Network Analysis in Corporate Finance

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Ali Bayat
University of Aberdeen

Marc Goergen
IE Business School and ECGI

Luc Renneboog
Tilburg University, CentER and ECGI

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Ali Bayat
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Abstract

Social networks are formed by relationships between social units (e.g., individuals or organizations). They affect social outcomes, which are shaped not only by the characteristics of individual social units but also by the ties that link them to other units. For example, the impact of directors on their firms may depend on their connections with directors of other firms. A social network consists of nodes or vertices (i.e., the social units) connected via ties or links based on, e.g., membership of the same organizations and a shared educational background. There might also be multiple ties between two social units, i.e., so-called multiplex relationships, which amplify the strength of the relationship. E.g., directors who not only serve on the same board, but also studied at the same university and are members of the same social club, are likely to have strong ties. Social networks can be of the one-mode or two-mode type. The former type consists of a single set of social units, such as directors with shared board membership. The latter type involves two sets of actors (e.g., directors and firms). For one-mode networks, centrality measures are used to quantify the prominence of social units. Q-analysis is used to study two-mode networks. In corporate finance, network theory has many potential applications, such as those that relate to informational diffusion across, e.g., directors and corporations; access to resources (e.g., capital); insider trading; monitoring quality; asymmetric information (e.g., bank lending relationships); financial contagion and systemic risk; and strategic alliances.

Keywords: network analysis, social networks, director interlocks, centrality measures, Q-analysis, one-mode networks, two-mode networks, multiplex ties, connectedness, closeness

JEL Classifications: B40, C02, C60, G30

Ali Bayat
Lecturer
University of Aberdeen, Business School
King's College
Aberdeen, AB24 5UA, United Kingdom
e-mail: ali.bayat@abdn.ac.uk

Marc Goergen*
Professor of Finance
IE Business School, Department of Finance
María de Molina 11
28006 Madrid, Spain
e-mail: marc.goergen@ie.edu

Luc Renneboog
Professor of Corporate Finance
Tilburg University, School of Economics and Management, Department of Finance
Warandelaan 2
5037 AB Tilburg, The Netherlands
e-mail: luc.renneboog@tilburguniversity.edu

*Corresponding Author

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Ali Bayat
University of Aberdeen

Marc Goergen
IE Business School, IE University
European Corporate Governance Institute

Luc Renneboog
Tilburg University
European Corporate Governance Institute

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Social networks are formed by relationships between social units (e.g., individuals or organizations). They affect social outcomes, which are shaped not only by the characteristics of individual social units but also by the ties that link them to other units. For example, the impact of directors on their firms may depend on their connections with directors of other firms. A social network consists of nodes or vertices (i.e., the social units) connected via ties or links based on, e.g., membership of the same organizations and a shared educational background. There might also be multiple ties between two social units, i.e., so-called multiplex relationships, which amplify the strength of the relationship. E.g., directors who not only serve on the same board, but also studied at the same university and are members of the same social club, are likely to have strong ties. Social networks can be of the one-mode or two-mode type. The former type consists of a single set of social units, such as directors with shared board membership. The latter type involves two sets of actors (e.g., directors and firms). For one-mode networks, centrality measures are used to quantify the prominence of social units. Q-analysis is used to study two-mode networks. In corporate finance, network theory has many potential applications, such as those that relate to informational diffusion across, e.g., directors and corporations; access to resources (e.g., capital); insider trading; monitoring quality; asymmetric information (e.g., bank lending relationships); financial contagion and systemic risk; and strategic alliances.

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Introduction

While network analysis is a well-established methodological toolkit in social sciences (see, e.g., Davis et al., 1941; Leavitt, 1951), its uptake by corporate finance scholars has been much more recent. It is used by scholars to model and measure how relationships among social units, such as corporations or directors, shape information flows, incentives, the diffusion of practices, and decisions, among others. For example, network analysis (Renneboog & Zhao, 2011) helps understand how the position of a social unit within the overall network affects decision-making and outcomes. Network analysis has been applied across several corporate finance research areas, including mergers and acquisitions (e.g., Renneboog & Zhao, 2014; El-Khatib et al., 2015), executive compensation and governance (e.g., Butler & Gurun, 2012; Cvijanović et al., 2016; Engelberg et al., 2013; Renneboog & Zhao, 2011), insider trading (e.g., Goergen et al., 2019; 2025), cash holdings (e.g., Miranda-Lopez et al., 2019), corporate social responsibility (CSR) (e.g., Chahine et al., 2019), and other firm decisions (e.g., Cai & Sevilir, 2012; El-Khatib et al., 2015; Grieser et al., 2022; Song & Wang, 2024).

Network analysis is particularly valuable to researchers seeking to examine how transmissions occur between social units, so-called nodes or vertices. These transmissions may involve tangible exchanges such as capital or resources, or intangible forms of diffusion such as imitation, information, or behavioural contagion. Beyond offering analytical tools to study these relationships, network analysis provides a conceptual language to describe how connections form, strengthen, or decay, and how such connections influence the flow of information and decision-making within and across firms.

Traditional approaches in corporate finance have typically examined patterns in relationships without recognising their wider context. Yet corporations operate within dense webs of professional and social relationships that extend far beyond formal contractual boundaries (Bianchi et al., 2022). Consider the case of board independence. It is typically measured by counting directors who are reported to be independent or outside directors. However, director independence may be compromised by the social and professional ties they have to the executives. Evidence from initial public offerings (IPOs) shows that the connections between top managers and directors influence the offer pricing and post-listing

performance, suggesting that a simple headcount of outside directors potentially misrepresents the board's actual capacity for providing advice and independent monitoring (Chahine and Goergen, 2013).

