individual with little influence in the overall network is a weak link the "strength" of which is directly proportional to the gap between me and him/her.

The indicators of j on i are calculated as follows:

- If $Bet(j, total) > Bet(i, total)$:
 - In absolute: $Inf(i, j) = Place\ variation = Bet(i, total) - Bet(i, total - \{j\})$.
 - In relative: $InfR(i, j) = Inf(i, j) * Log[Bet(j, total) - Bet(i, total)]$
- If $Bet(j, total) < Bet(i, total)$: $Inf(i, j) = 0$ and $InfR(i, j) = 0$.

¹¹ Admittedly, this hypothesis is flawed. Nothing allows for the exclusion in the sense of the strength of weak links of individuals better positioned than myself according to a given criterion. However, to be consistent with Milnor's criterion of "row adjunction", we wish to test to what measure the addition or the deletion of a lower placed individual can change my ranking.

With $Bet(i, total)$ the ranking of director i within the overall network with regard to the criterion of betweenness centrality, and with $Bet(i, total - \{j\})$ that is this very ranking, but in the network without the links of director j , the relative value balances the absolute value in relation to the log deviation of the initial position between the two directors.

We limited the calculations to the first 100 directors of the initial ranking (i.e. i such as $Bet(i, total) < 101$). In fact, we are looking for directors who are potentially indispensable to the initially influential directors.

It should be mentioned that the deletion of a j director's links can have two types of influence on i :

- a positive influence if $Inf(i, j) > 0$: i.e. deleting the links of j will improve the position of i . For instance, the path from a 10th place to a 3rd place will give the value $Inf(i, j) = 7$. In the same way, we will have $InfR(i, j) > 0$. Consequently, i will do anything to keep j out, or, if the latter is already within the network, to exclude him.
- a negative influence if $Inf(i, j) < 0$ (and in fact $InfR(i, j) < 0$): the deletion of j 's links will make i drop places within the rankings. Example: the path from a 3rd place to a 7th place gives $Inf(i, j) = -7$. In this case, i will do anything to keep j within the network or to have him join it.

We suggest that the influences be calculated separately as well as overall¹². The following tables (table 1 and 2) provide us with the top 20 most influential/indispensable (the first 100 are provided in Appendix A, section A.4).

Proposition 2: An influential individual is not indispensable unless he has an overall negative influence. If not, he is undesirable.

¹² The overall indicator is calculated for each j by squaring the sum of $Inf(i, j)$ in relation to i . The "positive" ("negative") only takes into account the "positive" ("negative") sums of $Inf(i, j)$. The same methodology applies to the relative indicators.

Starting with Table 1, before anything it is apparent that François Henrot or even Ernest-Antoine Seillière are influential, but not indispensable. In fact, their absence benefits a certain number of directors, who recover places in the rankings.

Bet(j,Total)	Name	Inf(pos)	Bet(j,Total)	Name	Inf (neg)
70	Henrot François	30	44	Ferrero Dominique	-38
79	Potier Benoît	30	28	Seillière Ernest-Antoine	-37
71	de Rudder Thierry	28	70	Henrot François	-30
59	Pinault François	28	79	Potier Benoît	-30
62	David François	26	71	de Rudder Thierry	-28
52	Lebègue Daniel	26	72	Desmarais Paul Jr	-28
53	Ricard Patrick	26	73	Lauvergeon Anne	-28
64	Arnault Bernard	25	59	Pinault François	-28
28	Seillière Ernest-Antoine	25	17	Dumas Jean-Louis	-27
96	Badin Jacques	24	52	Lebègue Daniel	-27
44	Ferrero Dominique	24	45	Seydoux Jérôme	-27
253	Halley Robert	24	62	David François	-26
299	Leal-Maldonado José Luis	24	53	Ricard Patrick	-26
313	March Carlos	24	64	Arnault Bernard	-25
45	Seydoux Jérôme	24	47	Chodron de Courcel Georges	-25
412	Vandelvele Luc	24	65	Rohatyn Félix G.	-25
54	Douroux Lucien	23	96	Badin Jacques	-24
58	de La Martinière Gérard	20	253	Halley Robert	-24
75	Gallois Louis	20	299	Leal-Maldonado José Luis	-24
80	Rodocanachi Pierre	20	313	March Carlos	-24

Table 1 - The 20 most influential according to the positive or negative absolute criterion

Starting with Table 1, before anything it is apparent that François Henrot or even Ernest-Antoine Seillière are influential, but not indispensable. In fact, their absence benefits a certain number of directors, who recover places in the rankings. Thus, Sylvia Jay (initially 69th, just ahead François Henrot 70th) would recover 9 places without François Henrot's links. Obviously, in relative terms, François Henrot will not be the most easily influenced (in the

sense of weak links) as he is too close to Sylvia Jay. As far as Jacques Badin is concerned, who initially had the 96th place, hence further away from Sylvia Jay than François Henrot, he would drop 8 places in the rankings to Sylvia Jay if he were not there. From this, one can deduce that: a) François Henrot is the most influential at the overall network level and that, b) Jacques Badin is indispensable to Sylvia Jay, whereas François Henrot is undesirable.

Relatively speaking, it is Jacques Badin who appears as the *weak* link that is most influential and indispensable to Sylvia Jay. However, while Jacques Badin is first from the point of view of his relative positive influence (table 2), his nuisance is relatively weak. At most, he makes Jean-Louis Beffa (initially 77th) drop 2 places, and the same to Robert Halley (initially 253th). Note that the latter makes François Henrot climb 8 places; he is his most influential/indispensable weak link.

