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Exploratory social network analysis of affiliation networks of Indian listed companies

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ABSTRACT

Interlocking directorates play a crucial role in the corporate governance system. In this paper we analyse the structural characteristics of the network of the interlocking directorate of National Stock Exchange (NSE) listed Indian companies using the tools of social network analysis to examine the effects of the underlying network on the performance of companies and directors. A component analysis of the network shows that 78.5% of the companies fall under one giant component with the largest island containing 6 companies. The giant component was further analysed for clusters and centrality measures. The results show that the highly boarded directors who constitute just 2.25% of the director population are associated with 42% of the total listed companies which account for 65.5% of the total market capitalisation. The top central actors in both director as well as company networks have been identified. The calculated values of mean path length and global clustering coefficient provide evidence for the existence of small world structure in the Indian corporate field.

1. Introduction

The industry has played a crucial role in the transformation of India as an emerging global economic power. The policy of liberalisation in the early 1980s has brought about fundamental changes in the economic activities and industrial environment in India. Important among these changes is the growth and the stretch of the corporate sector in the country which in the pre-liberalisation era comprised of a few public sector companies and private manufacturing firms. In the past few years, Indian companies have participated in the worldwide trend of consolidation through cross-border mergers and acquisitions (Singla et al., 2012) and this has led to substantial changes in the structure of corporate governance in India. Corporate governance has become central to the financial performance and overall growth of Indian industries in the post-reform era.

The board of directors, which is the prime decision making body of a corporate firm, has a significant role in the governance of any corporate. *Interlocking directorate* refers to the situation in which the same person shares positions on the boards of more than one firm. Interlocks lead to a complex web of interconnected firms and directors with important socio-political and economic consequences. There has been quite a number of studies on the causes of interlocking (Scott, 1991; Glasberg, 1987; Mizruchi, 1996) and its effects on board relation ships, formulation of strategic decisions and sharing of information (Gulati and Westphal, 1999; Zaheer et al., 2000; Haunschild and Beckman, 1998). Most of the studies on interlocking directorate are focused on developed countries and there is a dearth of such studies relevant for developing and emerging economies like India.

In this paper we report the results of a detailed analysis of the interlocking board of directors of Indian industry using tools of social network analysis and its implications from a network perspective. We identify the major players in the Indian corporate sector by virtue of their position and ties in the network of interlocking directors and firms. The network is also analysed for the existence of small world structure.

2. Interlocking directorates

Corporate governance refers to the system by which corporations are directed and controlled. This includes monitoring the distribution of rights and responsibilities among different stakeholders in the corporation specifying the rules and procedures for making decisions in corporate affairs and providing the structure through which corporates set and pursue their objectives and

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respond to the social, political and market environments. At the core of corporate governance is the board of directors, which is the primary decision making body of any corporate company. The composition of the board of directors is an important factor affecting the relationship between corporate owners and managers on one hand and the liaison among corporate players on the other.

The board of directors usually consists of inside directors and outside directors. The inside directors are important persons who are directly associated with the firm such as the CEO, top executives, retired managers, directors of subsidiaries or parent organisers, etc. (Pennings, 1980) while outside directors are persons not directly associated with the firm. The practice of including outside directors has over the years given rise to the phenomenon of *interlocking directorate* which refers to the situation in which members of a board of directors serve on the boards of multiple companies. Two firms A and B may be interlocked directly when their boards share a director, or indirectly when they each have directors who also serve on the board of a third company.

The origin and growth of interlocking in the corporate world, as well as its socio-political impacts, have been an area of interest to many researchers (see Scott (1991), Glasberg (1987), Mizruchi (1996) and references therein). There are conflicting views as to the cause of the origin and spread of interlocking practice in the corporate world. Some researchers hold that the heightened dependence on resources and the need to reduce uncertainty have led to an increased demand for individuals holding multiple directorships as they are supposed to have greater access to information, resources, etc. (Salancik and Pfeffer, 1978). Class hegemony theory, on the other hand, assert that interlocks are formed based on social ties among the upper class where the elites seek to promote upper class cohesion through interlock across corporations (Koenig and Gogel, 1981; Sonquist and Koenig, 1975). Some companies go for co-opting executives of successful corporate players into their board to enhance their reputation and earn the good will of their stakeholders. Whatever be the reason, the increased linkages between board of directors resulting from interlocking has been reckoned as a key characteristic of the development of the global economy over the past two decades (Kentor and Jang, 2004).