Similar to board independence, many core mechanisms or decisions in corporate finance and corporate governance are affected by the relationships key actors may have with each other. They are therefore better captured through network analysis rather than through isolated firm-level measures or attributes of individuals (Bianchi et al., 2022; Grieser et al., 2022). As these relational features extend to seemingly non-relational concepts, understanding network dynamics enhances the interpretation of standard measures. For instance, director networks correlate with chief executive officer (CEO) pay and pay–performance sensitivity, even though CEO pay is typically examined at the firm level (Renneboog & Zhao, 2011).

Network analysis assists with mapping the web of ties and identifying a social unit's position or importance within the network to represent resource access, information flow, influence, and entrenchment (Bianchi et al., 2022). Through this analysis, it becomes possible to observe how power and information move through connections rather than inferring them from single-firm attributes. For instance, network analysis has shown that occupying a central position in a network enables chief executive officers (CEOs) to lower firm risk through improved information flow and greater capacity to implement ad-hoc policies (Fan et al., 2023) or to improve access to external financing, and achieve redeployment of resources towards off-balance-sheet opportunities (Miranda-Lopez et al., 2019).

Network analysis has also allowed scholars to investigate how power at the centre can harm governance. Studies have found that CEOs with central positions within their personal network (formed through common education, employment, and board directorships with other business professionals) tend to initiate more acquisitions (Renneboog and Zhao, 2014) and, on average, destroy value, providing evidence of entrenchment rather than superior information or skills (El-Khatib et al., 2015). Importantly, commonly used econometric techniques may not permit this level of relational analysis, as they cannot trace power or information through a structure of interconnected actors.

Examining network linkages is another area where network analysis has proved particularly effective. Studying relational ties enables researchers to identify and quantify influence across firms and to study how information flows across firms. For example, board-interlock networks have been used to study investment behaviour, showing that firms follow connected peers with higher information quality (Song & Wang, 2024). In contrast, relying on predefined peer groups rather than the relational structures revealed through network data may not fully help scholars understand such relationships.

The aim of this chapter is to introduce the analytical foundations and methodological applications of social network theory in corporate finance. The chapter begins with a section outlining the foundations of network analysis, defining the key concepts of networks – such as nodes and ties – and their roles in shaping information flows and power relations within corporate systems. Next, it provides a discussion of the types, strengths, and forms of ties that connect social units as well as a detailed account of multiplex ties that link social units through multiple affiliations. This is followed by a discussion of the theoretical network mechanisms and effects, explaining the key mechanisms. i.e., adaptation, binding, exclusion, and information diffusion. This section concludes with a review of structural holes, and how brokers can bridge these holes, thereby improving information access and control.

The chapter then compares one-mode and two-mode networks, discussing how each type of network represents different relational layers and how researchers move between them through projection. The discussion then turns to centrality measures, explaining how different metrics capture prominence, influence, and brokerage within a network. This is followed by an introduction to Q-analysis and high-dimensional affiliation networks, thereby providing a framework for analysing multi-layer connections.

The chapter concludes with a review of measurement choices and considerations, outlining the key methodological decisions and challenges researchers face when designing and interpreting network studies in corporate finance.

Foundations of network analysis

In social network theory, a network represents the relationships among a set of social units. These social units are called *nodes* or *vertices* and the relationships between them are called *ties* (or *edges*). In

corporate finance, nodes are typically firms, directors, or executives, and ties between them capture links such as shared board membership, transactions, affiliations, or information exchange. The key concepts of network analysis are the position of individual nodes within the network, the types of social units involved, and the features of the ties that connect them. Therefore, network analysis begins by defining and distinguishing these concepts. In what follows, we discuss each of these key concepts in detail.

Network ties serve as conduits for flows of tangible resources and intangible information or practices. This dual potential of networks to carry valuable information and resources, while also enabling power or collusion, lies at the heart of networks' relevance to corporate finance and corporate governance research. Studies frequently confirm that a social unit's privileged position within a network can confer informational advantages but can also entrench the social unit or facilitate collusion. This section starts by reviewing the different types of ties, including multiplex ties. It then outlines the theoretical mechanisms and effects of networks. It concludes by highlighting how structural holes can be bridged by social units that provide a brokerage role.

Network ties

Not all ties are alike. Network ties can be equity partnerships, director interlocks, lending links, past employment connections, and shared membership. The same two social units can be linked via several ties: this is multiplexity. For example, two CEOs might serve on the same non-profit board and also be former classmates. Together, these connections form a multiplex tie that is generally more meaningful than a single link, which on its own may be coincidental rather than indicative of a genuine relationship.

A tie's strength can then be measured by the number and the depth of relationships between social units. Multiple shared affiliations or repeated interactions usually signal a stronger bond. In sociology, strong ties, such as those with family or close friends, are distinguished from weak ties, which may stem from arm's-length acquaintances. Still, weak ties can be more useful. Indeed, Granovetter (1973) argues that weak ties often bridge otherwise distinct groups and carry novel information that seldom circulates within tightly knit clusters. In a corporate setting, an acquaintance with a distant investor might alert a

CEO to a new opportunity, whereas close contacts inside the firm are more likely to hold the same information. In turn, strong ties support trust and cooperation but are often embedded in dense clusters. Effective networks therefore combine both facets: enough weak ties to access new information and enough strong ties to maintain trust.