Bet(j,Total)	Name	InfR(pos)	Bet(j,Total)	Name	InfR(neg)
96	Badin Jacques	143	96	Badin Jacques	-142.25
253	Halley Robert	130.51	253	Halley Robert	-129.23
299	Leal-Maldonado José Luis	125.16	299	Leal-Maldonado José Luis	-123.54
313	March Carlos	123.26	313	March Carlos	-121.5
79	Potier Benoît	114.86	123	Bisschoff Manfred	-110.13
123	Bisschoff Manfred	111.19	28	Seillière Ernest-Antoine	-108.94
70	Henrot François	108.33	79	Potier Benoît	-105.79
245	Grube Rüdiger	102.99	44	Ferrero Dominique	-105.36
412	Vandelvede Luc	102.3	245	Grube Rüdiger	-101.32
92	Arnault Jean	101.47	92	Arnault Jean	-100.06
93	Arnault Delphine	101.42	93	Arnault Delphine	-100.02
107	Bazire Nicolas	100.8	107	Bazire Nicolas	-99.34
114	Belloni Lazard Antonio	100.48	114	Belloni Lazard Antonio	-98.992
117	Bernheim Antoine	100.34	117	Bernheim Antoine	-98.84
193	Della Valle Diego	96.388	412	Vandelvede Luc	-97.861
59	Pinault François	96.152	70	Henrot François	-96.566
99	Barberis Pierre	94.222	193	Della Valle Diego	-94.466
71	de Rudder Thierry	93.302	99	Barberis Pierre	-93.909

243	Godé Pierre	93.171	133	Bouygues Madame	-92.293
133	Bouygues Madame	92.639	243	Godé Pierre	-90.82

Table 2 - The 20 most influential according to the relative criterion

If we make the same calculations for all of the directors, we find that only 18 directors have no impact (positively or negatively) on the ranking of other directors. These directors all belong to the Arcelor Company. In fact, as shown in Figure 4 below, this company is initially isolated within the network by the fact that none of its directors has any links with a director of another company from CAC 40.

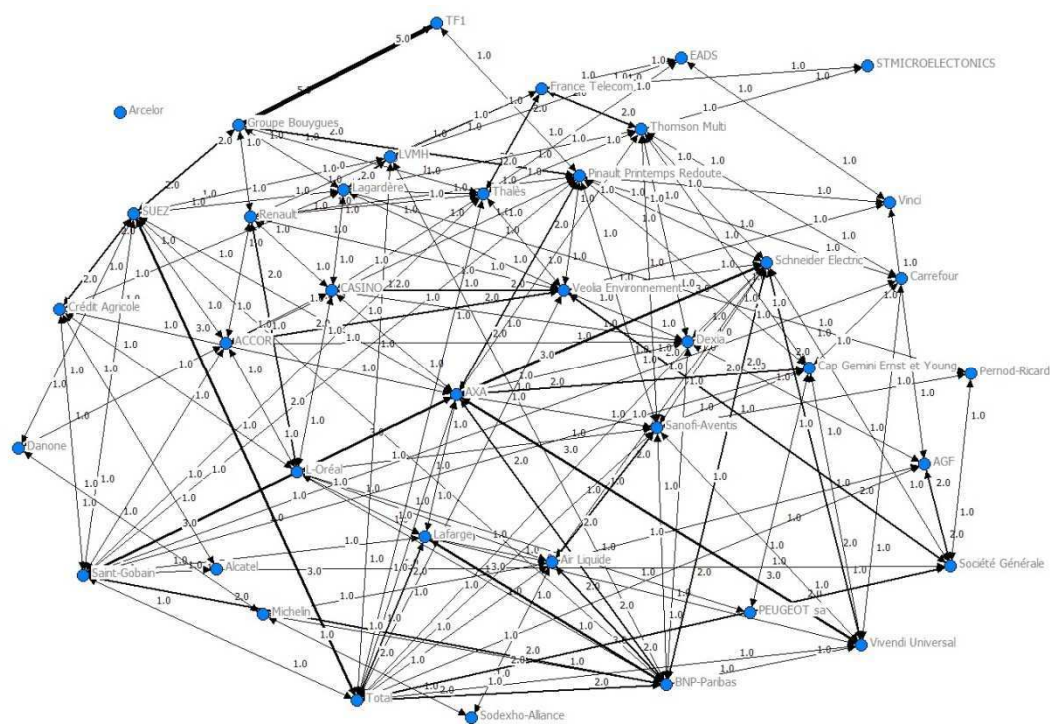


Figure - Network of the companies within CAC 40 2004

3.3. Where Are the Strong Links?

We undertake to find the *strong* links according to two criteria. First of all, by using the previous algorithm and giving up hypothesis 1. We allow the taking into account of the

influence of individuals better placed than me according to a given criterion. Thereafter, we will use a community cohesion criterion.

Starting with Table 3 (also see Appendix A.5), we finally notice very few changes to the initial betweenness centrality rankings with regard to the positive impact and no change with regard to the sum¹³.