Interlocks act as communication channels, enabling information to be shared between boards via multiple directors who have access to inside information of multiple companies. Thus interlocks can be seen as a diffusion instrument through which information is disseminated through a network (Chua and Petty, 1999). In particular, this may also lead to sharing of strategic information and inter-organisational knowledge among corporates allowing powerful and influential firms to exercise control over others (Seidel and Westphal, 2004; Haunschild and Beckman, 1998). The information flow resulting from interlocks may also promote coordinated action by two or more firms towards achieving a common objective (Sonquist and Koenig, 1975). This may also help develop mutual trust and obligations in an otherwise competition-ridden corporate world.

Interlocks have reportedly helped improve the performance of companies in many cases. In particular, profits made by firms have been shown to have a direct and positive correlation with the number of interlocks (Haunschild and Beckman, 1998). In business environments with greater uncertainty, firms with more interlocks exhibit better performance as measured by sales growth and return on equity (Nicholson et al., 2004).

There has been a few studies on the phenomenon of interlocking directorate in specific countries like the US (Roy, 1983), Kuwait (Mahdi et al., 2012), France (Yeo et al., 2003), Italy (Rinaldi and Vasta, 2005), New Zealand (Firth, 1987), Australia (Stening and Wai, 1984), Canada (Ornstein, 1984), etc. This paper examines the existence and implications of interlocking in the context of Indian corporate sector, using tools of social network analysis.

3. Indian corporate network

The economic policies of India, after gaining independence from the British rule in 1947, were essentially socialist in nature and oriented towards greater state control and intervention, presumably to insulate the country from economic shocks or upheavals. These included centralised planning, complex industrial licensing laws, nationalisation of banks, tight restriction on foreign investments, imports and exports, public ownership of major heavy industries etc.

The results were low rate of growth of the economy which stagnated at around 3.5% from 1950s to 1980s, low per capita income which averaged 1.3% and poor infrastructure investment due to public sector monopoly (Kaushik, 2013).

India's corporate sector consists of both private and publicly held companies with the private sector companies vastly outnumbering the public ones and constituting the bulk of small scale enterprises. However, until nearly the end of the twentieth century, the public sector, which consisted of mere 0.25% of the total number of companies and about 2% of the total listed companies, accounted for almost two-thirds of the book value of equity, more than one-third of paid up capital and about 15% of market capitalization (Goswami, 2002). Despite having monopoly in major heavy industries, most public sector companies suffered huge losses due to poor management and lack of competition while the role of private enterprises were minimal in the larger economic activities.

A Balance of Payments crisis in 1991 pushed the country to near bankruptcy in 1991 which acted as a catalyst required to transform the economy through a series of economic reforms and liberalisation policies in early 1990s to unshackle the economy. The effects of these changes became immediately evident. The total market capitalization, which was only 5% of GDP in 1980 reached 60% of GDP by the end of 1993. Between 1980 and 1993 the number of mutual funds investors rose from 2 to 40 million and the Indian stock market became one of the largest in the world (Singh, 1998). The fruits of liberalisation reached their peak in 2007 when India recorded its highest GDP growth of 9%, becoming the second fastest growing economy in the world, next only to China.

The increased competition to which corporate India was exposed since the mid-1990s has led to drastic restructuring of management practices and rise of professional managers who value corporate governance and transparency. There has been phenomenal growth in market capitalization with greater emphasis on creation and distribution of wealth. The Indian corporate world was faced with a greater need for capital which they tried to raise through international collaborations or mergers and by listing abroad. The tendency of foreign investors to increase their exposure in well-governed firms saw more and more companies adopting internationally accepted standards of transparency, accounting and disclosure and demanding new corporate governance standards (Afsharipour, 2009), leading to the growth of new managerial practices such as interlocking directorates.

A hallmark of the liberalisation policies in India was that the reforms in the industrial sector were complemented by the financial sector reforms that were introduced along with them (Guha-Khasnobis and Bhaduri, 2000). Prior to these reforms, banking in India was characterised by a greater degree of state ownership and far reaching regulations especially in the allocation of credit and the setting of interest rates. The reforms primarily included deregulation of interest rates, easing of directed credit rules under the priority sector lending arrangements, reduction of statutory pre-emptions and lowering of entry barriers for both domestic and foreign players (Roland, 2005). The financial sector reforms made it imperative for firms to rely on capital markets to a greater degree for their needs of additional capital (Varma, 1998). The institutionalization of the capital markets tremendously

enhanced the disciplining power of the market which was also responsible for the rise of tougher accounting practices, stringent disclosure norms and other healthy governance practices such as interlocking directorates among Indian corporates.

