Small Worlds and Board Interlocking in Brazil: A Longitudinal Study of Corporate Networks, 1997-2007

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Small Worlds and Board Interlocking in Brazil: A Longitudinal Study of Corporate Networks, 1997-2007[†]

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Abstract

Social Network Analysis (SNA) is an emerging research field in finance, above all in Brazil. This work is pioneering in that it is supported by reference to different areas of knowledge: social network analysis and corporate governance, for dealing with a similarly emerging topic in finance; interlocking boards, the purpose being to check the validity of the small-world model in the Brazilian capital market, and the existence of associations between the positioning of the firm in the network of corporate relationships and its worth. To do so official data relating to more than 400 companies listed in Brazil between 1997 and 2007 were used. The main results obtained suggest that the configuration of the networks of relationships between board members and companies reflects the small-world model. Furthermore, there seems to be a significant relationship between the firm's centrality and its worth, described according to an "inverted U" curve, which suggests the existence of optimum values of social prominence in the corporate network.

Keywords: Board Interlocking; Social Network Analysis in Finance; Company Boards.
Classification JEL: G3, G34, G39, L14.

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1. Introduction

An element of finance literature has assumed that the expansion of the frontiers of this field of knowledge is associated with the development of research, characterized by connected domain approaches, in which it is possible to see the integration of various areas of knowledge. In this context, for example, works on behavioral finance and economic sociology stand out. Along this same line of thinking, the corporate governance area has proved to be a fertile field for connected domain research, because it deals with a topic, to the development of which various professionals from different areas have contributed. It has to be emphasized that the corporate board is a theme of central relevance in the corporate governance area.

Since Mills (1956) published *The Power Elite*, critics have argued that the North American corporate environment can be seen as an insular, politically powerful network of "old boys". According to this logic, the sharing of attributes enables the establishment of ties between board members of the major publicly quoted companies, which begin to configure the network (a set of nodes linked by nodes). This network has been frequently seen as a small-world of mutual knowledge, characterized by the sharing of activities on company boards (board interlocking).

Is corporate Brazil a small world? Do members of the boards of listed companies know each other? The reply to questions like these can offer a better understanding of information flow, innovation and management practices. A small-world is understood to be an environment that is characterized by a network, whose actors are close to one another (few degrees of separation), resulting in an environment in which the actors are strongly clustered. This suggests a simultaneous sharing of views of the world and of standards of professional conduct on the part of the board members (Stafsudd, 2009). According to financial literature, in the context of the roles the board has to undertake the network formed by its members has shown itself to be a powerful means of propagating the practices of corporate management, everything from how to acquire a firm (Haunschild, 1993) to how firms respond to takeovers (Davis & Greve, 1997).

According to the arguments of Leitner (2005) and Davis, Yoo & Baker (2003, p. 301), the contagion process (via the network) between boards is clear: their members frequently get together (almost on a monthly basis), bringing knowledge and ideas, possibly obtained from some other board, based on their interactions with other board directors. Therefore, the topography of corporate social networks and the positioning of the firm in these networks are important, in view of their contagion dynamic and information flow (Coleman, 1990; Martínez-Jaramillo *et al*., 2010). Therefore, if the structure of the network of relationships

among board directors has an impact on the information flow between companies, it is expected that changes in network structures will have important consequences on strategies, including the financial strategies adopted by organizations.

In Brazil, studies that are characterized by extensive longitudinal studies into board interlocking, the central subject of this research, are still unknown, especially when dealing with checking the small-world of company boards of directors (Lazzarini, 2007). The "neighborliness" of the corporate elite is assumed to be the network of interlocks created when boards are connected to one another because they share one or more common directors (Schonlau & Singh, 2009; Bouwman, 2009).

In turn, board directors are connected by the common service they provide on one or more corporate boards. They also have attributes in common, e.g. courses and the universities where they were educated (Cohen, Frazzini & Maloy, 2010).In the Brazilian experience, significant changes have occurred in companies, caused by events such as: i) internationalization processes; ii) a more active stance by institutional investors; iii) mergers and acquisitions; iv) redefinition of government practices, seen as highly recommendable; v) reclassification of the Brazilian economy as far as concerns the risk of its public securities; and vi) the supposed stability of the Brazilian economy (even though in a context of crisis).

However, even though the idea that facts like these drive changes in the way in which the people who comprise the top administration, and by extension the companies, establish ties in the corporate environment is little questioned; analysts have never documented a representative number of the net results of these transformations. The main contribution of this article is based on the attempt to develop a point of reference for future works, whose purpose is to expand the frontiers of knowledge in finance, using Social Network Analysis (SNA).

In other words, the article describes research in the area of corporate governance using a connected domain approach, an aspect that is widely recognized as contributing to the construction and advance of scientific knowledge, especially in the field of finance. In view of the arguments presented above, starting from a small-world approach the purpose of this article is to analyze how the configuration of the global relationship network evolved between listed companies in Brazil and their board directors between 1997 and 2007, using SNA to do so. Furthermore, the impacts that the firm's position in the network of corporate relationships can have on its worth is checked.

Two main results were obtained: i) the network of relationships between board members (and between companies too) reflects a small-world model. In other words, the

average distance between board directors (and the company) is sufficiently small. At the same time the values for the clustering coefficient of the board members are high. In addition, there is evidence that points to the existence of a relationship between the centrality of the firm and its worth, which may be described as an "inverted U" type curve. In other words, within the scope of the network of corporate relationships there is evidence that points to the existence of the centrality values of companies that maximize their worth.

This article is structured in 5 sections, including this introduction. In Section 2 the theoretical bases are presented that support the research arguments, in which the following are mainly dealt with: the concept of interlocking boards, their relevance to the modern study of corporate governance and to expansion of the frontiers of accumulated knowledge in this particular field, and the definition of small worlds in the light of the graph theory. Section 3 discusses the method used for developing this work. Section 4 centers on discussion and analysis of the empirical results. Lastly, Section 5 presents the final considerations of the research.

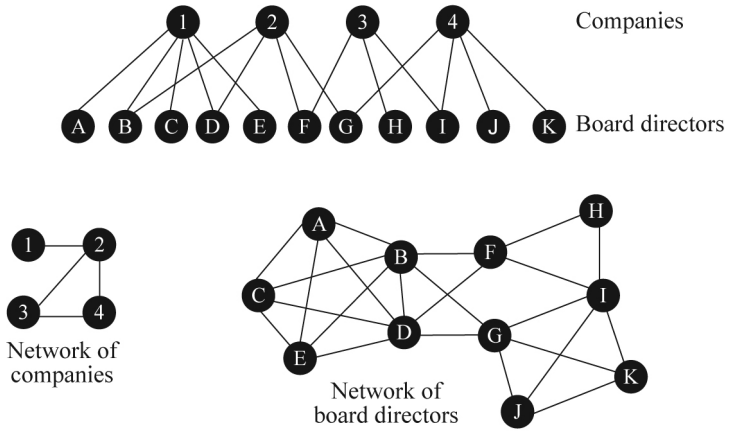
2. Theory and hypotheses of corporate networks and the firm value

2.1 The composition of company boards and board interlocking

The significant interest shown in the topic of board interlocking both by academia and the business community is not a recent phenomenon (Bearden *et al*., 1975). However, definition of the term 'board interlocking' has not been unanimous. Among the various opinions that exist on the topic are those most frequently found in work based on the arguments that it only needs one member of the board of a company to simultaneously occupy a place on the board of directors of another company for there to be interlocking boards (Mizruchi, 1996).

However, in the Brazilian corporate environment this topic was only included in the agenda of discussions about best corporate governance practices in Brazil (IBGC, 2009, p. 40) at the end of 2009.In this research, it is assumed that the occurrence of interlocking boards leads to the rise of personal and corporate networks. Figure 1 shows a basic scheme in which four companies (nodes) are linked by ties that reflect the sharing of attributes - in this case the sharing of members of company boards, nodes linked by ties that form a network.