Bet(j,Total)	Inf(Pos)	Bet(j,Total)	Inf(Neg)	Bet(j,Total)	Inf(Pos)+Inf(Neg)
1	Owen-Jones Lindsay	1	Owen-Jones Lindsay	1	Owen-Jones Lindsay
2	Breton Thierry	21	Barbizet Patricia	2	Breton Thierry
21	Barbizet Patricia	2	Breton Thierry	3	Mestrallet Gérard
3	Mestrallet Gérard	10	Friedmann jacques	4	Proglio Henri
10	Friedmann jacques	3	Mestrallet Gérard	5	Bouton Daniel
6	de Royère Edouard	6	de Royère Edouard	6	de Royère Edouard
9	Roger Bruno	22	Lagardère Arnaud	7	Pébereau Michel
4	Proglio Henri	9	Roger Bruno	8	Lombard Didier
5	Bouton Daniel	35	Gandois Jean	9	Roger Bruno
7	Pébereau Michel	13	Jeancourt-Galignani Antoine	10	Friedmann jacques
13	Jeancourt-Galignani Antoine	17	Dumas Jean-Louis	11	Carron René
22	Lagardère Arnaud	5	Bouton Daniel	12	Mayer Francis
17	Dumas Jean-Louis	7	Pébereau Michel	13	Jeancourt-Galignani Antoine
11	Carron René	4	Proglio Henri	14	Fourtou Jean-René
8	Lombard Didier	29	Pineau-Valencienne Didier	15	Ladreit de Lacharrière Marc
19	Barbier de la Serre René	19	Barbier de la Serre René	16	Desmarest Thierry
16	Desmarest Thierry	11	Carron René	17	Dumas Jean-Louis
35	Gandois Jean	44	Ferrero Dominique	18	De Croisset Charles
29	Pineau-Valencienne Didier	8	Lombard Didier	19	Barbier de la Serre René
24	Minc Alain	16	Desmarest Thierry	20	Riboud Franck

Table 3 - The 20 most influential directors

¹³

The measure of the betweenness centrality of i is in fact the sum over j of $\text{Inf}(i,j)$, whatever j is.

We can see that Lindsay Owen-Jones is influential, but not indispensable to the other directors who, as it is case for almost half of them, would all go up one place if he left the network. The presence of Patricia Barbizet in 3rd place and 2nd place is worth mentioning. Moreover, she is the strongest non indispensable individual influence in the network. Without her links, François Henri Pinault would climb 35 places in the betweenness rankings. On the other hand, the strongest indispensable individual influence is that of Edouard de Royère (6th within the network). Without his links, Gérard de la Martinière (initially 58th) would drop 19 places.

Of course, these results pertain to the applied efficiency criterion (here, the changes of position in the rankings of betweenness degree). As will become apparent, using a different criterion yields different results. Using the notions of cohesion and of communities, proposition 3 redefines the notion of indispensability.

Proposition 3: The individuals indispensable to the network are those whose dismissal (respectively appointment) increases (diminishes) the number of communities.

Proposition 3 succeeds remarks in connection to Figure 3 and to *KPP-Neg*. When deleting a director's links takes away some cohesion via creating an additional community, then, indeed, that director was indispensable to the network.

We are using the community research algorithm given by Blondel *et al.* (2008) to search for individuals. This algorithm¹⁴ provides us the size of communities (163; 118; 67; 63; 18)¹⁵ after 2 cycles of clustering and (411; 18) after 3 cycles of clustering¹⁶. We then reuse the

¹⁴ See Appendix B for a presentation. There are other detection algorithms, such as Pons's WALKTRAP (2005) and Pons and Latapy (2006).

¹⁵ The size 18 community consists of the directors of Arcelor.

¹⁶ After a first round, the algorithm provides 26 communities of respective sizes (31; 30; 30; 26; 25; 23; 19; 18; 18; 17; 17; 17; 16; 15; 14; 14; 14; 13; 11; 11; 11; 8; 8; 8; 8; 7).

algorithm deleting all the links of a given individual each time. An individual non indispensable to the community, and therefore undesirable, needs to manage to lower by **1** the size of an existing community and to add to it one of size **1** (himself in relation with himself alone), for example (**162**; 118; 67; 63; 18: **1**) and (**410**; 18; **1**). Focusing on the communities after 2 cycles of clustering, we note that deleting the links of 5 directors leads to the disappearance of the community. We are talking here about Gerhard Cromme, Yves Cannac, Michael Blakenham, Michel Bon et François Pinault¹⁷. It can be deduced that the 5 individuals are indispensable to the non inclusion of their community in the network within another community. From the point of view of overall network cohesion, they are undesirable¹⁸. It should be noted that the deletion of the links of these individuals not only changes the number of communities and their respective sizes, but it also changes the internal makeup of the remaining communities. Thus, in the case of deleting Michel Bon's links the third (i.e. his) community in size (67) is completely redistributed between the first 2 communities (see Appendix B.5.). Similarly, 8 directors initially belonging to community 1 switch to community 2. However, these changes are due to the fact that directors belong to ST Microelectronics, a company whose directors are relatively isolated within the network, excluding Didier Lombard.

It should also be noted that deleting René Carron's links strongly increases the second community, which goes from 118 to 143. Its connections switch from the penultimate community (initially size 63, size 37 afterwards) to the second. It should be noted as well that there are 97 directors who are more or less highly "indispensable", in the sense of our proposition 3, to define communities after two clustering cycles (around 22.6 %). Finally,

¹⁷. See Appendix B.2.

¹⁸ A more selfish dynamic reading could tell us something different. They are indispensable, they are the trigger elements of a potential new dynamics in the construction of a community having as sole aim to compete with the old ones.

many directors influence the size of communities without, however, their being indispensable to the existence of the communities.