Ties can also be organised by what they connect in corporate settings. Person–person ties include prior co-employment, mentorship, friendship, committee co-membership (i.e., individuals sitting on the same committee), and shared board service. Firm–firm ties arise through ownership links, shared directors, alliances, joint ventures, lending, and underwriting syndicates, or supply-chain relations. Person–firm ties connect individuals to organisations – such as executives to companies, directors to professional bodies and clubs, or alumni to universities – or events – such as investors attending road shows (Renneboog and Zhao, 2011; 2013).

A further distinction refers to how ties operate. Some relationships reflect direct flows and interactions, e.g., information exchange, lending, underwriting, analyst coverage, audit and legal mandates, or repeated trade. Others capture social or governance channels that connect decision makers across organisations, such as board interlocks, committee co-membership, and cross-membership (i.e., an individual holding formal positions in multiple, distinct organizations, thus creating links between those entities). Additional ties arise from kinship and family relations, from similarity in background or cohort, from co-membership, and from spatial proximity such as co-located headquarters.

Multiplex ties

Multiplex ties, meaning multiple connections linking the same nodes, usually signal a stronger or more consequential relationship. For example, if two firms share several board members, their interconnectedness exceeds that of firms linked by, e.g., a single board interlock. Researchers often capture this by weighing links, for instance, attributing double the weight to two shared directors, or by distinguishing different channels in addition to as board overlap such as strategic alliances, where firms are connected through relational contracts that blur firm boundaries, or a common investor, where firms are tied by sharing the same shareholder, such as the same venture capital firm.

An example of a network with multiplex ties is the financial sector, where banks are directly connected through interbank lending markets but also through connective financial infrastructure. The latter constitutes the "plumbing" of the financial system, comprising, e.g., clearing houses, payment systems, exchanges, central securities depositories (Berndsen, Leon, and Renneboog, 2018). The former can be regarded as *connectivity links* (i.e., links that enable the carrying out of functions), while the latter are *dependence links* (i.e., links that are critical for participants' functioning). A strongly connected but failing bank amplifies the sector's financial instability, as the banking network may fail to isolate negative feedback loops and fail to limit cascades of failing banks. Likewise, a faltering part of the financial infrastructure could hinder bank connectivity. Both types of problems can induce contagion in a dense network and hence augment systemic risk.

Classic social network studies examine multiplexity in communities where the same individuals connect through church, neighbourhood, and workplace ties, which can produce tight, homogeneous clusters. In corporate finance, multiplex ties arise when executives share several affiliations. Chahine and Goergen (2013) identify five social ties between top managers and directors in US IPO firms: former employer, club membership, professional association, alma mater, and ethnic origin. Rather than collapsing these into one binary link, they model each category as a separate network layer, to account for manager–director pairs that share multiple affiliations.

This multi-dimensional connectedness is analytically useful. It distinguishes a weak or coincidental link, such as attending the same large university, from a strong bond that spans several relationships. Using Atkin's Q-analysis, Chahine and Goergen (2013) measure tie strength by the number Q of types of ties shared. They show that IPO firms whose top management team and board are more strongly interlinked through multiple social ties tend to perform better at the IPO. By contrast, family ties, such as those between the CEO and a related director, are associated with weaker performance. Therefore, the type of tie matters: a multiplex of professional and social links can enhance alignment and information-sharing, whereas kinship links can undermine effective governance.

Theoretical network mechanisms and effects

Why and how do networks matter? Social network theory identifies several mechanisms through which a network's structure shapes behaviour and outcomes. Borgatti et al. (2009) highlight foundational mechanisms, i.e., adaptation, binding, and exclusion, alongside the broader process of diffusion or contagion within networks. In what follows, we review these mechanisms in more detail.

Adaptation mechanism: Social units, who are connected to the same third parties, often become more homogeneous in their behaviour and outlook as shared networks generate mimicry and common influence. For instance, if two CEOs are both tied to a powerful investor, they may align with that investor's expectations and ultimately make similar strategic decisions. This mechanism aligns with theories of peer effects and structural equivalence: social units occupying comparable positions in a network receive similar informational and normative inputs, which can lead to similar behaviour or common practices.

Binding mechanism: Direct social ties can bind social units into cohesive clusters that develop their own collective identity or norms. Within such dense networks, individuals may exhibit shared values or mutual obligations. This mechanism is particularly relevant to *ego networks* centred on one social unit. For example, if each of a CEO's contacts is connected to all the other contacts, thereby forming a closed network, the CEO is embedded within a bonded group that may act in concert. These cohesive structures can enhance trust and coordination but may also produce insularity or groupthink. A fully closed ego network has few structural holes, i.e., missing links between pairs of social units, to exploit but can indicate a powerful inner circle around the focal social unit. Figure 1 illustrates this mechanism, contrasting (a) a fully closed ego network with (b) one containing a few structural holes. A fully closed ego network has no missing links between pairs of units to exploit but can nevertheless indicate a powerful inner circle around the focal unit.

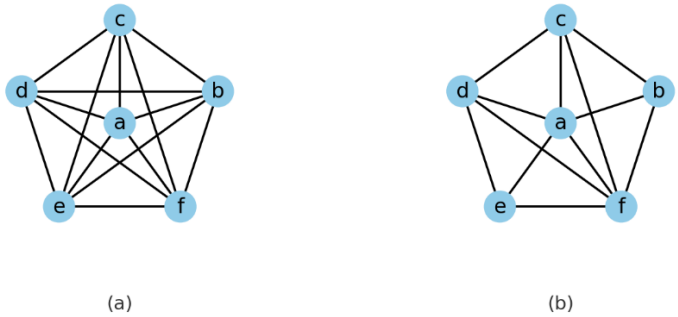

Figure 1: Ego networks illustrating the binding mechanism.