Figure 1–Schematic representation of corporate networks



Source: Prepared by the author (adapted from Newman, Strogatz & Watts, 2001). N.B.: This figure represents the typical scheme of a non-directional network with 4 companies (nodes/vertices 1 to 4), linked by 11 board directors (nodes/vertices *A* to *K*). In the top part of the figure is the two-mode projection of the sharing of company board members (network of companies). In the lower part and to the left is the set of *X* nodes = {1,2,3,4}, which represents the one-mode network of companies. On the right hand side is the *Y* node= {*A*,*B*,.....,*J*,*K*}, which shows the network of board directors (linked by companies in common).In this research the one-mode analysis structure was adopted, or rather, it was either assumed that the network was formed by board directors or merely by companies. However, literature already offers discussion of two-mode approaches (Robbins & Alexander, 2004).

2.2 Definition of the small-world model

Recent advances in the areas of mathematics and computing and, more precisely, developments in the graph theory (which is based on knowledge of SNA) have encouraged the rise of countless pieces of research into social networks. In particular, the small-world model is a powerful tool with which it becomes feasible to check details relating to the phenomenon of network formation (Conyon & Muldoon, 2006). The small-world phenomenon was initially analyzed in the work of Milgram (1967). This consisted in an experiment that involved sending letters to various people who forwarded them, via a network of people they knew.

As a result the conclusion is that apparently distant people may be in actual fact connected by a very short chain of known intermediaries. Milgram (1967) found a critical path in this close chain of 6 (six) steps. In other words, according to this author there is a great tendency that someone known by someone also forms part of the circle of relationships of the other. The theoretical small-world model is described in detail by Newman *et al*. (2001). Two global characteristics of the network of this theoretical model, which has profound consequences for the social phenomenon, must be observed, with particular attention to the characterization of a small world: i) *the distance between actors* (*L*), and ii) *the clustering coefficient* (C_{Δ}).

In social networks, as corporate networks are (*i.e*. companies or board directors), locally grouped and globally connected actors are expected; or rather, many less prestigious companies linked to others that have greater social prominence. So, Baum *et al*. (2004), emphasize the relevance of studying the properties of networks, as well as their evolution over time, in view of their impacts on small-world consequences, since this type of configuration can significantly affect the speed of interaction between the component companies of a network of corporate relationships, for example (Davis *et al*., 2003).

The first property of the small-world model is that pairs of randomly chosen nodes may be unexpectedly close to each other. A graph/network with *N* nodes contains *N* (*N* - 1)/2 pairs of nodes. If they are numbered 1, 2,....., *N* and $d_{i,j}$ is the distance between nodes *i* and *j*, then someone can calculate the typical distance between the component nodes of the network, using the following equation (1):

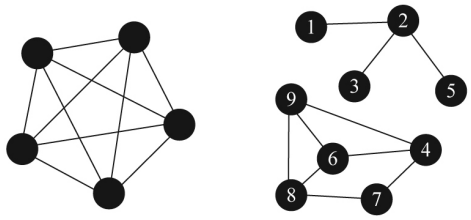
$$L = \frac{2}{N(N-1)} \sum_{i<j} d_{i,j} \qquad (1)$$

In the context of corporate boards (and in accordance with the analysis unit: firms or board members), term *L* measures the (typical) number of steps necessary to move from one actor to another within the context of the network. Put another way, in a network of corporate relationships information will reach a director after being passed on by *L* intermediary members, since typically there are *L* directors separating director *i* from director *j*. The second property of the small-world model is the high clustering coefficient, a measure of the density of the network. According to Newman *et al*. (2001), the *clustering coefficient* for the (global) network is calculated as follows (2):

$$C_{\Delta} = \frac{3 \times number\ of\ triangles\ in\ the\ graph}{number\ of\ connected\ links} \qquad (2)$$

where a triangle is a set of three different nodes, *j*, *k*, *l*, in which each node (or actor) is connected to two others. A connected link consists in a set of three nodes, *j*, *k*, *l,* in which *j* is connected to *k*, and *k* is connected to *l* (*l* need not be connected to *j*);the factor 3 in the numerator is necessary to ensure that $0 \leq C_{\Delta} \leq 1$,as each triangle contributes to the increase in the 3 connected links. Figure 2 illustrates this notion. To the right of the Figure there are two complete triangles (6-8-9) and (4-6-9), but thirteen connected links(6-4-7; 6-4-9; 7-4-9; 4-6-8; 4-6-9; 8-6-9; 4-7-8; 6-8-9; 6-8-7; 7-8-9; 4-9-6; 4-9-8; 6-9-8), so: $C_{\Delta} = 3 \times \frac{2}{13} = \frac{6}{13}$.The distance (*L*) between node 6 and node 9 is 2 (2 degrees of separation).

Figure 2 – Examples of simple graphs



SOURCE: Prepared by the author. N.B: The left-hand side of the figure shows a complete graph (all the nodes are interconnected), illustrating a component/cluster. On the right-hand side of this figure two connected components/clusters are shown. By way of illustration: in any network, if three nodes, *j*, *k*, and *l* form a connected link, then *j* is connected to *k*, *k* is connected to *l*and, if "is-connected-to" were a strictly transitive relationship, then the conclusion is that node *j* is connected to node *l*. Therefore, in the network shown in this figure node 9 is linked to node 8, and node 8, in turn, is linked to node 7. So, by transitivity node 9 is linked to node 7. Therefore, the clustering coefficient C_{Δ}, computed according the expression. (2) represents the proportion of links for which the transitive conclusion is verified. It needs to be emphasized that there is a local clustering coefficient measure (for each component node in the network), as proposed by Watts & Strogatz (1998).

Small-world validity can be checked by comparing the values obtained for these two measures relative to the networks being analyzed, starting from the values for these two parameters in random networks (simulated) with a same number of actors *n*, and ties, *k*. For random networks, $L_{\text{expected}} \sim \ln(n)/\ln(k)$ and $C_{\Delta\text{expected}} \sim k/n$, where *n* is the number of nodes (or actors) in the network, and *k* is the average degree centrality (average number of adjacent ties) of each component actor in the network (Watts & Strogatz, 1998). So in the light of the measures found the strictly typical finding of small-world will be seen if $L_{\text{observed}} \sim L_{\text{expected}}$, while $C_{\Delta\text{observed}} >> C_{\Delta\text{expected}}$. However, just like the procedure assumed by Baum *et al*. (2004) and Davis *et al*. (2003), in this research verification of the existence of a small-world in the context of personal and corporate networks will be satisfied when $Q_{sw} = (C_{\Delta\, observed}/L_{observed}) \times \left(L_{expected}/C_{\Delta expected}\right) \gg 1$.

2.2.1 The small-world model in the corporate environment

One important social network, especially in the fields of economics, finance and management, is the board of directors. Some (few) recent studies have documented that, even in Brazil, directors frequently hold more than one position on corporate boards (Santos & Silveira, 2007; Mendes-Da-Silva *et al*., 2008). Fama & Jensen (1983) emphasize that, at least in the North American economy, outside board members (outsiders) act like executives in other companies, or are important decision-making agents in other organizations. However, in the Brazilian experience there seems as yet to be no research that supplies results that enable this phenomenon to be understood within the national context.

In this sense it is expected that the connectivity of companies leads to consequences, such as: dissemination of executive remuneration practices (Subrahmanyam, 2008); the adoption of anti-takeover measures, poison pills, and the spread of golden parachutes (Davis & Greve, 1997). Over the last few years, both the capital markets specialist media (including in Brazil), as well as academic publications, have discussed the supposition that certain corporate boards are configured like a type of 'closed club'. So as far as concerns the application of the small-world approach to the study of the interlocking boards phenomenon, the clustering coefficient measure is a way of investigating the 'clique' or 'clubby' aspects of boards (Conyon & Muldoon, 2006).