After 3 cycles, communities are influenced by only 2 directors: Edouard de Royère and Didier Lombard. Without these, a certain number of directors (10, including Edouard de Royère, and 8, including Didier Lombard) find themselves isolated within a separate community from the main one. It will be noted that the two directors are not the most indispensable to the communities after two cycles. These potentially isolated directors are those of Sodexo-Alliance whose link with the rest of the network is Edouard de Royère and those of St Microelectronics who depend on Didier Lombard.

Proposition 4: The individuals who are indispensable to small communities are not necessarily indispensable to big communities.

Comparing the variations of communities after a clustering cycle, we note that if Edouard de Royère and Didier Lombard are indispensable to the cohesion of the large community detected after 3 cycles, their respective impact on the communities after one cycle is weaker, even negligible. Likewise, among the 11 directors indispensable for the existence of a community after a cycle, only two remain so after two cycles, namely Michel Bon and Michael Blakenham. Moreover, François Pinault and Yves Cannac, indispensable to the existence of a community after two cycles, have no impact on the size and number of communities after one cycle (Gap = 2).

3.4. Comparison with the Network of Independent Directors of the CAC 40

We know that within social networks, “power rings” are formed, connected, for instance, to qualitative criteria such as gender, studies, nationality or even occupation. This also applies to

the network of directors of the CAC 40. How do indispensability measures change when examined based on a qualitative subnetwork this time?

From a “qualitative” point of view, among all of the directors that make up the Board of Directors of the CAC 40 companies, those who are declared independent appear particularly interesting to us. Historically, this notion of independence of directors appeared in the reports on corporate governance that flourished at the beginning of the 1990s in numerous countries following often fraudulent bankruptcies and financial scandals (Maxell, BCCI Bank) that certainly blamed company directors, but also the insufficient internal (Board of Directors) and external (auditors) control (Massol et al. (2009a)). These reports¹⁹, that were echoed by the “Principles of good governance” published by the OECD (2004), aimed to formulate recommendations designed to allow for a better control of the managers that were sometimes found to be more inclined to maximize their pension value than to act in the interest of the company as a legal entity.

Within all “good conduct” preparations, that stipulate, amongst other things, the improvement in terms of transparency of information, the creation of special audit, appointment and remunerations committees, the presence of directors declared independent within the BOD holds a key place²⁰. By virtue of their very presence, these directors are supposed to improve the functioning of the BOD, particularly by means of a better management of conflicts of interest between management and shareholders, but also between the shareholders themselves. Through their outsider perspective, their expertise and lack of links with various stakeholders within the company, they are meant to improve the reliability and the quality of

¹⁹As an example, we can cite: the Cadbury report in 1992 in the United Kingdom one of the first of its kind, and in France the reports Viénot I in 1995 and Viénot II in 1999, then the Bouton report in 2002. The various reports were then included in a unique document placed under the aegis of the AFEP (The Association of French Private Companies) and of the MEDEF (Mouvement des Entreprises de France – the largest union of employers in France), in 2003. In France, this document serves as “Code of Corporate Governance” and as a reference to companies.

²⁰To be considered independent, a director needs to fulfill a certain number of criteria which are detailed within the Bouton report or within the document of the AFEP – MEDEF that we have already cited.

the information provided to the market (investors who are already present or potential investors). Despite their shortcomings, analyses and external controls relying on information provided ultimately by the management are added value in terms of their extra reliability and rationality of policy, accounting or company resource management decisions.

a) Comparative Statistics

Based on the CAC 40 network of directors, we have created a related network: that of the directors who were declared independent at least once (ID) in the sense of the Bouton Report (2002). It is not easy to create a network of so-called independent directors. In fact, the same director can be declared independent within one company, but not be independent within another. Therefore we have considered the ID network in a broad sense: all directors who were declared to be independent at least once belong to this network. Table 1 compares the number of directorships.

Number of directorships	1	2	2+	3	3 et +	4	5	Total Number of Directors
CAC 40 2004 ID	108 (63.53%)	37 (21.76%)	62 (36.47%)	16 (9.41%)	25 (14.71%)	8 (4.71%)	1 (0.59%)	170
CAC 40 2004	343 (79.95%)	58 (13.52%)	86 (20.05%)	18 (4.20%)	28 (6.53%)	9 (2.10%)	1 (0.23%)	429

Table - Distribution of the number of directorships per director (in France, this number is limited to 5)

Table 1 allows highlighting the following observations:

- There are only a few persons who hold several directorships (one or two as the case might be). Nevertheless, there continues to be a significant number of directors with three or more directorships (close to 6% for the CAC 40).
- The network of so called “independent” directors seems to be more “concentrated”: the number of directors with several directorships is far more important than in the associated CAC40 network: more than 36% of the ID hold at least two directorships as opposed to 20% of directors in general. .

Obviously, an ID type of network can be created within the CAC 40, a network that includes the most influential members of the CAC 40. The latter can always find at least one company within which they stand and which will provide them with an ID status. If we were to compare the directors declared independent at least once to those that were only declared independent, we will be able to conclude that the average number of directorships goes from 1.55 to 1.14. In fact, the percentage of single directorships within the network of strict ID is more important than the “greater” ID network.

b) Difference of Communities

To return to the approach developed in section 2.3., we have measured the levels of influence of independent directors in their specific networks. As expected, this network engenders several small size communities. Thus, after a clustering cycle, the ID network consists of 24 communities (of respective sizes: 9; 18; 17; 13; 11; 11; 10; 9; 8; 8; 8; 7; 7; 5; 5; 4; 3; 1; 1; 1; 1; 1; 1; 1), after two cycles another 12 remain (57; 48; 33; 20; 5; 1; 1; 1; 1; 1; 1; 1) and after 3 cycles another 9 remain (158; 5; 1; 1; 1; 1; 1; 1; 1; 1). The first conclusion is that only 7 directors have no link to other independent directors. This converges with the analysis detailed in the previous subsection.