Panel (a) shows a fully closed ego network in which all nodes are connected to one another and to the ego, forming a cohesive clique. Panel (b) shows a similar network with a few missing ties among nodes, forming structural holes.

Exclusion mechanism: Networks can also generate bargaining power if certain social units are able to monopolise or restrict access to valuable connections. Consider a simple chain network with five nodes (a–b–c–d–e) (see Figure 2). While node c is at the centre of the network, nodes b and d possess greater bargaining power. Indeed, each of these two nodes controls access to one of the end nodes (i.e., a and e), which lack alternative partners. By leveraging their exclusive ties, b and d can form advantageous bilateral relations and effectively bypass c, leaving it isolated. In this example, power is not determined by centrality, but it depends on the availability of alternatives within the network. More generally, a node's influence arises from the structure of interdependence – power depends not only on one's own connections but also on the connectivity and options of the others. Consequently, changes in one part of the network can propagate widely, altering relationships and outcomes elsewhere.

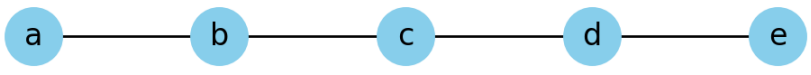

Figure 2: Chain network

A simple chain network of five nodes. Nodes b and d, each adjacent to an end node with no alternative partner, have greater bargaining power than the central node c. This example illustrates the exclusion mechanism: the central position within a network is not always the most powerful one if others can broker exclusive ties, thereby excluding that central node.

Underlying the mechanisms discussed above is the mechanism of *information diffusion*. Networks act as conduits through which information, ideas, practices, and even behaviours spread by imitation. In a corporate context, a well-documented example is the diffusion of governance practices or strategic approaches through interlocking directorates. When firms share directors, such individuals can transmit ideas from one boardroom to another. If Firm X adopts a new environmental, social, and governance (ESG) policy and one of its directors also sits on Firm Y's board, Firm Y may adopt the same policy. The process resembles epidemic contagion, except that the "virus" is a corporate practice or a strategic choice.

Empirical studies show that corporate policies, such as acquisition strategies, dividend policies, and executive compensation arrangements, often propagate through board network ties. Board directors with friendship or advisory links to the directors of other boards may imitate each other's approaches, consciously or unconsciously. The strength-of-weak-ties argument discussed earlier is fundamentally a diffusion mechanism: weak ties act as bridges that bring in non-redundant information from outside the immediate circle, whereas strong ties within a cohesive group tend to reinforce known information.

Ronald Burt's (1992) theory of structural holes extends this logic. Social units who bridge gaps between otherwise disconnected groups enjoy what Burt terms a vision advantage because they have access to novel information that others, confined to silos, do not have. Consistent with Burt's *brokerage mechanism*, managers whose networks span structural holes have their ideas more often judged valuable by colleagues and superiors (Burt, 2004). Yet, as Coleman (1988) argues, a closed network, whereby most social units are interconnected, also has benefits via the promotion of trust, cooperation, and norms enforcement. The two perspectives are therefore complementary: open networks maximise exposure to novel information, while closed networks promote cohesion and reliability. Effective governance and innovation often rely on maintaining a balance between the two. In what follows, we examine in more detail structural holes and the way they can be bridged by social units that assume a brokerage role.

Structural holes, bridges, and brokerage

Network position is defined not only by the number of connections a social unit holds but also by how those connections are arranged. Burt's (1992) theory of structural holes is based on the argument that gaps in the network, where ties between certain social units are absent, create opportunities for brokerage. A structural hole represents a missing connection between two clusters that could benefit from contact but remain unlinked. A social unit that connects both sides of this gap occupies a brokerage position, facilitating or mediating exchanges between otherwise separate groups. Such brokers gain access to novel or non-redundant information and resources that could otherwise not be accessed, allowing the brokers to combine ideas from different domains and exploit informational asymmetries. A venture capitalist who moves between distinct technological communities, or a director who sits on boards across unrelated industries, exemplifies this bridging advantage.

Burt (1992) operationalised his theory through two key measures: *effective size* and *network constraint*. Effective size represents the number of a person's contacts adjusted for redundancy, while network constraint increases when those contacts are themselves interconnected. For instance, if a person's contacts form a closed network where they are all connected to one another, the information flowing among them is likely to be redundant, increasing network constraint. In this highly interconnected scenario, the effective size of the person's network remains small regardless of the total number of contacts, as their ties largely convey similar local information and are therefore redundant. Low network constraint indicates sparse overlap among contacts and therefore greater brokerage potential. Studies in corporate finance have used these measures to examine how bridging positions affect firm outcomes. Research on board networks shows that firms with a lower average director constraint, implying that directors span more structural holes between companies, tend to perform better through more efficient operations and investment decisions. Such directors act as informational intermediaries, connecting otherwise isolated corporate groups and reducing organisational blind spots.