There is a limited number of studies that examine the small-world properties of social networks within the context of corporate governance. With regard to this, and considering the Brazilian market, only one study was found, by Vidal & Mendes-Da-Silva (2010). These works typically compare small-world characteristics (the L and C_{Δ} measures) with those that are expected from a family of random graphs, originally introduced in the work done by Erdös & Rényi (1959).

Among the works that deal with the properties of small-worlds within the context of company boards, Davis *et al*. (2003) examine a sample of boards in the United States at three points in time; the results obtained by these authors suggest that the North American corporate environment can truly be understood as a "small world". Conyon & Muldoon (2006) found that the small-world concept applies to the United States, Germany and the United Kingdom.

The small-world approach has also been used in other studies on networks comprising ties and actors, which go beyond board interlocking. The link between companies that comes from sharing controlling shareholders in Brazil was studied by Lazzarini (2007), who recommends research into corporate boards that is similar to what has been undertaken in this study. Also along the lines of using the small-world concept within the corporate environment, Baum *et al*. (2004) study the network formed by underwriting banks in operations for raising funds in the Canadian capital market.

2.3 Positioning in the corporate network and the firm value

There are two basic classes of measures for understanding social networks: the positioning of each node/actor in the network and the topography of the network (Wasserman & Faust, 1994). In the first category are to be found the social prominence measures (centrality), which describe how influential a node/actor may be within the context of its/his/her network. It was

decided to use two of these measures: degree centrality (*degree*) -the number of adjacent ties to each actor; and betweeness centrality (*betweeness*)- the capacity to intermediate contacts between various actors in the network.

Pfeffer & Salancik (1978) start from the assumption that firms create tiesto obtain desired resources and manage uncertainties in the corporate environment. Therefore, networks are seen as a way firms can employ for connecting to other organizations that have the required resources and the capacity for helping these firms support the restrictions imposed by the external environment. Bunderson (2003) also notes that groups seem to achieve higher performance levels (take better decisions) when their board members share an accurate understanding of the expertise of the other. Pirson & Turnbull (2011) present a structured analysis of the gains that boards constituted in a network enjoy relative to isolated boards, *e.g*. a reduction in the judgment bias in decisions, better risk control and a greater capacity to react to crisis. It is therefore expected that the greater the influence a company has in a corporate network, the greater will be its access to resources, whether they are negotiated in the market or not. Given these reasons, it is understood to be interesting to test the following hypothesis:

H_{1a}: *There is a significant association between degree centrality and the firm value.*
H_{1b}:*There is a significant association between betweeness centrality and the firm value.*

Literature offers arguments and evidence, however, that point to the existence of trade-offs with regard to the firm's centrality. In this line of thinking Harris & Shimizu (2004) underline the idea of boards that are so occupied (the increase in the number of connections may result in more directors accumulating functions) that they compromise their functions within the company environment, i.e. monitoring executive activities and considering the adequacy of the decisions taken by the management relative to shareholder expectations, thus reflecting in a reduction in the firm's value. A study carried out by Santos *et al*. (2007) found results that support this argument in the Brazilian market. Fich & Shivdasani (2006) found results that point to the idea that firms in which the boards keep 'busy' (*busy boards*), which according to these authors means essentially outsiders who hold three or more places on boards, have poor corporate governance. Labianca & Brass (2006) also highlight the negative role of

relationships within the context of social networks, which may reduce the firm value[1]. Given these arguments, which suggest the existence of limits to the firm's centrality, the following hypothesis is tested:

H_2: *There are values associated with the firm's centrality that maximize its worth.*

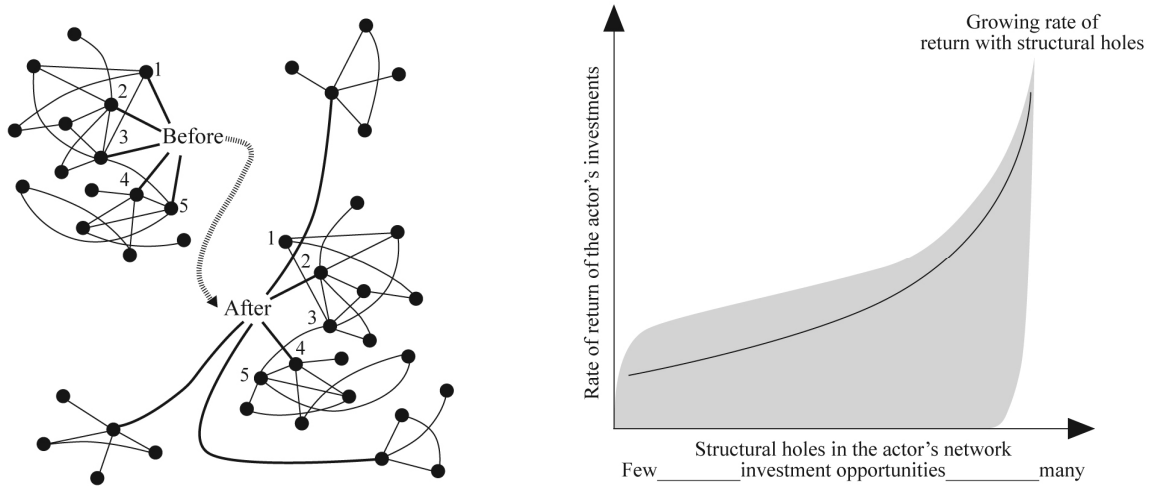
Over and above centrality in the network there are other interesting measures, such as the efficiency of the links (structural holes), for example. Noyes (2007), in a recent piece of work, and in a way that is in line with the arguments of Burt (1992) and Yang, Lin & Lin (2010), examined the relationships between the firm's structural holes and the identification of investment alternatives. In constructing non-redundant ties (coming from positioning it self in the network of corporate relationships in such a way as to optimize structural holes, a procedure shown in Figure 3), the company can benefit because of its access to information that enables it to identify new investment opportunities (whose proxy adopted here is Tobin's Q). The right-hand side of Figure 3 shows the expectation of the creation of value because of the greater efficiency of the firm's ties.

In the Brazilian experience a sole and recent study, carried out by Mendes-Da-Silva *et al*. (2008), tested and was unable to find any associations between positioning in the network of corporate relationships and the firm value. This work, however, did not consider the efficiency of the firm's ties and started with a group of 90 companies that were listed on Bovespa's New Market in 2007. As a consequence of the firm's greater inclination to invest (as evidenced by the efficiency of its ties), it is expected that the market will judge the firm's investment opportunities in a better light , as reflected in its market worth, which motivates a test of the following hypothesis:

H_3: *There is a significant association between the firm's structural holes and its value.*

[1]Along this line of thinking, Fracassi & Tate (2011), based on data relating to North American companies for the 2000-2007 period, deal with the firm's external ties, as constituted between board directors and executives. In this study the conclusion is that: i) firms whose CEOs are more powerful tend to elect directors linked to the CEO; ii) CEO-director ties reduce the firm's worth; iii) firms in which there are CEO-director ties have a greater tendency to become involved with acquisitions that have a negative Present Net Value.

Figure 3 – Structural holes and the firm value



Source: Adapted from Burt, 1992, p. 22 and p. 37. The left-hand side of this figure illustrates a procedure for optimizing the firm's structural holes (redefining its position in the network in such a way as to reduce the inefficiency of the ties that are constituted). On the right-hand side of the figure is an illustration of the expected association between the firm's structural holes and the return for shareholders.

According to Scott (2001), informal social networks between board members can resolve problems associated with a lack of team spirit, coordination and cooperation. Such informal networks may result from various types of relationship. For example, ties formed from teaching institutions may facilitate an approximation between directors, thus increasing their linking capacity in various types of network. A similar educational background may also facilitate dialogue, since professions operate like approximation mechanisms between executives, given the cultural-cognitive affinity attributed to a shared identity.