Based on the table described in Appendix C.1., one can find that: the most influential independent directors of the network are not necessarily those who are the most influential in the network of independent directors. Whereas Michel Bon goes from 5th place to the 69th and Gerhard Cromme from 1st place to the 12th, Jacques Lagarde goes from the 282nd place to the 6th at the same time. Naturally resulting from this is the following proposition.

Proposition 5: An individual indispensable within the overall network is not necessarily so within his own qualitative network.

Conclusion

All in all, resorting to different instruments in the analysis of a network's centrality engenders two types of difficulties: the need for almost perfect information and the possibility of an overall reading of a network. But, within a social network, each individual seeks, by definition, to establish his relative authority. If the appointment or the non renewal of a director does not escape this realization, the reasons of the co-opting member can be nuanced by the fact that his relative authority (micro perspective) depends on the ranking of his company/community within the overall network (macro perspective). Our micro perspective analyses lead us to the conclusion that a central individual is ultimately the one who most destabilizes the relative authority of others. We thus suggested an indicator of this influence and its possible variation in terms of indispensability or of non desirability. It was shown how this indicator, in relative terms, allows us to provide a measure of the strength of weak links. Moreover, this modified indicator (giving up on the hypothesis of a lower initial ranking) also provides a measure of indispensability from a macro perspective, as well as a community based approach. The limitations of this work are obvious, as illustrated by the difficulties of

the transition towards a qualitative network. Whatever the criterion applied, the notion of indispensability is in itself a function of the researched network and of the efficiency criterion applied; not to mention that efficiency can be an external *a priori* aspect of the network, such as the network's ability to generate pricing agreements.

Finally, an ongoing research endeavors to test the pertinence of an indispensability measure defined, for instance, on the basis of the betweenness criterion in order to understand the changes observed throughout a given period within Boards of Directors.

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APPENDIX A – The Network of CAC 40 Directors

A.1. Methodology and Descriptive Statistics Concerning the Network of Directors

We conducted an analysis of the network of directors within CAC 40 for the year 2004. The data that were used came directly from documents published by the companies (generally annual reports or reporting documents). We have built two networks within CAC 40: one consisting of the directors of boards of directors or supervisory boards (be they independent or not); and the other, consisting of the companies that they manage. Inside these networks, belonging to the same company generates a link between two directors and having a common director is the source for creating a link (network) between two companies. Based on this, it would untimely to extrapolate the hypothesis that there is a causal link between the size of boards (i.e. the number of directors) and the company’s ability to create links with other companies. In fact, such a relationship does not exist (figure A.1.).