The advantages of brokerage, however, have limits. Excessive bridging can lead to volatility, coordination problems, or strategic incoherence. Firms whose executives span too many structural holes

may face conflicting demands or suffer from a lack of focus due to incompatible projects or perspectives. A moderate level of brokerage appears most beneficial, providing access to new information without undermining managerial cohesion. In contrast, Coleman (1988) emphasises the virtues of *network closure*, a dense and cohesive structure in which social units are highly interconnected. Closure fosters trust, facilitates norm enforcement, and strengthens reputation effects. Within corporate boards, closure may promote collective oversight and coordination but can also increase the risk of groupthink or collusion.

Brokerage and closure therefore represent two complementary forms of social capital. Open networks, i.e., networks that contain structural holes, enhance flexibility and access to novel information, while closed networks support reliability and cooperation. The optimal configuration often lies between these extremes. Empirical evidence from research reflects this balance: highly interlocked boards can become insular and self-reinforcing, while boards lacking any prior connections may suffer from weak cohesion. Moderate connectivity, sufficient to sustain trust, yet open enough to attract diverse insights, often yields the most effective outcomes.

Analytically, combining measures of structural holes with the position or centrality of a social unit within a network provides a multidimensional understanding of that social unit's prestige within the network. A CEO with many connections but also high constraint may be well connected yet embedded within a tightly knit circle that limits brokerage potential. Conversely, a CEO with fewer connections but very low constraint may bridge disparate groups, occupying a strategically valuable position. Recognising this distinction is crucial when assessing how network structures influence information flow, governance quality, and firm performance.

One-mode vs. two-mode networks

An important methodological choice in network analysis concerns whether to represent relationships as a one-mode or a two-mode structure. A one-mode network contains a single set of homogeneous social units, among which ties exist only within that set. Most empirical applications in corporate finance

adopt this approach. For example, a director–director network links two individuals who have served together on a board, while a firm–firm network connects companies that share a director or a significant shareholder. Such networks are intuitive and allow for the direct computation of centrality, distance, and clustering measures.

Renneboog and Zhao (2011) employ a one-mode network of UK directors to assess how central a CEO is within the web of interlocks and to examine how this position relates to firm behaviour. Similar studies show that firms occupying central positions in firm–firm networks tend to have greater exposure to information flows, such as merger and acquisition opportunities.

Many corporate and social relations, however, are inherently two-mode as they link two distinct sets of social units, such as people and organisations. A two-mode network explicitly represents these two sets of nodes and the ties between them. The board affiliation network is a common example: one set of nodes represents directors, the other represents firms, and a tie indicates that a director sits on a firm's board. In this network, directors are connected through shared boards, and firms are connected through common directors. The two-mode representation thus preserves the full affiliation structure.

Two-mode networks differ from multiplex ties mentioned earlier in that they connect different types of social units (e.g., directors and firms), whereas multiplex ties describe multiple types of relationships among the same set of units (e.g., firms linked simultaneously through directors, auditors, and analysts).

Formally, a two-mode network can be defined as $N = (U_1, U_2, R, w)$, where U_1 and U_2 denote the two node sets (for instance, directors and firms), $R \subseteq U_1 \times U_2$ represents the relations linking units across the two sets, and $w: R \to \mathbb{R}$ is an optional weighting function capturing the strength, frequency, or duration of ties. By definition, there are no links among nodes within U_1 or within U_2; all connections occur between the two sets.

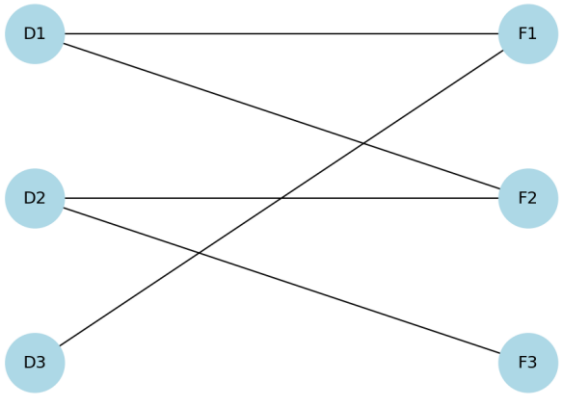

Figure 3: Example of a two-mode network (Directors–Firms)

Example of a two-mode network (bipartite graph) with two node sets: directors and firms. A tie indicates that a director sits on a firm's board. For instance, director D1 serves on the boards of firms F1 and F2, creating ties D1–F1 and D1–F2. This representation captures the affiliation structure directly, without collapsing it into one-dimensional director–director or firm–firm links.

Two-mode networks are common in corporate finance whenever individuals are affiliated with organisations, such as directors with boards, investors with firms, or banks with borrowers. These datasets have a bipartite structure linking two distinct node sets. For analytical convenience, researchers often convert a two-mode network into a one-mode network. The familiar "board interlock network" among firms, for instance, is a one-mode projection of the director–firm affiliation network: two firms are linked in the converted graph if they share one or more directors according to the original two-mode data.

This conversion is useful because it produces a direct firm–firm graph that can be analysed using standard network metrics. However, projections can obscure the strength of the connection. When two companies appear connected in an interlock network, the link may exist because they share a single director. The firms are not directly connected to one another but are connected through an intermediary. The interpretation therefore requires remembering the two-mode logic, as structural changes such as director turnover or mergers may alter or remove the link entirely. Researchers should be cautious not to infer relational properties that do not exist in the underlying data. In contrast, the original two-mode network enables the researcher to assess the strength or vulnerability of the link.