4. Social network analysis (SNA)

Social networks refers to a social structure made up of *actors* (individuals, groups of individuals, societies, organisations or countries) and *interactions* or *ties* among them arising from any kind of relationship between two or more actors (such as friendship, political alliance, professional collaboration, or business alliance). Social network analysis (SNA) refers to the analysis of social interactions using network theory, where the actors are represented as nodes (or vertices) and the interactions among them by means of arcs connecting the nodes. Over the years SNA has become a powerful tool for analysing social structure alongside the quantitative methods of statistics. The literature on SNA has grown extensively over the years, especially in the last decade owing to developments in the field of graph theory and computing (Wasserman, 1994; Carrington et al., 2005; Nohria and Gulati, 1997; Degenne and Forsé, 1999; Scott et al., 2000; Borgatti et al., 2002)

Most social networks are *one-mode* networks consisting of nodes of the same kind representing actors of the same type or category. In *two-mode networks*, also called *affiliation networks* or *bipartite graphs*, the nodes can be classified into two different sets representing different types of actors (such as persons and groups), with ties existing only between nodes belonging to different sets. Such networks are useful in studying, for example, the relationship between individuals arising out of their affiliation to certain groups or societies. From a two-node network we can generate two one-node networks, one for each type of node, by suitably 'folding' the graph, i.e. by replacing appropriate paths of length two by single arcs. This would be useful in analysing hidden relationships among the actors of the same type, which would otherwise be deep buried in the complexity of the network.

Another concept that has become relevant in the study of social networks is based on the works of Milgram (Milgram, 1967; Travers and Milgram, 1969) who found through some simple experiments that pairs of people chosen at random from a certain population are only six steps apart in the network of first-name acquaintances. Thus apparently distant actors in a social network may in fact be connected to one another by a short chain of known intermediaries, a situation which has come to be known as the *small world phenomenon*. Many simple quantitative measures have recently been introduced to identify the small world phenomenon in a network (Watts and Strogatz, nature; Newman et al., 2001; Newman, 2003, 2009) and studies based on these measures have revealed the existence of small world in many social networks, especially in the context of corporate governance (Baum et al., 2003; Davis et al., 2003; Robins and Alexander, 2004)

5. SNA of interlocking directorate of Indian corporate world

In this paper we analyse the phenomenon of interlocking directorate in the Indian corporate sector. The relevant data for the analysis consists of 8184 directors affiliated to the boards of 1220 companies listed by NSE. The data was collected from official portal of NSE India Ltd in May, 2013. Extensive manual and computer procedures were used to ensure the quality of the data by removing duplications and ambiguity in designations, ensuring uniqueness of designation by upgrading multiple designations to the highest designations if necessary etc. Finally interlocking and non-interlocking directors were separated from this *cleaned data.* Out of the 1220 companies, 958 are interlocked with a total of 3198 interlocking directorships shared by 1209 directors.

Table 1
Summary of board of directorate data set.

	Data available	Interlocking	Highly boarded
Number of companies	1220	958	512 (42%)
Number of directors	8184	1209	184 (2.25%)
Total directorship	10182	3198	916 (9%)
Market (billions of rupees)	66,562.32	64,153.7	43,951.54

Table 1 shows an overall summary of interlocking status based on a prima facie analysis. We may regard a director as *highly boarded* if he shares 4 or more directorships. It is seen from the table that among 8184 directors, 184 are highly connected sitting in 524 board positions in 347 companies. Hence, while 78.5% of the companies are director-interlocked, only 14.7% of the directors hold multiple directorships of which a meagre 2.25% are highly boarded. Thus while interlocking is clearly seen to be a prevalent practice among Indian corporate companies, the bulk of interlocking comes from a thin cream of directors.

Table 1 also shows the market capitalisation of the companies to which the highly boarded directors are linked. It is seen that the highly boarded directors who constitute just 2.25% of the director population are associated with 42% of the total listed companies which account for 65.5% of the total market capitalisation. The fact that 2.25% of the directors control 65.5% of the total market capital of all NSE listed companies, indicates high concentration of power and wealth in the hands of few individuals in the Indian market. While this is not a desirable scenario from public policy perceptive, it has positive influence on transferring best practices and technologies among companies.

Table 2 shows the top 10 sectors based on the number of companies with interlocking directorships. The computer sector has got the largest number of companies with interlocking directors while auto and banking sector have got the highest percentage.

5.1. Network of Indian companies

In an interlocking scenario, a director may be affiliated to more than one board of directors and two or more boards of directors may have one or more directors in common. This situation is probably best modelled by a two-mode (affiliation) network in which the two node types are the directors and the board of directors and the ties arise from the affiliation of directors with boards.

A *component analysis* carried out on the affiliation network throws further light on the interlocking structure of the network. There are a total of 275 connected components with the largest among them containing 958 companies accounting for 78.5% of the total number of companies. There are a few islands also, with the single largest among them containing 6 companies. The remaining 253 (≈20%) companies are largely isolated. Fig. 1 shows a schematic

Table 2
Top 10 Sectors based on interlocking directorate of companies. Column headings: TC – total number of companies, IC – interlocking companies.