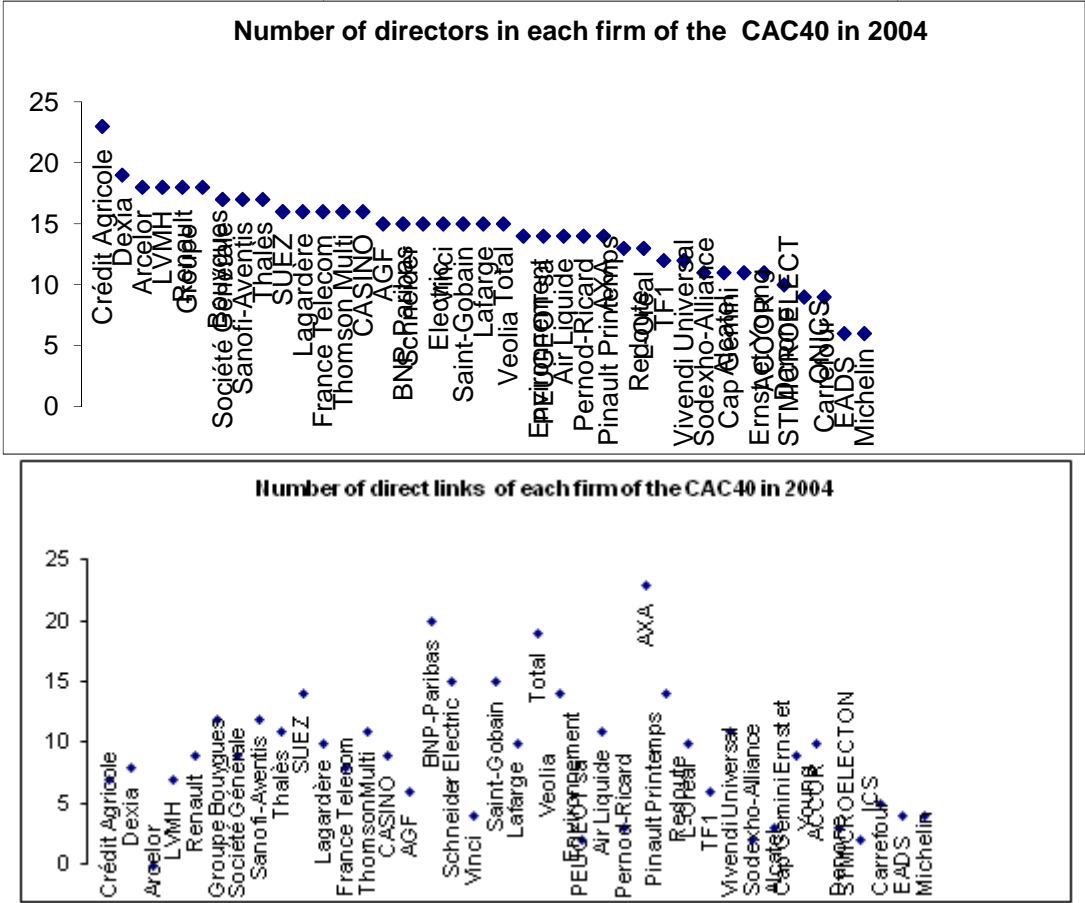


Figure A. 1 - Number of directors and direct links within CAC40

It is to be noted that AXA, even if it has only 14 directors, manages to create 23 links with other companies (sometimes links towards the same companies) via the presence of its directors in other boards of directors of companies from within CAC 40. This remark leads to the conclusion that the

directors do not have the same importance, some being more influential than others. The centrality criteria seek to emphasize such types of “influence/importance” within the network.

A.2. Degree Centrality Criterion

This criterion consists of measuring the centrality of an individual by his number of connections to the others. An individual is central if he is connected to other members of the network, he is considered as marginal if he is only loosely connected to them. The higher the number of links attached to a node, the more central it will be considered. The centrality is thus an indicator of the implication and of the engagement of a node within the network. For our networks, this indicator corresponds to the number of links of a director within his network. The following table provides the first 10 directors according to this criterion.

1	Mestrallet Gérard	61
2	Pébereau Michel	61
3	Breton Thierry	58
4	Proglio Henri	58
5	Bouton Daniel	55
6	Mayer Francis	54
7	Owen-Jones Lindsay	53
8	Carron René	51
9	De Croisset Charles	50
10	Fourtou Jean-René	47

Table A. 2- Ranking of the first 10 premiers according to the criterion of degree centrality

A.3. Betweenness Centrality Criterion

This measuring unit, more precise than degree centrality, draws on the faculty of betweenness of an individual: it is the number of individuals/companies to which an individual/a company is indirectly connected, via his direct links. More specifically, this entails measuring the number of times a node is placed on the path between two other nodes that are not interlinked. An individual can be loosely connected to others and yet prove to be an indispensable intermediary for the exchanges. It is obvious that a high degree of betweenness is synonym with the ability to influence/co-ordinate the network. Within our networks, this indicator is also a measure of the likelihood of a director or of a company to be placed on a geodetic path (i.e. the smallest of path lengths connecting two nodes within a network) of different directors or companies of the network and so to be a mandatory path for connecting two directors or companies.

Name (Entire Newtork)	B. score	Name (without F. Riboud's links)	B. score
Owen-Jones Lindsay	6584.3	Breton Thierry	6638.1
Breton Thierry	6552.6	Owen-Jones Lindsay	6457.3
Mestrallet Gérard	5360	Mestrallet Gérard	5477.5
Proglio Henri	5190.7	Proglio Henri	5310.7
Bouton Daniel	5180.5	Bouton Daniel	5215.8
de Royère Edouard	4517.4	de Royère Edouard	4542.4
Pébereau Michel	4368.7	Pébereau Michel	4458.1
Lombard Didier	4127.8	Ladreit de Lacharrière Marc	4290.5
Roger Bruno	4047.8	Roger Bruno	4243
Friedmann jacques	3772	Lombard Didier	4145.5
Carron René	3710.7	Mayer Francis	3806.3
Mayer Francis	3646.9	Friedmann jacques	3788.7
Jeancourt-Galignani Antoine	3142.1	Carron René	3778.5
Fourtou Jean-René	3121	Jeancourt-Galignani Antoine	3157.6
Ladreit de Lacharrière Marc	3043.3	Fourtou Jean-René	3144.3
Desmarest Thierry	2999.9	Desmarest Thierry	3042.4
Dumas Jean-Louis	2902.6	Barbier de la Serre René	2918.5
De Croisset Charles	2842.8	De Croisset Charles	2768
Barbier de la Serre René	2796.7	Lagardère Arnaud	2678.1
Riboud Franck	2788.3	Dumas Jean-Louis	2666

Table A. 3 - Changes in the betweenness centrality ranking without Franck Riboud's links

APPENDIX B – Evolution of Communities

B.1. The Algorithm of Blondel, Guillaume, Lambiotte and Lefebvre (2008)

This algorithm uses a cluster approach. Initially each node (director) forms a community by itself. Then, according to a maximization of the modularity gain criterion, a node i is potentially attached to the community of node j . These grouping cycles can be reiterated until a final criterion is reached, natural or to be defined (there is only one community left). Within our CAC 40 2004 database, after a grouping cycle, there were 26 communities left. After two cycles 5 communities remained, and after 3 cycles only 2 remained.

B.2. Communities after 2 Cycles

The table below classifies directors according to the importance of their impact on the communities. This importance is measured by the Gap variable, which is the squared sum of

the size gap between the communities without the links of that particular and the communities of the entire network (sizes in red)²¹.