With regard to the relevance of personal characteristics to strategy and corporate performance, Labianca & Brass (2006, p. 606) emphasize that research in the area of social networks, especially that which focuses on companies, has ignored the relevance to corporate performance of personality and the personal characteristics of individuals. With regard to this, Cohen, Frazzini & Maloy (2008) presented an in-depth discussion on the relevance to the firm's performance of the ties constituted by sharing courses and schools, a thinking that is also shared by Kilduff (1992); Mendes-Da-Silva et al. (2008) and Mehra, Kilduff & Brass (2001).

In these terms the prominence of the director's board, through the sharing of personal characteristics, e.g. the company in which they serve as director (*corporate ties*), their graduate school (*university ties*), and/or their professional qualifications (*similarity in educational background*), would be a source of competitive advantage on some occasions, in

view of the increase in mutual trust, integration of behavior and cooperation between board directors.

Using these arguments, the owning of share capital by board directors also supplies elements that may lead to an increase in the legitimacy of organizations in terms of their actions (Scott, 2001; Westlund & Adam, 2010), since it starts from the assumption that influential directors tend to have more access to information as well as enjoying a greater reputation with financing mechanisms and market regulators (Lin, 2001). These arguments lead us to test the following hypotheses:

> **H_{4a}**: *There is a significant association between the centrality of the board that comes from corporate ties and the firm value;*
>
> **H_{4b}**: *There is a significant association between the centrality of the board that comes from university ties and the firm value;*
>
> **H_{4c}**: *There is a significant association between the centrality of the board that comes from a similar educational background and the firm value.*

In addition, Coleman (1990), Mendes-Da-Silva *et al*. (2008) and Pirson & Turnbull (2011) argue that by acquiring competences, better access to information, the minimization of redundant efforts and the identification of investment opportunities, and by using the social capital that comes from greater cohesion, it is expected that the company can enhance its worth because of its greater density/local clustering position, which leads to the following hypothesis:

> **H_5**: *There is a significant and positive association between the local clustering coefficient of the firm and its value*.

3. Procedure

3.1 Data collection

Official annual data was made available by the Brazilian Securities Commission (*CVM*) and by consultancy company, Economatica®. The unit of analysis used here was either the boards of directors of companies listed on the stock exchange or board directors themselves within the Brazilian context between 1997 and 2007. Information was collected about the actual

board directors of a group of 415companies (forming an unbalanced panel), the consequence of which was a group of thousands of board directors.

In the collection and database preparation phase extensive manual and computer procedures were used to ensure the quality of the data relating to the boards, the aim being to ensure accuracy in identifying the ties between individuals/firms. This included reading and standardizing each of these names via the companies, while at the same time eliminating any ambiguities. For example, one board director was found with four different renderings of his name: i) Antonio Carlos Augusto R. Bonchistiano; ii) Antonio Carlos Augusto R.Bonchistiano; iii) Antonio Carlos A. R. Bonchistiano; iv) Antonio Carlos Augusto R. Boncristiano.

3.2 Variables

For the panel data regression, as a dependent variable for the proxy of the firm's value the Tobin Q index was used, which was estimated in accordance with a procedure proposed by Chung and Pruitt (1994). The independent variables used in the panel data regression were organized in 3 groups, namely:

- Measures relating to the positioning of the firm in the corporate network: Computer procedures, available with a specific software for SNA; Ucinet 6.0 for Windows, were used to obtain the variables relating to the positioning of the firm in the corporate network: i) *Degree centrality* (*degree*) in absolute terms, an actor included in a network comprising *g* actors can achieve $(g-1)$ ties, at most. *Degree* considers only adjacent relationships, or rather, the local centrality of the players. According to Freeman (1979), the degree centrality index, defined by $C_D(n_i)$of an actor n_i participating in a network is given by (3):

$$C_D(n_i) = d(n_i) = x_{i+} = \sum_j x_{ij} = \sum_j x_{ji}\,, \qquad (3)$$

In this work the normalized form of *degree centrality* was used, which is expressed in a percentage form (degree divided by the maximum number of ties possible, expressed as a %). In Figure 1, for example, board director *G* has *degree centrality* = 5 and normalized *degree centrality* = 50%.

However, interaction between two non-adjacent actors may depend on a group of other actors, who may exercise some control over the interactions between two non-adjacent actors. Therefore, if in order to put two actors, n_2 and n_3, in contact with each other the shortest path is $n_2 \rightarrow n_1 \rightarrow n_4 \rightarrow n_3$, then it can be said that actors $n_1$and n_4 control interactions between actors

n_2 and n_3. This is, therefore, the concept of *betweeness centrality* (*betweeness*), which considers the interaction between non-adjacent actors.

If all distance communications $d(n_j, n_k)$, which go through actor k are counted, this provides a measure of "stress". When there is more than one possible path between j and k, all paths that pass through actor I are considered equiprobable. Therefore, the *betweeness centrality* for n_i is the sum of the estimated probabilities for all pairs of actors, not including the *i-th* actor. This is given by the equation (4):

$$C_B(n_i) = \sum_{j<k} \frac{g_{jk}(n_i)}{g_{jk}}, \tag{4}$$

where g_{jk} is the number of paths that link two actors. Therefore, if all these paths are equiprobable in terms of choice for establishing communication, the probability of a path being chosen is simply $\frac{1}{g_{jk}}$. In short, this measure indicates the number of pairs of nodes that an actor is capable of linking. In this research the normalized form (expressed as a %) was used. For example, in Figure 1, board director G has *betweeness centrality* = 12.5 and normalized *betweeness centrality*= 27.77%.

The third variable of the positioning of the firm is *structural holes*, which are types of non-redundant relationship between two contacts (Burt, 1992). Therefore, the smaller the number of redundant ties, the greater the number of structural gaps, there being less information redundancy. We specifically use the efficiency measure of the ties (Burt, 1992, p. 53), which measures the number of non-redundant contacts, *EffSize,* relative to the total number of contacts *n* of an actor *i*.

The fourth positioning variable of the firm is the *local clustering coefficient*: C_i to the *i-th* node is given by the proportion of ties between the vertices in its neighborhood, divided by the number of ties that could exist between them. By way of illustration, in Figure1 the node G has $C_i = 0.40$. According to a procedure by Watts & Strogatz (1998), a graph $G = (V, E)$ formally consists in a set of nodes V and the ties E between them. A tie, e_{ij}, connects node i to node j. Neighborhood N to the vertex v_i is defined as those immediately connected neighbors. Therefore, if node v_i has k_i neighbors, $\frac{k_i(k_i-1)}{2}$ ties would exist between the neighborhood nodes. So C_i is formally defined in (5):

$$C_i = \frac{2\left|\{e_{jk}\}\right|}{k_i(k_i-1)} : v_j, v_k \in N_i, e_{jk} \in E. \quad (5)$$

The three other independent variables, *corporate degree centrality, university centrality and knowledge centrality* consist in the average degree centrality of board directors in the networks of directors formed by these three ways of establishing ties, which led to **H_{4a}**, **H_{4b}** and **H_{4c}**.

- Structure of the firm's board of directors: i) *Size of the board,* expressed by the ln of the number of directors of the firm in each year studied; ii) *Outsiders*, expressed by the percentage of board members that are external to the firm (Yermack, 2006).
- Control variables: selected on the basis of the possible influence they exercise over the dependent variable (the firm value) and the independent variables. If the control variables have a correlation with some of these variables and are not considered in the model, the relationship between the variables of interest cannot be shown in an adequate manner: *age of the firm* (ln of the number of months between registering the firm with the *CVM* until the end of the financial year t); *Superior performance* (difference between the Ebit index/total sales of the *i-th* firm and the Ebit index/total sales of the economic sector to which the firm belongs); ln*quick ratio* of the *i-th* firm in the *t-th* year; ln *total assets of the i-th* firm in the *t-th* year.