Rank	Sector	TC	IC
1	Computers	95	65
2	Auto	63	60
3	Finance	69	59
4	Construction and contracting	74	54
5	Metal	63	51
6	Pharmaceuticals	76	50
7	Textiles	62	47
8	Infrastructure	48	41
9	Banks	41	39
10	Media and entertainment	38	33

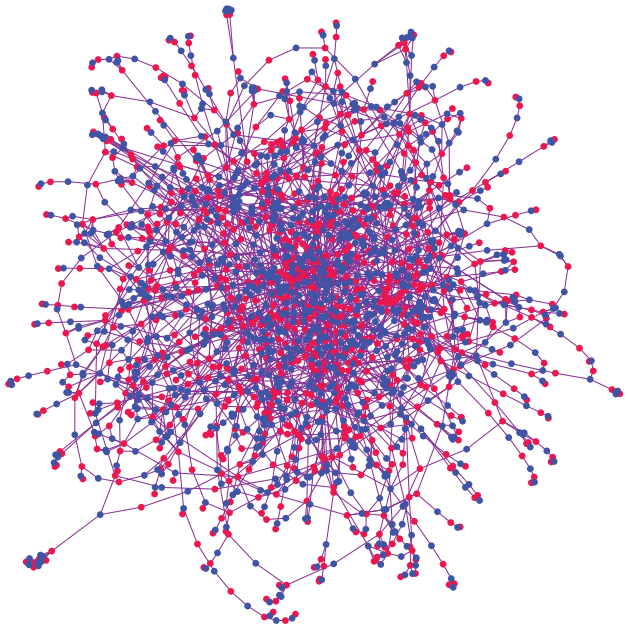

Fig. 1. The giant component of the affiliation network after removing director nodes with degree one, in which the red filled circle represents company and blue circle represents director nodes. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

of the largest (giant) component of the affiliation network with all director nodes with degree one removed.

The giant component of the affiliation network was further split into the components of the one-mode networks of directors and companies and the giants in each of them were used for the subsequent analysis. Table 3 gives an overview of the giant components of the company and director networks. In the company network, the nodes represent the companies and an arc between two nodes indicate that the corresponding firms have at least one director in common. Similarly, in the director network, two director-nodes are connected if the directors have at least one board in common. There were 4982 directors with single directorship which we eliminated before further analysis. The frequency counts of the directorship as well as the board size of the companies in the giant component are given in Fig. 2. The highest number of directorship is 14 possessed by two directors who belong to legal and management professions. The highest size of the board is 23 possessed by a government owned metal company. Boards of size 8 have got the highest count (141) and the average number of board membership of interlocking directors is 3.

5.2. Cluster analysis

In a typical cluster analysis of a network, nodes are grouped into different *clusters*, each cluster containing nodes of *similar* types. We

Table 3
The network properties of the giant components of the company and director networks.

	Company networks	Director network
Number of nodes	902	1163
Number of edges	3047	5241
Average degree	3.378	4.506
Degree of separation	4.4683	4.168
Network diameter	14	13
Graph density	0.00749	0.007749
Average clustering coefficient	0.173	0.265
Average path length	3.77	4.71

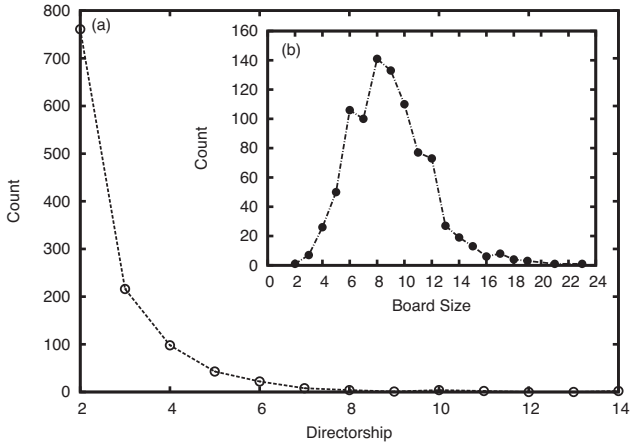

Fig. 2. The frequency count of (a) board size and (b) directorship of companies in the giant component.

have carried out a clustering analysis on the giant component of each of the company network as well as director network (Blondel et al., 2008; Lambiotte et al., 2009). With a resolution of 2.75 the company network falls into 6 clusters as represented in Fig. 3. The largest cluster contains 352 companies of which 42 companies belong to banking and finance sectors which constitute approximately 12% of the total number of companies in the cluster. The other major sectors in this cluster are computers (31 companies), auto-mobiles (21 companies) and pharmaceuticals (21 companies). Each of the remaining clusters in the network are nearly half or less than half the size of the largest cluster and is again a heterogeneous mix of companies belonging to different sectors. The details of these clusters are presented in Table 4.