NAME	163	118	67	63	18	0	GAP
Cromme Gerhard	211	104	95	18	1	0	5309
Cannac Yves	214	133	63	18	1	0	4867
Blakenham Michael	207	141	62	18	1	0	4515
Bon Michel	207	141	62	18	1	0	4515
Pinault François	180	163	67	18	1	0	4339
Blanc Christian	125	123	99	63	18	1	2493
Henrot François	125	123	99	63	18	1	2493
Leal-Maldonado José Luis	126	122	99	63	18	1	2409
March Carlos	126	122	99	63	18	1	2409
Rodocanachi Pierre	126	122	99	63	18	1	2409
Vandelvele Luc	126	122	99	63	18	1	2409
Breton Thierry	134	115	98	63	18	1	1811
Azéma Jean	163	110	99	38	18	1	1713
Bouton Daniel	163	110	99	38	18	1	1713
Carron René	163	143	67	37	18	1	1301
Ranque Denis	169	89	85	67	18	1	1217
Lagardère Arnaud	162	91	87	70	18	1	1179
Bisschoff Manfred	163	91	87	69	18	1	1165
Arnault Bernard	163	92	87	68	18	1	1101
Rohatyn Félix G.	163	92	87	68	18	1	1101
Mestrallet Gérard	168	93	87	62	18	1	1051
Chodron de Courcel Georges	163	94	86	67	18	1	953
Douroux Lucien	163	94	86	67	18	1	953
Fontanet Xavier	163	94	86	67	18	1	953
Peyrelevade Jean	163	94	86	67	18	1	953

Table B. 1 - First 20 directors based on the GAP criterion.

B.3. Communities after 3 Cycles

NAME	411	18	0	0	GAP
de Royère Edouard	400	18	10	1	121
Lombard Didier	402	18	8	1	81

Table B. 3- Communities after 3 cycles

²¹ In theory, it should be $2 \cdot (-1)^2 + (1)^2$.

B.4. Communities after 1 Cycle

We present here only the most “indispensable” 20 directors and 4 particular directors. 125 directors out of 429 (29.13%) have a stronger impact on the structure of communities than the mere creation of an individual community.

NAME	GAP	31	30	26	25	23	19	18	18	17	17	17	16	15	14	14	14	13	11	11	11	8	8	8	8	8	7	0	0		
Bakemam Michée	408	48	31	30	30	25	23	19	'8	17	16	16	'6	15	14	'4	'3	11	11	10	8	8	8	8	8	8	7	1	0	0	
Éon Miché	408	48	31	30	30	25	23	19	'8	17	16	16	'6	15	14	'4	'3	11	11	10	8	8	8	8	8	8	7	1	0	0	
Babéar Cauds	210	42	31	30	30	25	23	22	'9	18	17	16	'5	15	14	'4	'3	11	11	11	8	8	8	8	8	8	7	1	0	0	
Léonann Héri	192	42	31	30	30	25	23	19	'8	18	17	17	'6	15	14	'4	'4	13	11	11	8	8	8	8	8	8	7	1	0	0	
Éaiffa Jean-Louis	86	36	31	30	25	25	23	23	'9	18	17	16	'6	15	15	'4	'4	13	13	11	11	9	8	8	8	8	7	1	0	0	
Arault Berrac	84	30	30	26	25	23	20	19	'8	18	17	17	'7	16	15	'4	'4	14	13	12	11	9	8	8	8	8	8	7	1	0	
Robaty Fé x G.	84	30	30	26	25	23	20	19	'8	18	17	17	'7	16	15	'4	'4	14	13	12	11	9	8	8	8	8	8	7	1	0	
Azeirra Lear	74	31	30	26	25	23	22	19	'8	18	17	17	'6	16	15	'4	'4	14	13	11	11	8	8	8	8	8	8	7	1	0	
Eoulton Danie	74	31	30	26	25	23	22	19	'8	18	17	17	'6	16	15	'4	'4	14	13	11	11	8	8	8	8	8	8	7	1	0	
Crómme Gerhard	70	37	31	30	30	25	23	19	'8	17	16	16	'5	15	14	'4	'3	13	11	11	10	8	8	8	8	8	7	1	0	0	
Bassara Philippe	58	31	30	30	26	25	23	23	'9	18	17	17	'7	16	15	'4	'4	14	13	11	11	8	8	8	8	8	7	1	0	0	
Bour: Frank	58	31	30	30	26	25	23	23	'9	18	17	17	'7	16	15	'4	'4	14	13	11	11	8	8	8	8	8	7	1	0	0	
Eonnell Bruc	56	31	30	30	26	25	24	23	'9	18	16	17	'7	16	15	'4	'4	14	13	11	11	8	8	8	8	8	7	1	0	0	
David-Weill Miché	56	31	30	30	26	25	24	23	'9	18	16	17	'7	16	15	'4	'4	14	13	11	11	8	8	8	8	8	7	1	0	0	
Jay Sylvia	48	32	30	30	27	24	23	20	'9	18	17	16	'5	15	14	'4	'3	12	11	11	11	9	8	8	8	8	7	5	0	0	
Eanze Pierre	42	31	30	30	26	25	23	20	'9	18	16	17	'7	17	16	'5	'4	14	13	11	11	8	8	8	8	8	8	7	1	0	0
Éaillot Jean	42	31	30	30	26	25	23	20	'9	18	16	17	'7	17	16	'5	'4	14	13	11	11	8	8	8	8	8	8	7	1	0	0
Fabereau Miché	36	31	30	30	26	25	23	23	'9	18	17	17	'6	15	14	'4	'4	13	11	11	11	9	8	8	8	8	7	5	0	0	
Eanc Cristan	34	32	30	30	26	24	23	19	'8	18	17	17	'6	15	14	'4	'4	13	12	11	11	10	8	8	8	8	8	7	5	0	
Hérot François	34	32	30	29	26	24	23	19	'8	18	17	17	'6	15	14	'4	'4	13	12	11	11	8	8	8	8	8	8	7	5	0	
de Royère Edoarç	12	31	30	30	26	25	23	21	'9	18	17	17	'7	16	15	'4	'4	13	11	11	10	8	8	8	8	8	7	1	0	0	
Lombarc Didier	3	32	30	30	26	23	23	19	'8	18	17	17	'7	16	15	'4	'4	14	13	11	11	8	8	8	8	8	8	7	1	0	0
Carnac Yves	2	31	30	29	26	25	23	19	'8	18	17	17	'7	16	15	'4	'4	14	13	11	11	8	8	8	8	8	8	7	1	0	0
Fénel: François	2	31	30	30	26	25	23	19	'8	18	17	17	'6	16	15	'4	'4	14	13	11	11	8	8	8	8	8	8	7	1	0	0