The principle that many one-mode links arise from underlying affiliations is long established in network analysis. The classic sociological study by Davis et al. (1941) on social event attendance among Southern women was originally a two-mode dataset (women–events) that became widely studied after projection into a one-mode co-attendance network. In corporate finance, Chahine and Goergen (2013) retained the two-mode structure to examine ties between members of the top management team (TMT) and board members within IPO firms, while weighting each tie by the multiple relations (e.g. same alma mater and same former employer) that may exist between each TMT member and director. In contrast, Renneboog and Zhao (2011) analysed a one-mode director network spanning multiple companies. Both approaches are valid but serve different purposes. Retaining the two-mode form allows explicit modelling of both node sets and supports specialised techniques such as Q-analysis, whereas projection to the one-mode form facilitates the use of conventional graph algorithms and centrality measures. Formal procedures for analysing two-mode data without projection are detailed by Doreian, Batagelj, and Ferligoj (2004) and are also reviewed once we have discussed centrality measures for one-mode networks.

Centrality measures for one-mode networks

A core question in the analysis of one-mode networks is who occupies the most central or influential position within the network. Centrality measures quantify different aspects of a node's structural importance and are widely applied in corporate finance to capture access to information, influence, and power within director, executive, investor, institutional, or corporate networks. Each of the following measures reflect a distinct dimension of prominence and connectivity.

Degree centrality: Degree centrality is the simplest measure, defined as the number of direct ties a node has. In a director network, it reflects the number of distinct colleagues a director is connected to across all boards on which they sit, while in a firm network it represents the number of other firms a firm is linked to through shared directors or alliances. Degree centrality can be interpreted as local popularity: social units with more connections have greater access to information and opportunities. In corporate settings, this often corresponds to an executive's network size or a firm's span of relationships.

Renneboog and Zhao (2014) find that firms with more board interlocks are significantly more active acquirers, suggesting that degree centrality increases exposure to deal opportunities and partner information.

Eigenvector centrality: Eigenvector centrality extends degree centrality by weighting connections according to the importance of their connections. A node scores high if it is connected to others who are themselves well connected. Computation proceeds iteratively by assigning each node an initial score of one, then updating its score as the sum of the scores of its neighbours, and normalising by the dominant eigenvalue of the adjacency matrix. The result identifies nodes that lie within the "core" of the network. In corporate contexts, this measure captures influence or prestige: a director or CEO linked to other central figures has a high eigenvector score. In contrast, a director with few connections or connections to other directors who are not well connected will have a low eigenvector score.

El-Khatib et al. (2015) use eigenvector centrality to represent a CEO's position within the executive–director network, finding that those connected to other powerful individuals hold positions of influence. This measure captures quality rather than quantity of ties, recognising that connections to key industry figures carry more weight than connections to peripheral social units. However, eigenvector centrality can be dominated by cohesive elite clusters (i.e., exclusive and dense subgroups of directors whose strong, mutual connections dramatically inflate their centrality score) and is best interpreted alongside other measures.

Closeness centrality: Closeness centrality reflects how near a node is to all others in terms of network distance. It is typically defined as the inverse of the total shortest-path lengths, the so-called *geodesic distances*, from the node under consideration to all other reachable nodes. A node with high closeness centrality can reach others through no or few intermediaries. In corporate terms, an executive with high closeness centrality might be a one or a few introductions away from any key decision-maker, implying efficient access to information and influence. High closeness thus signals global reach and speed of information diffusion.

Betweenness centrality: Betweenness centrality measures how often a node lies on the shortest path between other pairs of nodes. It identifies social units that serve as bridges or brokers within the network. A node with high betweenness connects otherwise separate clusters and can mediate or control the flow of information. In a corporate setting, directors sitting on the only board linking two clusters of firms would have high betweenness, as many communication paths run through them. This brokerage position is often associated with the concept of structural holes: social units who span gaps between disconnected groups have access to diverse information, potentially giving them bargaining power. Banks positioned between multiple client firms or directors linking business and policy communities exemplify this role.

Renneboog and Zhao (2011) distinguish between *direct centrality* (degree and eigenvector centrality), which they associate with managerial power, and *indirect centrality* (closeness and betweenness centrality), which they associate with informational advantages. They find that both types of centrality measures correlate with higher CEO compensation, but they imply different mechanisms: direct connections create entrenchment, whereas brokerage and reach confer informational benefits to the firm. Together, these measures provide complementary insights into how a network's structure shapes influence, opportunity, and control in corporate governance.

All standard centrality measures have normalised versions that adjust for differences in network size. A degree of ten, for instance, may indicate strong connectedness in a network of just twenty nodes but is trivial in a network of one thousand. Normalised degree centrality accounts for this by dividing by the maximum possible degree centrality $(n-1)$. Closeness is similarly scaled by the total geodesic distance between all nodes to ensure comparability across networks of different sizes.

In empirical applications, the choice of centrality measure should align with the theoretical mechanism that is being studied. When the focus is on prominence, status or power, or access to resources, degree or eigenvector centrality is typically appropriate. When the interest lies in information brokerage or control over communication channels, betweenness or related measures such as Burt's network constraint (discussed above) are more appropriate. Some studies combine multiple dimensions of

centrality to capture an overall measure of connectedness. For example, Miranda-Lopez et al. (2019) employ principal component analysis to construct a composite centrality index that summarises several metrics into a single connectedness factor.

The interpretation of centrality requires contextual understanding. High-centrality social units may indeed hold influence, yet centrality can also be an outcome rather than a cause of success. Prominent firms or executives might attract more connections precisely because of their past or current performance or reputation. Researchers should be aware of such endogeneity issues and exercise caution when drawing causal conclusions from centrality alone, ensuring that observed correlations are not mistaken for structural effects.