The director network has 7 clusters at resolution 2.5 as shown in Fig. 4 with details in Table 5. The first 4 clusters are roughly similar in size while the last two are comparatively smaller. The largest cluster in this network contains 276 directors with 1055 connections which is significantly larger compared to the rest of

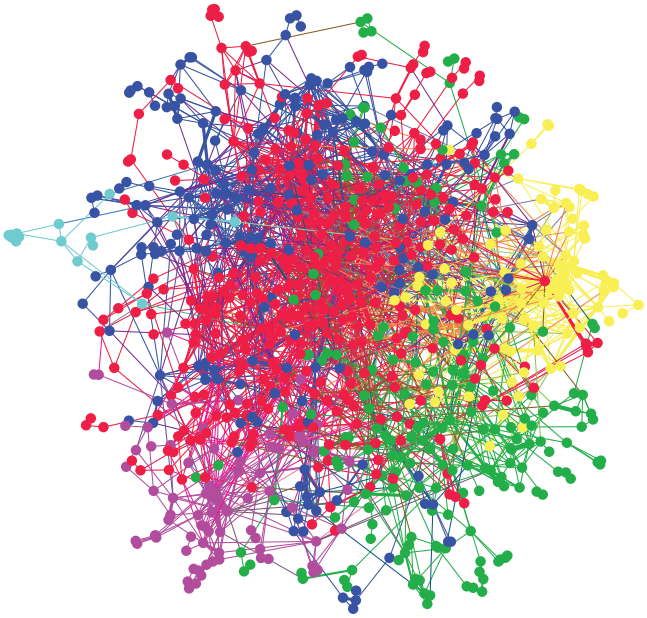

Fig. 3. Different clusters of the company network. The sizes of the clusters in percentage are red – 39%, blue – 21.18%, green – 20.18%, yellow – 9.42%, pink – 7.98%, cyan – 1.66%. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Table 4
The details of the clusters in company network. Column headings: N – number of nodes, E – number of edges, Ad – average degree, D – diameter, GD – graph density, ACC – average clustering coefficient, APL – average path length.

No.	N	E	AD	D	GD	ACC	APL
1	352	1047	5.95	11	0.02	0.43	4.21
2	191	492	5.15	13	0.03	0.48	4.50
3	187	367	3.93	13	0.02	0.45	5.10
4	85	262	6.17	8	0.07	0.72	3.41
5	72	150	4.17	11	0.06	0.51	3.80
6	15	22	2.93	7	0.21	0.58	3

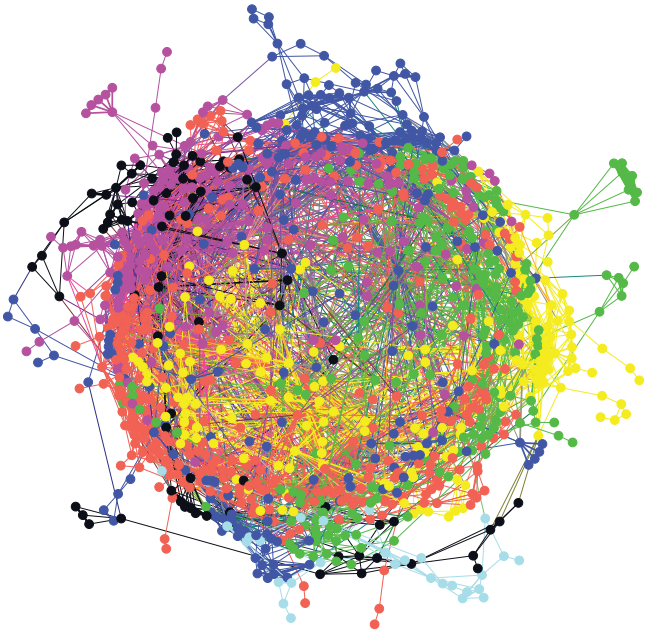

Fig. 4. The director network has 7 clusters at resolution 2.5. The sizes of the clusters in percentage are red – 25.54%, blue – 18.4%, green – 16.94%, pink – 15.74%, yellow – 14.19%, black – 6.79%, cyan – 2.41%. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Table 5
The details of the clusters in director network. Column headings: N – number of nodes, E – number of edges, Ad – average degree, D – diameter, GD – graph density, ACC – average clustering coefficient, APL – average path length.