3.3 The model

In view of the purpose of this research the data analysis is organized into two main blocks: i) verification of the validity of small worlds to the Brazilian market (using a procedure suggested by Davis, *et al*., 2003 and by Staffsud, 2009); and ii) verification of the existence of associations between the positioning (of the company) in the network of corporate relationships and the firm value, using panel data regression (unbalanced statistic). From the set of variables detailed in Sub-section 3.2, the model to be tested is (6), with: $N = 415$ and $T = 11$.

$$Valor_{it} = \beta_0 + \sum_{k=1}^{K} \beta_k x_{kit} + u_{it}, \qquad i = 1, \ldots, N, \quad t = 1, \ldots, T. \quad (6)$$

in which the value of the *i-th* firm in the *t-th* year, $Valor_{it}$, depends on *K* exogenous variables, $(x_{1it}, \cdots, x_{Kit})$, which differ between the firms at two given moments in time and also vary

over time. The error term, u_{it}, which is assumed as an IID random variable, with an average of zero and variance σ_u^2, independent of $(x_{1i}, \cdots, x_{iT})$, represents the effects of the omitted variables that are specific to both the firms as well as to the period studied.

4. Results

This section is divided into two parts. Initially, for the period studied, 1997-2007, the configuration measures of the networks of the board directors and companies listed in Brazil are presented in an evolving way, while at the same time discussing the validity of small worlds within the Brazilian corporate environment. This procedure was adopted both for the network formed by board members as well as for the network formed by listed companies (which are linked by interlocking boards). Secondly, the results of the panel data regression are discussed, the dependent variable being the firm value.

4.1 Verification of small-worlds

4.1.1 Verification of the small-world phenomenon in board director networks

According to Davis, Yoo & Baker (2003), the results obtained (summarized in Tables 1and2) are indicative of the existence of the small-world phenomenon between listed companies and between board members, respectively. It has to be emphasized that the strength of this configuration, Q_{SW}, grew over the period and maintained values that were considerably greater than 1 (Q_{SW}>> 1), whether for the network of directors or the network of companies.

The results in Table 2suggest that board directors are highly grouped from the local point of view, but maintain their distance (between each other) in the network, which does not impede the finding that their world is considered to be “as small as” could be expected. This indicator shows how structurally consistent the conditions of the small-world phenomenon are. These results are empirical evidence of the cooperation between board directors in terms of links with the companies, without this necessarily representing a deliberate effort on the partof the directors to constitute this configuration of the network. Therefore, one can understand that the Brazilian corporate environment has behaved just like a small world, or rather, it seems that the Brazilian capital market has grown in such a way that demand for directors from outside the firm has led to choice mechanisms of professionals being used in such a way as to establish a network in which distances between people are smaller (consequently the companies will be closer). Among aspects that can contribute to a better understanding of this phenomenon one can mention the presence of board directors who

represent the interests of investors and economic groups (this was not dealt with in this research).

Obviously this does not provide sufficient elements for being able to imply, with any degree of certainty, that there is a development of relationships between board directors within the environment of the Brazilian capital market. However, it does at least lead to an important reflection about the corporate environment: even though relationships between board directors have not been very close globally, the high clustering coefficients (C_Δ) found indicate the formation of "neighborhoods" and, therefore, the possibility of forming social capital via cohesion (Coleman, 1990). To calculate small-world statistics it is necessary to assume that there is a totally connected network. Therefore, the main component of the complete network was adopted. By way of illustration Figure 4 shows the segregation of a main component[2].

4.1.2 Verification of the small-world phenomenon in company networks

In Table 1 it can be seen that the Q_{SW} index for the network of companies is considerably greater than 1 throughout the whole period, highlighting that in addition to being bigger than the unit value, it has been growing. In other words, in 1997 it assumed the value ~6.54 and by 2007it had tripled this value to ~17.30. In short, in the light of the measures found for the network of corporate relationships and conscious of the small-world checking procedures suggested by Watts and Strogatz (1998) and the experiences applied to capital markets by Baum *et al*., (2004, p. 312) and Davis *et al*. (2003), it seems that the Brazilian market, even though it grew between 1997 and 2007, behaved just like a small world. This characteristic has been particularly strong in recent years[3].

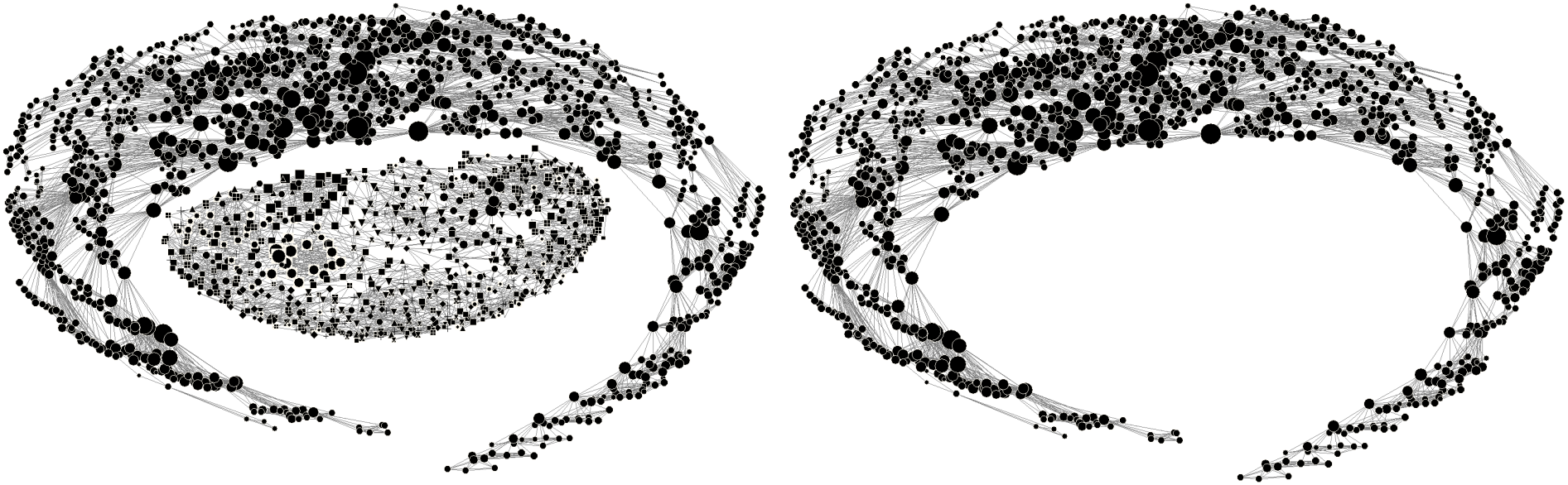
This type of finding suggests that contagion power may have increased as a result of the speed of communication, which is the function of the power of dissemination of

[2] The main component is the largest cluster of inter-connected nodes. By way of illustration, in Panel A in Table 2 it can be seen that of the 1,941 directors in the network in 2007, 1,191(~61.4% of the directors belonged to the same cluster) were inter-connected (see Figure 4).