Q-analysis and two-mode networks

Q-analysis, introduced by Atkin (1974), was developed to analyse two-mode networks, where individuals are linked to groups, organisations, or events. Q-analysis uses concepts from algebraic topology to represent these overlapping affiliations as *simplices*, which are geometric objects that capture multi-node interactions in increasing dimensionality. A 0-simplex represents a single unconnected social unit, a 1-simplex a link between two units that share at least one affiliation, a 2-simplex a triangle among three units with at least one common affiliation, and a 3-simplex (or tetrahedron) four units jointly connected through shared affiliations. Figure 4 illustrates the structures of 0- to 3-simplices.

In two-mode settings, a simplex on the *backcloth* represents a set of social units sharing common affiliations, such as membership of the same board or professional club. For example, four directors sitting on the same board form a 3-simplex on that backcloth, while a trio of directors who are alumni of the same university form a 2-simplex. The dimension Q of a simplex equals one less than the number of social units it contains. Conversely, a simplex on the *traffic* represents the set of affiliations minus one belonging to a single individual. If a director belongs to three professional associations, these three affiliations form a 2-simplex on the traffic, all referring to the same director.

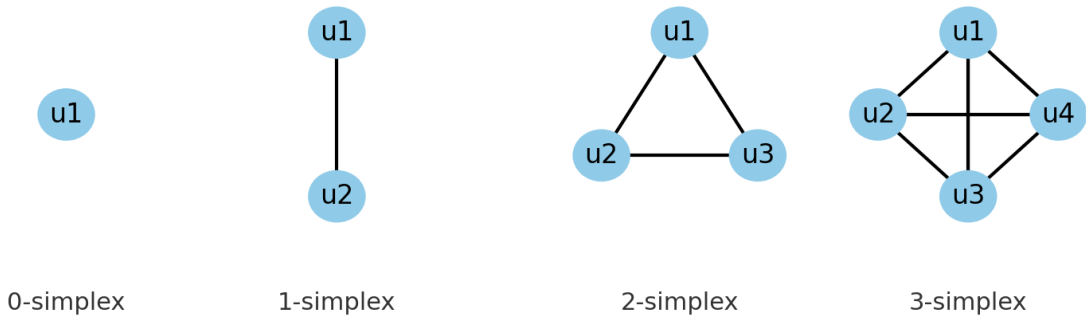

Figure 4: Building blocks of simplices in Q-analysis

This figure shows simplices ranging from a 0-simplex to a 3-simplex. The 0-simplex corresponds to a single unconnected unit, the 1-simplex to two connected units, the 2-simplex to three units sharing a common affiliation, and the 3-simplex to a tetrahedral configuration formed by four jointly connected units.

Q-analysis examines how these simplices intersect through shared subsets or "faces." This allows researchers to identify high-order structures that extend beyond pairwise connections. The method captures how social units are linked through potentially multiple overlapping affiliations, providing a richer view of cohesion within the network. In corporate finance, this is valuable if individuals or firms are connected through multiple shared experiences. Two executives who attended the same university, worked at the same company, and belong to the same professional club would, for example, form a 2-simplex based on these three affiliations. If a third executive shares two of those affiliations, their simplices overlap, forming a *simplicial complex* that reflects higher-order connectivity.

In practice, Q-analysis generates measures of multi-dimensional connectivity. Chahine and Goergen (2013) apply this framework to IPO firms, defining each type of social tie (such as alma mater, club, or prior employment) as a distinct affiliation. They compute a *Q-score* for each executive–director pair that reflects the number of types of ties shared. A pair with $Q = 1$ (for example, common alumnus status and previous employment) is more strongly connected than one with $Q = 0$ or just one connection. Using these Q-scores, they measure the dimensionality or the strength of the social ties between the TMT, defined as all top-level executives regardless of whether they also hold board seats,

and the board members. Effectively, this makes their two-mode network a weighted two-mode network. They examine how the strength of this TMT–board connectivity affects firm performance at the IPO. Their findings suggest that higher-dimensional social connectivity between the TMT and the board is associated with superior IPO performance, likely due to improved information flow and coordination. By contrast, family ties, although forming connections, are negatively related to IPO performance.

Follow-up work by Chahine and Goergen (2014) reveals that, for IPO firms, strong social networks enhance pay–performance sensitivity, aligning managerial interests with those of the shareholders. In contrast, studies of mature firms (e.g., Hwang & Kim, 2009) suggest that similar social ties can entrench managerial power and reduce their incentives to create shareholder value. The evidence thus indicates that the effects of networks depend on the context: in new ventures, the existence of several connections may promote trust and cohesion, while in established firms they may foster complacency and lack of monitoring of the executives by the board. Q-analysis, by capturing the dimensional richness of social connections between individuals, offers a rigorous way to quantify these differences and enables researchers to control for relationships that vary in depth and complexity rather than using simply binary links between individuals.

Measurement choices and considerations

Performing network analysis in corporate finance involves a series of measurement decisions in relation to both the structure of the network and the interpretation of the results. The first decision is about defining what constitutes a tie within the given context. For a board network, for instance, a tie might be based on shared board membership, but one must decide whether to count only concurrent service or any past overlap. Requiring a minimum duration, such as at least one year of joint service, changes the density and meaning of the resulting network. Similar choices apply to other relationships, such as past employment, shared education, or investment syndication.