B.5. Community Changes

The table below highlights the way how communities evolved after Michel Bon's links were deleted (each director is represented by a number between 1 and 429; Michel BON = 50). Initially, Michel Bon belonged to the 163 size community. In red, the community with Michel Bon in the network, in black the community without.

163	207	118	141	67	0	63	62	18	18	0	1
4	1	6	5	1		2	2	3	3	0	50
5	4	7	6	11		40	40	80	80		
10	10	8	7	13		41	41	112	112		
12	11	9	8	22		43	43	113	113		
14	12	15	9	24		47	47	116	116		
17	13	16	15	26		51	51	152	152		
21	14	18	16	39		59	59	162	162		
23	17	19	18	48		66	66	201	201		
27	21	20	19	56		68	68	207	207		
28	22	25	20	61		77	77	210	210		
29	23	33	25	62		79	79	240	240		
30	24	34	26	72		91	91	277	277		
31	27	37	33	76		93	93	285	285		
32	28	38	34	85		95	95	286	286		
35	29	42	37	86		96	96	293	293		
36	30	44	38	89		98	99	318	318		
45	31	57	42	103		99	105	374	374		
46	32	58	44	106		105	107	418	418		
49	35	69	57	108		107	119				
50	36	70	58	124		119	123				
52	39	82	69	125		123	130				
53	45	83	70	128		130	134				
54	46	84	82	138		134	139				
55	48	88	83	140		139	151				
60	49	92	84	154		151	161				
63	52	97	88	155		161	174				
64	53	101	92	157		174	180				
65	54	102	97	159		180	188				
67	55	110	101	176		188	192				
71	56	111	102	183		192	193				
73	60	114	103	187		193	198				
74	61	118	106	209		198	202				
75	62	121	110	212		202	204				
78	63	131	111	221		204	216				
81	64	132	114	222		216	237				
87	65	133	118	226		237	251				

APPENDIX C – Communities of Independent Directors

Amongst the directors, we examine the network of directors that declared themselves as independent at least once. This network is compared to the network of non-independent directors. The following table gives the first 20 independent directors in terms of the GAP criterion defined in appendix B.2., and using communities after two cycles.

Bet(I,Total) Entire network	Bet(I,Total) Independent director network	NAME	57	48	33	20	5	1	1	1	1	1	1	1	0	0	GAP
12	1	Breton Thierry	86	38	33	5	1	1	1	1	1	1	1	1	0	0	1182
21	2	Mestrallet Gérard	78	33	26	20	5	1	1	1	1	1	1	1	1	0	716
126	3	Bernheim Antoine	76	48	33	5	1	1	1	1	1	1	1	1	0	0	602
146	4	Brufau Antonio	76	48	33	5	1	1	1	1	1	1	1	1	0	0	602
192	5	Della Valle Diego	76	48	33	5	1	1	1	1	1	1	1	1	0	0	602
282	6	Lagarde Jacques	76	48	33	5	1	1	1	1	1	1	1	1	0	0	602
298	7	Lord Simon of Highbury	76	48	33	5	1	1	1	1	1	1	1	1	0	0	602
179	8	de La Garanderie Dominique	73	49	35	5	1	1	1	1	1	1	1	1	0	0	502
67	9	Friedmann jacques	59	49	49	5	1	1	1	1	1	1	1	1	0	0	502
304	10	Martre Henri	73	49	35	5	1	1	1	1	1	1	1	1	0	0	502
379	11	Studer Robert	73	49	35	5	1	1	1	1	1	1	1	1	0	0	502
79	12	Joly Alain	71	48	38	5	1	1	1	1	1	1	1	1	0	0	462
87	13	Ploix Hélène	71	48	38	5	1	1	1	1	1	1	1	1	0	0	462
135	14	Bouillot Isabelle	72	33	32	20	5	1	1	1	1	1	1	1	1	0	452
84	15	Mayer Francis	72	48	33	5	4	1	1	1	1	1	1	1	1	0	452
23	16	Douroux Lucien	64	48	45	5	1	1	1	1	1	1	1	1	0	0	434
25	17	Peyrelevade Jean	64	48	45	5	1	1	1	1	1	1	1	1	0	0	434
102	18	Alphandéry Edmond	66	48	43	5	1	1	1	1	1	1	1	1	0	0	422
108	19	Barberis Pierre	66	48	43	5	1	1	1	1	1	1	1	1	0	0	422
280	20	Lachmann Henri	66	58	33	5	1	1	1	1	1	1	1	1	0	0	422