[3] In the study of Stafsudd (2009, p. 72) small-world statistics are shown for company networks connected by their shareholders. In this research the author presents Q_{SW} statistics for: Denmark, Germany, Sweden, the United Kingdom and the United States. Because the tie between companies was through their shareholders and not interlocking boards, here it was decided not to report such values comparatively. However, by way of illustration the values computed by Stafsudd (2009, p. 72) are in the interval [1.04;5.65], with the exception of Germany, which according to this author has a network of companies linked by its shareholders with $Q_{SW} \approx 87.96$, which suggests the validity of the small-world model for that market. According to this result, in the opinion of Stafsudd (2009, p. 72), Germany, which has limited investor protection and considerable small-world strength, may not generate sufficient control to complete/substitute the formal mechanisms for protecting the interests of minority shareholders. A recent illustration of this in Brazil was made by Lazzarini (2007).

management practices, driven by interlocking boards. Put another way, the Brazilian corporate environment, even though it has grown significantly, as shown in Tables 1and2 (Δ%# of companies and Δ%# of board directors), is a cohesive network, in which contact between companies is ever closer, thus increasing the relevance of the reputation of the firm in its access to resources that are judged to be essential to its operation. In this sense, and according to the thinking of Subrahmanyam (2008), it is to be expected that the connectivity of companies results in consequences, such as the dissemination of executive remuneration practices. It has to be emphasized that management practices will depend on the firm's performance level and, by extension, its value in the perception of market agents.

Figure 4 – Segregation of the main component of the network of board directors in 2007



SOURCE: Prepared by the author, based on official data collected from the IAN/CVM. Notes: i) This figure illustrates the segregation of the main component of the network of relationships between board directors in 2007; ii) On the left-hand side is the complete network arrangement of directors (1,941 professionals grouped in 134 components/clusters); iii) On the right is the main component of the network (a component that brings together the greatest number of interconnected nodes), in which 1,191 directors participate; iv) Each node represents a director belonging to the network of corporate relationships, the size of each node indicates the *degree centrality* of each director; v) It is worth emphasizing that this research considered the board directors and executives (those who are also board directors in other companies) of the companies participating in the research. The intention was not to fail to compute a tie between two companies when an executive simultaneously performs director functions in at least one other company (to do so a function was developed in Visual Basic that can be obtained on request from the author of this study).

4.2 Panel data regression analysis

The results of the impact of the chosen independent variables on the value of the company, estimated using 3 different procedures (OLS, Random Effects (RE) and Fixed Effects (FE)), are presented in Table 3; FE with a robust standard error was found to be adequate (Hsiao, 2005; Petersen, 2009)[4]. Since: i) the Breusch-Pagan test ($p < 0.001$) rejected the adequacy of the pooled OLS, suggesting the use of RE; ii) the F test ($p < 0.001$) suggested that the coefficients generated by the pooled OLS are not consistent (suggesting greater consistency when controlling for FE); iii)the White test indicated problems of heteroscedasticity ($p < 0.001$); iv)the Hausman test ($p < 0.001$) contradicted the null hypothesis that the parameters' model controlling for RE was consistent.

So, as Yermack (1996) assumed, and following the recommendations of Hsiao (2005), in this research the regression model controlling for Feb (as a result of the existence of non-observed variables that probably affect the firm value) was more consistent in terms of its parameters. In situations like this the FE model controls the variables omitted from the regression. In addition, the FE model allows a single intercept for each firm, being thus indicated for modeling panel data when the intercept α_i is dealt with as a fixed parameter. It is equally desirable to use FE when observations are obtained from the whole population (SNA does not admit use of samples) and it is wished to make inferences for the individuals (firms) for which data are available. All these conditions apply to this work[5].

Assuming the fixed effects model as being the most suitable, discussion of the results using panel data regression diagnosis, revolves around the estimated parameters in Model 3, although all the simulated models are reported in this particular Table. With regard to the 9 position regressors of the firm in the corporate network, the results obtained in the FE model indicate that there are signs of the existence of values for the degree centrality of the firm[6] that maximize its value. In other words, if the linear coefficient,$\beta_1 \approx 0.1798$ ($p < 0.01$) is positive and the quadratic coefficient $\beta_1' \approx -0.0496$ ($p < 0.05$) is negative, it is understood that there may be an association between degree centrality in the corporate network and the firm value, described as an "inverted U" type curve (existence of the point of maximum curvature).

[4] No indications were found of the correlation between regressors and regression error, which suggests the non-existence of problems of endogeneity.

[5] These arguments are supported by the assumptions assumed by Jackson (2008, p. 434-458).

[6] Bearing in mind the transversal character of this research and the growth in corporate networks over the period studied, it was decided to use centrality in its normalized form.

It seems that the value of both those companies with lower centrality values and with higher centrality values reduces, probably for different but similar worth-reducing reasons. This result is in line with the arguments of Bunderson (2003) and Labianca & Brass (2006), and support not rejecting the $\mathbf{H_{1a}}$ and $\mathbf{H_2}$ hypotheses. It is understood, therefore, that there will be a combined effect between the linear and quadratic terms of the independent variable. The optimum point will therefore be seen when $\partial E(\gamma)/\partial(x) = 0$.

According to the estimated parameters for *degree centrality* (*normalized degree*), the point of maximum curvature for degree centrality is around 1.8125; in other words, provided the other estimated coefficients in Model 3 are respected, with the dependent variable being Tobin's Q, it seems that a value for normalized *degree centrality* ≈ 1.8125% indicates a maximum for Tobin's Q index *vis-à-vis* the estimated parameters in the regression obtained in Model3, all things being equal. Put another way, according to the estimated coefficients for normalized degree centrality a firm can maximize its value if it establishes, on average, a value close to 1.8% of the possible adjacent ties with other companies. Therefore, in 2007, when 385 companies were found to be in the corporate network, the degree (via interlocking) that maximizes the firm value is around 7 companies, *i.e.* [0.018125×(385-1)], all things being equal.

On the other hand, with regard to betweeness centrality no results were found that support the idea that this positioning measure of the firm in the network exercises a significant influence on its worth ($\beta_2 \approx 0.0121$; $p > 0.1$),which leads to rejection of hypothesis $\mathbf{H_{1b}}$, thus contradicting the arguments of Buderson (2003) and Labianca & Brass (2006).

In line with the defense of Burt (1992) and Yang, Lin & Lin (2010), the structural holes of the firm are positive and significantly associated with its value ($\beta_3 \approx 0.1198$; $p < 0.1$). This suggests that those companies whose interlocking board ties are less redundant achieved greater worth. In other words, it seems that the companies that optimized structural holes increased their worth. This supports non-rejection of $\mathbf{H_3}$. A result along these same lines is that the firm's clustering coefficient proved to be negatively associated with its worth ($\beta_4 \approx -0.1643$; $p < 0.05$) and this suggests that companies with a greater degree of local alignment tend to be worth less, which leads to rejection of $\mathbf{H_5}$, at the same time as contradicting the logic of the findings of Mendes-Da-Silva *et al*. (2008).A reasonable understanding is that actually there are limits to the firm's centrality and the level of local alignment. This was demonstrated by the significance of the quadratic term of the firm's *centrality degree* ($\beta_1' \approx -0.0496$; $p < 0.05$). Hypotheses $\mathbf{H_{4a}}$, $\mathbf{H_{4b}}$ and $\mathbf{H_{4c}}$ were rejected, indicating the non-significance of the association of the firm's worth with the relative densities of the ties of the board

directors as a result of sharing boards, universities and areas of knowledge, respectively, thus contradicting the arguments of Lin (2001) and Cohen, Frazzini & Maloy (2008).

Put another way, based on the arguments of Burt (1992), the information flow in personal relationships and social groups presumes that the probability of a piece of information being propagated in a network grows with the strength of its ties, which from the empirical point of view is estimated by two independent dimensions: i) the frequency of the ties, and ii) emotional closeness (Burt, 1992). But the results obtained did not support this argument. In the view of Labianca & Brass (2006), the existence of ties (e.g. having attended the same university and/or having done the same course), despite the asymmetry of values and preferences of the network actors, would produce negative results for the firm (negative externalities), *vis-à-vis* the difficulty of maintaining common objectives.

The interaction term between the firm's degree centrality and structural holes (*degree vs. SH*) received a positive and significant coefficient ($\beta_8 \approx 0.0332$; $p < 0.1$), strengthening the idea that companies with a larger number of ties and better ones tend to achieve higher levels of worth in the view of market agents. This is an indication that supports the assumptions of Burt (1992), that a larger and less redundant number of ties enables identification of new investment opportunities, which lead to an increase in the firm's worth.