Tie weighting is another consideration. Ties can be binary, indicating the mere presence of a single tie, or can be weighted to reflect intensity, frequency, or duration. In firm–firm networks, ties may be

weighted by the number of shared directors or total years of overlap, while in bank–firm networks weights may capture loan frequency or size. Multiplex ties, discussed earlier, can be represented as separate network layers or aggregated into a single weighted tie depending on whether different types of ties convey distinct or overlapping information.

The appropriate level of analysis is another key decision. Corporate networks can be examined at either the director or the firm level. When studying director networks, centrality can be computed for each director. However, if the research question concerns firm-level outcomes, the director-level measures must be aggregated. One common approach is to calculate the mean or maximum centrality of all directors on a given board, yielding a firm-level indicator of board connectedness. The mean captures the overall network integration of the board, while the maximum reflects the presence of a particularly well-connected individual. Bianchi et al. (2022) and Renneboog and Zhao (2020) aggregate individual-level network measures into firm-level variables to examine how board centrality relates to CEO turnover and performance. The choice between mean and maximum has substantive implications, distinguishing between a board that is collectively well connected and one that is dominated by a single influential “rainmaker.”

Normalisation and scaling also matter. Centrality values often need to be normalised by their theoretical maximum or by network size to ensure comparability across time or samples. For example, a degree centrality of ten is relatively high in a network of only twenty nodes but trivial in a network of one thousand. Many network measures are also highly skewed, with a few nodes exhibiting extreme centrality. Researchers therefore often use the logarithm or rank of centrality rather than its raw value.

A further decision relates to the identification strategy. Network positions are not randomly assigned and may reflect unobserved characteristics or reverse causality. For example, a CEO may become highly connected because of prior success rather than prior connections causing success. To address this, researchers may use lagged network variables, instrumental variables, or natural experiments. Miranda-Lopez et al. (2019) instrumentalise board centrality using the average centrality of peer firms within the same industry, arguing that industry-level connectedness is plausibly exogenous to an

individual firm's outcomes. Others apply panel fixed effects or difference-in-differences designs when shocks reconfigure networks, such as through the sudden death of a central social unit. These strategies aim to separate the effects of network structure from underlying firm quality or reputation.

Conclusion

This chapter introduced the main concepts of social network analysis and demonstrated how they have been applied in corporate finance research. It outlined the concepts of nodes, ties and centrality, showing how the structure and position of social units affect information flow, coordination, and decision-making. It also explained how networks can be represented in one-mode or two-mode forms, each capturing distinct dimensions of relationships, and described how Q-analysis extends these ideas to higher-order affiliations and group structures.

In many instances, network analysis provides a richer level of analysis than the analysis that results from studying firm-level attributes in isolation. Researchers aiming to utilise network analysis should begin with a clear mechanism, justify tie definitions and weighting schemes, choose the appropriate level of analysis, apply suitable normalisation and adopt the right identification strategies. If designed correctly, network analysis can serve as a valuable tool in the researcher's analytical arsenal.

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Ali Bayat is a researcher in the fields of corporate governance and corporate finance. He earned his MSc and PhD in Business Management from Alliance Manchester Business School and has served as an Assistant Professor of Business Management at the University of Aberdeen since 2018. His research focuses on topics such as corporate governance, CEOs, corporate boards, ESG and sustainable finance, and corporate decision-making. Ali's work has been published in international journals, including the *Journal of Corporate Finance* and the *Journal of Banking & Finance*.

Marc Goergen holds a DPhil in Economics from Oxford University, a master's degree from Solvay Business School, and a bachelor's degree in economics from the Université Libre de Bruxelles. He is a full professor of finance at IE Business School, IE University, in Madrid. Previous appointments include UMIST and the Universities of Cardiff, Manchester, Reading and Sheffield. Marc is a visiting professor at the University of Vaasa, an Honorary Professor at Cardiff Business School, a Research Member of the European Corporate Governance Institute (ECGI), and a board member of the International Corporate Governance Society (ICGS). He is an associate editor of the British Accounting Review, the British Journal of Management, and the European Journal of Finance. Marc's research interests lie at the intersection of corporate finance and corporate governance. His research papers have appeared in top academic journals, such as *Entrepreneurship Theory and Practice*, the *Harvard Business Review*, the *Journal of Business* Ethics, the *Journal of Finance*, the *Journal of Financial Intermediation*, and the *Journal of Corporate Finance*. His research has also been covered by The Financial Times, The Times, and WirtschaftsWoche. The second version of his successful textbook "Corporate Governance. A Global Perspective" was published by Cengage in 2018.

Luc Renneboog is a professor of corporate finance at Tilburg University. His research interests span corporate finance, corporate social responsibility, law and economics, household finance and health economics, and cultural (art) economics. He graduated with degrees in business engineering (BSc, MSc) and philosophy (BA) from the Catholic University of Leuven, with an MBA from the University of Chicago, and a PhD in financial economics from London Business School (Univ. of London). Prior to joining Tilburg University, he was on faculty at the Universities of Leuven and Oxford, and held visiting positions at Cambridge University, HEC Paris, and London Business School. He has

published in the *Journal of Finance*, *Journal of Financial Economics*, *Review of Financial Studies*, *Review of Finance*, *Journal of Financial and Quantitative Analysis*, *Journal of Accounting Research*, *Management Science*, *Organization Science*, *Strategic Management Journal*, *Journal of International Business Studies*, *American Economic Review*, *European Economic Review*, *Journal of Law and Economics*, *Journal of Corporate Finance*, *Journal of Financial Intermediation*, *Journal of Business Ethics*, etc.

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