No	N	E	AD	D	GD	ACC	APL
1	276	1055	7.65	9	0.03	0.65	3.88
2	194	639	6.59	15	0.03	0.67	4.59
3	185	743	8.03	9	0.04	0.72	3.48
4	170	512	6.02	11	0.04	0.67	4.03
5	161	578	7.18	11	0.05	0.69	4.06
6	99	331	6.69	11	0.0	0.74	4.20
7	64	157	4.91	8	0.08	0.66	3.77

the clusters. Most of these directors are experts in the fields of finance and law. Together with the observation of heterogeneous mix of sectors in the company clusters, this indicates that majority of interlocking comes not from professionals in the respective sectors but from directors whose expertise in financial, managerial and legal matters are of universal demand across all sectors.

5.3. Centrality measures

Centrality measures are numbers used to quantify the degree of interconnectedness of nodes in a network (Freeman, 1977, 1979). Among the various centrality measures, the most popular are *degree centrality*, *closeness centrality*, *betweenness centrality* and *eigen vector centrality*. Each of these measures quantifies how close each node is to the central position in the network, but the concept of being central is defined differently in each case.

The simplest centrality measure is the degree centrality (DC), which counts the number of ties that a node has with other nodes in the network. It is a measure of immediate connectivity or popularity of a node and its vulnerability to catching whatever flows though the network.

While the degree centrality counts only the immediate ties of a node, the closeness centrality (CC) takes into account the distance of each node to every other node in the network. Thus the greater the value of closeness centrality the shorter is its total distance to all other nodes in the network. It is often used as a measure of how long it will take for information to pass between a node and all other nodes.

Betweenness centrality (BC) measures the proportion of times a node falls along the shortest path between pairs of other nodes. Betweenness measures the ability of a node to control the flow of information through it and nodes with high betweenness centrality may have the ability to change or hinder the flow of information through them.

Eigenvector centrality (EC) not only counts the number of nodes each node is connected to-as in closeness centrality, but also weights these nodes according to their centrality. Essentially, it is a measure of how well connected are the nodes to which a given node is connected. It is a measure of the influence of a node in the network.

To identify the central actors in the network of Indian companies and directors, the centrality measures were computed for each node in both the company network and the director network. The top 10 actors in the director network based on the various centrality measures are shown in Table 6. he degree centrality identifies the most popular directors who share the maximum number of boards with directors of other companies. The closeness centrality, on the other hand, identifies the directors who have the fastest access to information in the network. The top players identified by the betweenness centrality are the mediators, power brokers and gate keepers of communication in the network who can control and influence the diffusion of

Table 6
Top 10 central actors, identified by their node number with area of expertise in parenthesis, in director's network based on different centrality measures.

Rank	Closeness	Betweenness	Degree	Eigen value
1	133 (Legal)	133 (Legal)	133 (Legal)	178 (Economist)
2	330 (IT/ Management)	18 (Financial Advisor)	467 (Management)	17 (Management)
3	18 (Financial Advisor)	467 (Management)	379 (Legal)	160 (Legal)
4	178 (Economist)	160 (Legal)	160 (Legal)	5 (IT/ Management)
5	160 (Legal)	299 (Finance)	319 (Finance)	184 (Management)
6	164 (Financial)	769 (Management)	184 (Management)	467 (Management)
7	299 (Finance)	204 (Management)	18 (Financial)	185 (Finance)
8	467 (Management)	184 (Management)	299 (Finance)	177 (Financial)
9	5 (IT/Management)	319 (Finance)	5 (IT/Management)	170 (Management)
10	17 (Management)	330 (Advisor)	241 (IT/Management)	176 (Management)

Table 7
Top 10 central actors, identified by the node number with sector in parenthesis, in company network based on different centrality measures.

Rank	Closeness	Betweenness	Degree	Eigen value
1	149 (Paints)	531 (Miscellaneous)	154 (Auto)	107 (Diversified)
2	107 (Diversified)	708 (Infrastructure)	708 (Infrastructure)	149 (Paints)
3	145 (Cement)	702 (Cigarettes)	214 (Infrastructure)	145 (Cement)
4	531 (Miscellaneous)	194 (Finance – housing)	486 (Hotels)	531 (Miscellaneous)
5	289 (Computers)	145 (Cement)	493 (Chemicals)	309 (Pharmaceuticals)
6	55 (Dyes &pigments)	149 (Paints)	226 (Infrastructure)	229 (Pharmaceuticals)
7	372 (Packaging)	214 (Infrastructure)	73 (Finance)	55 (Dyes&pigments)
8	67 (Telecom service)	718 (Cement)	194 (Finance - housing)	788 (Pharmaceuticals)
9	501 (Packaging)	417 (Power)	460 (Pharmaceuticals)	195 (Computers)
10	493 (Chemicals)	628 (Shipping)	231 (Auto)	813 (Graphite)

Table 8
Structural properties of networks.