In observing the results obtained for the two variables relative to the composition of the board it is found that board size did not prove to be significantly associated with the firm's worth ($\beta_9 \approx 0.0081$; $p > 0.1$), which contradicts the results obtained by Yermack (1996). In addition, the number of outside directors, even though it obtained a significant coefficient, has a small marginal effect on the firm's Tobin's Q ($\beta_{10} \approx -0.0031$; $p < 0.05$). Therefore, an innovative result and one that may merit greater attention from the academic community is that, rather than the size of the board, the way in which this board is linked by board interlocking to other companies may have a greater influence on the firm's worth. Among the four control variables, both the *firm's age* ($\beta_{11} \approx 0.04781$; $p < 0.01$), as well as the *quick ratio* ($\beta_{13} \approx -0.1741$; $p < 0.01$) were significant.

The results obtained in the panel data regressions support the idea that the firm's degree centrality and structural holes are resources the company can and must manage with a view to achieving its corporate objectives. Therefore, the way in which the firm configures its board will determine its positioning in the network and consequently will have an impact on its access to market resources, whether formally negotiated or not, through interlocking boards.

Table 1–Small-world statistics of the network of relationships between companies listed on the stock exchange in Brazil (1997-2007)

Parameters for diagnosis of small-world	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Panel A: Parameters observed in the network											
Density (Δ)	0.049	0.031	0.031	0.024	0.029	0.032	0.034	0.026	0.022	0.019	0.018
# of companies in the network	222	299	294	324	323	318	319	329	344	383	385
# of companies in the main component (n)	57	133	146	171	152	146	139	161	182	230	237
Average no. of ties per company (k)	3.263	4.617	5.137	4.959	5.184	5.164	5.223	4.783	4.407	4.652	4.599
$C_{\Delta observed}$: Clustering coefficient observed (global)	0.449	0.552	0.546	0.516	0.531	0.596	0.586	0.528	0.501	0.520	0.501
$L_{observed}$: Average distance observed	4.098	5.948	5.080	5.641	7.270	5.681	6.168	6.079	5.667	5.242	5.349
Maximum distance (diameter)	11	18	15	14	18	13	15	16	16	18	19
Panel B: Expected parameters for the network											
$C_{\Delta\ expected}$: Clustering coefficient expected (k/n)	0.057	0.034	0.035	0.029	0.034	0.035	0.037	0.029	0.024	0.020	0.019
$L_{expected}$: Average distance expected (ln(n)/ln(k))	3.42	3.20	3.05	3.21	3.05	3.04	2.99	3.25	3.51	3.54	3.58
Panel C: Calculation of the small-world coefficient (Q_{SW})											
Small-world indicators											
$C_{\Delta\ observed}/ L_{observed}$	0.11	0.09	0.11	0.09	0.07	0.10	0.10	0.09	0.09	0.10	0.09
$L_{expected}/ C_{\Delta\ expected}$	59.72	92.09	86.55	110.73	89.52	85.82	79.44	109.29	144.90	174.89	184.68
$Q_{SW} = [C_{\Delta\ observed}/ L_{observed}]\times[L_{expected}/ C_{\Delta\ expected}]$	6.54✓	8.55✓	9.30✓	10.13✓	6.54✓	9.00✓	7.55✓	9.49✓	12.81✓	17.35✓	17.30✓

SOURCE: Prepared by the author and based on data collected in the research. N.B.: This table shows (for the period from 1997to 2007) the parameters actually observed in the network (Panel A) and the parameters obtained by simulation (Panel B) for diagnosis of the small-world phenomenon, according to Watts & Strogatz (1998). To do so, data relative to all companies listed on the Bovespa [São Paulo stock exchange] were used, with data relating to the composition of the boards of directors published by the Securities Commission, the Brazilian market regulatory agent. Comparing the results of Panels A and B, it is possible (using established premisses) to assess in Panel C the feasibility of admitting that the network of relationships in listed companies in Brazil is similar to a small-world model, bearing in mind the values obtained for its indicator (Q_{SW}>> 1), which suggests the existence of strong indications that its configuration is similar to that of a small world. The measures shown in this Table relate to the main component of the network of companies for each of the years studied. The (✓) symbol indicates that the measure found in the network (compared with the measures obtained by simulation) are strictly in accordance with small-world assumptions. The (✗) symbol indicates that he measure found in the network did not strictly achieve small-world parameters, in accordance with the assumptions established by Watts and Strogatz (1998) and applied to the capital markets by Baum *et al*., (2004, p. 312) and Davis *et al*. (2003).[(a)] Density is a structural measure of the network, which expresses the relationship between the possible and observed number of ties between the actors.

Table2–Small-world statistics for the network of relationships between members of the boards of companies listed on the stock exchange in Brazil (1997-2007)

Parameters for diagnosis of small-world	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Panel A: Parameters observed in the network											
Density (Δ)[(a)]	0.0200	0.0145	0.0141	0.0136	0.0175	0.0152	0.0153	0.0131	0.0107	0.0080	0.0175
# of directors in the network	1.140	1.472	1.449	1.617	1.594	1.572	1.505	1.569	1.680	1.879	1.941
# of directors (n)	494	683	712	766	577	681	625	726	866	1140	1191
Average no. Of ties per director (k)	10.07	9.87	10.04	10.39	10.07	10.36	9.54	7.46	9.25	7.56	9.22
$C_{\Delta observed}$: Clustering coefficient observed (global)	0.914	0.903	0.897	0.900	0.904	0.897	0.895	0.893	0.896	0.898	0.899
$L_{observed}$: Average distance observed	5.048	6.373	6.102	6.362	8.055	6.153	6.344	6.898	6.383	6.319	6.503
Maximum distance (diameter)	11	14	15	15	19	14	16	17	14	19	19
Panel B: Expected parameters for the network											
$C_{\Delta expected}$: Clustering coefficient expected (k/n)	0.0204	0.0145	0.0141	0.0136	0.0174	0.0152	0.0153	0.0103	0.0107	0.0066	0.0077
$L_{expected}$: Average distance expected ($\ln(n)/\ln(k)$)	2.686	2.850	2.847	2.837	2.753	2.790	2.854	3.278	3.040	3.480	3.189
Panel C: Calculation of the small-world coefficient (Q_{SW})											
Small-world indicators											
$C_{\Delta observed}/ L_{observed}$	0.18	0.14	0.15	0.14	0.11	0.15	0.14	0.13	0.14	0.14	0.14
$L_{expected}/ C_{\Delta expected}$	131.82	197.15	201.88	209.19	157.82	183.31	187.02	318.96	284.47	525.01	412.12
$Q_{SW} = [C_{\Delta\ observed}/ L_{observed}] \times [L_{esxpected}/ C_{\Delta expected}]$	23.87✓	27.93✓	29.68✓	29.59✓	17.71✓	26.72✓	26.38✓	41.29✓	39.93✓	74.61✓	56.97✓

SOURCE: Prepared by the author and based on data collected in the research. N.B.: This table shows (for the period from 1997 to 2007) the parameters actually observed in the network (Panel A) and the parameters obtained by simulation (Panel B) for diagnosis of the small-world phenomenon, according to Watts & Strogatz (1998). To do so, data relative to all companies listed on the Bovespa [São Paulo stock exchange] were used, with data relating to the composition of the boards of directors published by the Securities Commission, the Brazilian market regulatory agent. Comparing the results of Panels A and B, it is possible (using established assumptions) to assess in Panel C the feasibility of admitting that the network of relationships in listed companies in Brazil is similar to a small-world model, bearing in mind the values obtained for its indicator (Q_{SW}>> 1), which suggests the existence of strong indications that its configuration is similar to that of a small world. The measures shown in this Table relate to the main component of the network of companies for each of the years studied. The (✓) symbol indicates that the measure found in the network (compared with the measures obtained by simulation) are strictly in accordance with small-world assumptions. The (✗) symbol indicates that he measure found in the network did not strictly achieve small-world parameters, in accordance with the premisses established by Watts and Strogatz (1998) and applied to the capitals markets by Baum *et al*., (2004, p. 312) and Davis *et al*. (2003). [(a)] Density is a structural measure of the network, which expresses the relationship between the possible and observed number of ties between the actors.