Property	Affiliated network	Company network	Director network
Total actors	2065	902	1163
Total Links	3087	3047	5241
Degree of separation	8.59516	4.4683	4.168
Density	0.00294279	0.0074901	0.007749
Diameter	28	14	13

Table 9
Rank order correlation between different centrality measures of company network where DC stands for degree centrality, CC for closeness centrality, BC for betweenness centrality and EC for eigenvector centrality.

	DC	CC	BC	EC
DC	1	−0.9050518	0.7944876	0.916803
CC		1	−0.675 901	−0.982357
BC			1	0.651663
EC				1

technologies and innovation in the network. And the eigenvector centrality identifies the most influential and authoritative actors in the network. It turns out that most of these central actors are from finance or legal profession who rose to their respective positions by virtue of their professional qualifications and expertise, with little political or elite family connections.

Similar comments with obvious modifications apply to the results shown in Table 7, regarding the top players in the network of companies, identified on the basis of the various centrality measures. These results also explain why some become "early adopters" of innovations and technologies and how the existing social network structure helps or impedes the spread of innovations. The overall network structural properties are given in Table 8

We have also calculated the rank correlation between various centrality measures of both company and director networks and is given in Tables 9 and 10. The degree and eigen vector centrality rankings are strongly correlated, and both of these are reasonably well correlated with the betweenness centrality ranking as well. However, all these three rankings are negatively correlated with closeness centrality. Thus, one might say that the degree of influence of an actor or the capacity of the actor to control the flow of information or technology are in proportion to the connectivity or popularity of the actor in the network.

Table 10
Rank order correlation between different centrality measures of Director network where DC stands for degree centrality, CC for closeness centrality, BC for betweenness centrality and EC for eigenvector centrality.

	DC	CC	BC	EC
DC	1	−0.8517646	0.6997408	0.908575
CC		1	−0.618102	−0.958819
BC			1	0.585534
EC				1

5.4. Small world phenomenon

The number of actors in a network may be quite large and most actors not neighbours of one another, yet most actors may be reachable from every other by a chain of very few intermediate actors. This situation, referred to as the phenomenon of small world, has been observed in many social networks. We will now describe a few measures commonly used to identify the existence of small world in a network.

The *geodesic* between a pair nodes in a network is the shortest path between them, that is, the minimum number of edges that must be traversed to go from one node to the other. The *diameter* of a network is the longest of all the calculated geodesics between all possible pairs of nodes in the network. It is a measure of the linear size of the network. The calculated diameter of the affiliation network, the director network and the company network of the Indian listed companies are respectively 28, 13 and 14. The longest geodesic in the company network has MVL and GEI Industrial as end nodes with 13 companies in between. Similarly the longest geodesic in the director network has Mr Rakesh Gupta and Mr Sanjiv Singhal as end nodes with 12 nodes in between. The diameter represent the worst situation in which an information may take the longest to reach from one actor to another. As for the Indian corporate scenario, the comparably smaller values of the network diameters indicate better connectivity among the actors even in the worst situation.

The *mean path length* is another benchmark to measure the small world property of a network. It is the average of the geodesics in the network, averaged over all pairs of nodes. For an undirected graph of N nodes, the mean path length is given by

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

where $d_{i,j}$ is the geodesic distance between nodes i and j. While the diameter represents the worst scenario for the flow of information across a network, L symbolises the typical scenario applicable to most nodes in the network.

A third measure of small world property is the *global clustering coefficient* defined by (Newman, 2003, 2009)

$$C^{\Delta} = \frac{3 \times \text{Number of triangles}}{\text{Number of triplets}}$$

where a set of three nodes $\{i, j, k\}$ is called a *triangle* if every two of them are connected by an arc, and a *triplet* if i is connected to j and j is connected to k. The factor 3 ensures that $0 \le C^{\Delta} \le 1$. The clustering coefficient indicates what proportion of triplets in a network are in fact triangles. A network is said to be a small-world network if $L \ge L_{\text{rand}}$ and $C^{\Delta} \gg C^{\Delta}_{\text{rand}}$ where L and C^{Δ} are the mean path length and clustering coefficient of the network under study and

Table 11
The mean shortest path length and clustering coefficient of company network (CN) and director network (DN) and their the equivalent Erdös–Rényi (E-R) random graphs.