Table3–Estimated parameters for the worth of the firm

Independent variables	Model 1			Model 2			Model 3		
	Coefficients forOLS	Standard error		Coefficients forRE	Standard error		Coefficients for FE	Standard error	
Constant	2.3336	0.2205	***	2.4088	0.3931	***	2.3787	1.8334	
Position of thefirm in the network									
1. *Normalized degree centrality* (*degree*) [(a)]	0.5593	0.0894	***	0.3705	0.0639	***	0.1798	0.0591	***
Normalized degree centrality^2	-0.1411	0.0300	***	-0.0990	0.0219	***	-0.0496	0.0204	**
2. *Normalized betweeness centrality*[(b)]	0.0331	0.0378		0.0097	0.0277		0.0121	0.0257	
3. *Structural holes by boardinterlock of the firm* (*SH*) [(c)]	0.0952	0.0747		0.1249	0.0640	*	0.1198	0.0618	*
4. *Clustering coefficient* (local)[(d)]	-0.1336	0.0772	*	-0.1358	0.0648	**	-0.1643	0.0828	**
5. *Corporate degree centrality*[(e)]	-1.7104	0.4583	***	-0.3184	0.3979		0.4992	0.4198	
6. *University degree centrality*[(f)]	-0.0027	0.0029		-0.0006	0.0020		0.0007	0.0016	
7. *Knowledge degree centrality*[(g)]	0.0053	0.0044		0.0045	0.0046		0.0031	0.0061	
8. Interaction term *Degree * SH*	0.0216	0.0219		0.0347	0.0164	**	0.0332	0.0178	*
Board composition									
9. ln of the *# of directors of the firm*	0.0249	0.0677		0.0176	0.0766		0.0081	0.1083	
10. % of outside directors of the firm	0.0041	0.0012	***	-0.0008	0.0011		-0.0031	0.0013	**
Control variables									
11. ln of the *firm's age*	-0.1721	0.0237	***	0.1060	0.0334	***	0.4781	0.0848	***
12. *Firm's superior performance*	-0.0132	0.0075	*	-0.0017	0.0066		0.0069	0.0099	
13. ln of the *firm's quick ratio*	-0.3139	0.0287	***	-0.1702	0.0294	***	-0.1741	0.0471	***
14. ln of the *firm's total assets*	-0.1027	0.0155	***	-0.1270	0.0280	***	-0.1933	0.1460	
Akaike's criterion		4277.17			4526.03			2803.38	
R^2(R^2 adjusted)	0.1487	(0.1409)					0.7650	(0.7030)	
F		19.1344	***					12.3475	***

SOURCE: Prepared by the author, based on collected data. Notes: This table shows the results obtained for estimates of the panel data regression parameters in three different models (Model1: Minimum Ordinary Squares; Model 2: Random Effects; Model 3: Fixed Effects). It was found that Model 3 is adequate: Fixed Effects and robust standard error (with the dependent variable being Tobin's Q index), since these tests of premisses suggested that this method was convenient (1,659 observations of 332 companies over a period of 11 years). i) Breusch-Pagan's Test = 614.725 ($p < 0.001$); ii) White's Test, with LM statistic = 284.104 ($p < 0.001$); iii) Hausman's Test = 181.131 ($p < 0.001$); iv) F Test for examining group differences in the intercepts = 10.3982 ($p < 0.001$). *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. [(a)] # of ties adjacent to each firm; [(b)] capacity to intermediate contacts between firms; [(c)]strength of the firm's ties; [(d)] # of ties established by the firm relative to the number of ties that would be possible; [(e)]average degree of board directors of the firm in the network of boards (board directors who serve the same companies); [(f)] average degree of board directors of the firm in the network of universities (board directors from the same university); [(g)]average degree of board members of the firm in the knowledge areas' network (board directors with the same profession). OLS = Ordinary Least Squares; RE = Random Effects; FE = Fixes Effects; SH = Structural Holes.

5. Final considerations

Based on the graph theory, an attempt has been made in this article to check whether the small-world model is valid for the capital market and to verify the existence of associations between the firm's position in the network of corporate relationships with its worth, by means of interlocking boards. This becomes relevant when it is understood that in the context of the roles of corporate boards there are aspects that condition the flow of resources (whether negotiated or otherwise in the markets), such as capital, status, prestige and legitimacy within the corporate environment.

In the light of the results achieved, which are supported by a dataset relating to 415 non-financial companies listed on the BM&FBovespa [São Paulo Stock Exchange] in the 1997-2007 period, it can be supposed that the top administration of hundreds of publicly quoted companies listed in Brazil essentially consists of people who know one another very well. According to the findings of Milgram (1967), over the 11 years studied, the board directors belonging to the main component of the network of relationships (~50%) proved to be separated by a number of personal ties close to 6 degrees of separation, meaning that the small-world properties were seen as being valid in the relationship networks that comprised both board directors and companies.

This supports the argument that individuals involved in collaboration networks with an outstanding reputation, or who represent access to resources, experience or knowledge, for example, tend to be more sought after. Because of this, they increase their prestige while at the same time exercising an influence on the governance practices of other companies via articulation and the sharing of prospects (Merton, 1996 and Moody, 2004). As a consequence and because of their career paths in different institutions over time and because of their peers in these institutions, they can promote a stratified connection between corporate boards, especially those of companies that are looking for independent board members.

Such aspects raise questions as to the role exercised by certain companies in corporate governance via the activities of their board directors. Some companies may be more attractive in terms of establishing new relationships, thus increasing their tendency to be influential as far as regards their power to participate more actively in the flow of resources (financial and non-financial, whether formally negotiated in the markets, or otherwise) in the network of corporate relationships; they are key-links in the connections between those companies that are around them.

By way of extension to the worth of the company, results were found that point to the existence of optimum levels of centrality. This result points to the optimum levels of social

prominence of the firm (in terms of its degree centrality), which maximize the company's worth. In line with the idea of how relevant the position in the network is to the firm's worth, a positive association was found between structural holes and Tobin's Q index. This reaffirms the arguments of Burt (1992), which defend the opinion that a reduction in redundant ties can improve access to new investments and new ways of mobilizing resources (not only financial ones) through interlocking boards.

The results obtained with the positioning measures of the firm in the network, in comparison with the parameters estimated for the variables that relate to the composition of the corporate board, particularly the size of the board and the number of outside directors, support the idea that perhaps establishing the parameters of the way in which this organ of corporate power establishes ties with other boards is just as important as managing these board characteristics.

Along with the contributions of this study to expansion of the field of knowledge about corporate governance[7], within the scope of corporate finance, as an ethical duty some of the limitations inherent in this study must be pointed out. These are mainly the limited length of time studied, the scope, which is limited to the Brazilian context, and the non-exploration of other forms of connection (essentially because of difficulties in getting access to data). The topic here debated does not end with this work.

The aspects previously pointed out and the growth in the area of social network analysis in Brazil suggest an innovative field of research, with a high power of explanation of phenomena that intervene in questions related to corporate governance, which hitherto do not seem to have been adequately explored by Brazilian research.

[7] Recently published works in the finance area have pointed to the contribution that research about the informal mechanisms of governance (as corporate networks are) can make to a better understanding of governance models around the world. For an elucidatory discussion of this view it is recommended that the texts of Fracassi & Tate (2011); Cohen, Frazzini & Maloy (2010) and Stafsudd (2009) be reviewed.

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