	L	L_{rand}	C^{Δ}	C^{Δ}_{rand}
CN	4.4683	3.7663	0.3460	0.0099
DN	4.1680	3.4100	0.5291	0.0081

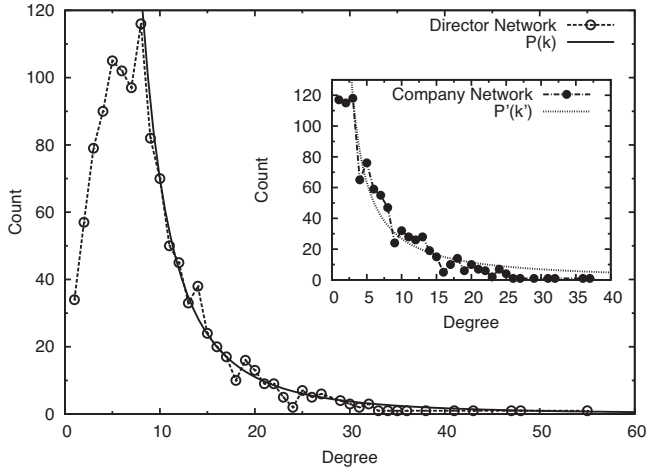

Fig. 5. The degree distribution of the director and company networks along with the fitted power law curves $f(k) = Ck^{-\alpha}$ and $g(k) = C'k^{-\alpha'}$ with $C = 18.71 \pm 2.69$, $\alpha = 2.51 \pm 0.06$ and $C' = 0.51 \pm 0.06$, $\alpha' = 1.24 \pm 0.07$.

L_{rand} and C^{Δ}_{rand} are those of the equivalent Erdös–Rényi (E-R) random graph with same number of nodes and edges (Humphries and Gurney, 2008; Bollobás, 2001). In the case of Indian listed companies, we calculated the mean path length and clustering coefficient for the director network, the company network and the equivalent Erdös–Rényi (E-R) random graphs. The values are shown in Table 11 which indicate that both the networks satisfy the small world property.

Another evidence for the existence of small world phenomenon in the above networks comes from the degree distribution $P(k)$ of the network, $P(k)$ being the fraction of nodes in the network having degree k. If $P(k)$ approximately follows a power law, $P(k) \sim Ck^{-\alpha}$, then it is believed to be a sign that the network is a small world. Fig. 5 shows the degree distribution of the director and company networks both of which are seen to scale like a power law with the functions $f(k) = Ck^{-\alpha}$ and $g(k) = C'k^{-\alpha'}$ respectively giving reasonably good numerical fits. The small world characteristic need not be intentional but it can be caused by a relatively small proportion of random ties as noted by Newman et al. (2001). It may also be noted that no particular node or edge is critical for maintaining the small world phenomenon of the network of corporate elite. The small world behaviour of these networks indicates that a very small number of intermediaries are only necessary and are available to disseminate information and knowledge among the firms, although the details of how exactly this happens might be obscured by the complexity of the network and hence may not be immediately evident. The small world characteristic of these networks has several other consequences on corporate governance. Frequent board meetings involving directors from a small-world network provide an ideal medium for the rapid spread of strategies, practices, rumours, structures, diseases, or anything else spread by face - to - face contact (Mills, 1999). The shorter characteristic path length of a small world network makes it easy to diffuse anything that spreads through connection of its nodes. The small world property of these networks has the potential to turn an otherwise geographically, educationally and professionally dispersed population of company directors into a compact social and psychological entity (Davis et al., 2003). This can lead to homogeneity in responses to corporate or governmental reforms.

6. Conclusions

This paper presents a study of the phenomenon of interlocking directorate in the Indian corporate sector, employing the tools of social network analysis to examine its structure. The data consists of 1220 companies listed by the National stock exchange of India encompassing 10,182 directors sitting in various boards of directors. The position of a company in the network has a significant impact on its access to market resources such as capital, status, prestige and legitimacy within the corporate environment. Only 14.7% of the total directors hold cross-company directorships, but this minority makes 78.5% of companies director-interlocked, showing the presence of a power elite in the Indian corporate field. Using various centrality measures we have identified the major players in the network, both among the firms and the directors. It turns out that the most influential directors and firms, as measured by means of the degree centrality, are not necessarily the most active power brokers and mediators, as measured by the betweenness centrality.

Another important observation is that both the network of firms as well as the network of directors satisfy the small world property, meaning that it is possible to go between two firms or two directors by a small number of hops across the networks, though the exact path along which to do so may not be visible to the players immediately. Thus there is a greater possibility of ideas and knowledge being transferred between firms much faster than expected, often inadvertently and unpremeditatedly. Because of this, the major players in the field, as identified by the centrality measures, ought to have a greater influence on the governance practices of other companies via articulation and the sharing of prospects.

This study furnishes an overall view of the effects of interlocking among the company director boards of Indian firms, and holds promise for deeper analysis of each of the observed phenomenon in this area which is a sparsely investigated topic in the Indian context.

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