COMBINING NETWORK THEORY WITH CORPORATE GOVERNANCE: CONVERGING MODELS FOR CONNECTED STAKEHOLDERS

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Abstract

Traditional corporate governance patterns are based on the interaction among composite stakeholders and the various forms of separation between ownership and control. Stakeholders cooperate around the Coasian firm represented by a nexus of increasingly complex contracts. These well-known occurrences have been deeply investigated by growing literature and nurtured by composite empirical evidence. Apparently, unrelated network theory is concerned with the study of graphs as a representation of (a)symmetric relations between discrete objects (nodes connected by links). Network theory is highly interdisciplinary, and its versatile nature is fully consistent with the complex interactions of (networked) stakeholders, even in terms of game-theoretic patterns. The connection between traditional corporate governance issues and network theory properties is, however, still under-investigated. Hence the importance of an innovative reinterpretation that brings to “network governance”. Innovation may, for instance, concern the principal-agent networked relationships and their conflicts of interest or the risk contagion and value drivers – three core governance issues. Networks and their applications (like blockchains, P2P platforms, game-theoretic interactions or digital supply chains) foster unmediated decentralization. In decentralized digital platforms stakeholders inclusively interact, promoting cooperation and sustainability. To the extent that network properties can be mathematically measured, governance issues may be quantified and traced with recursive patterns of expected occurrences.

Keywords: Adjacency Matrix, Big Data, Supply Chain, Digital Platform, Hub, Node, Artificial Intelligence, Blockchain, Decentralization, Game Theory, Theory of the Firm, Value Co-creation, Social Media, Circular Economy, B2B, B2C, P2P

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1. INTRODUCTION

Corporate governance issues and the interactions among composite stakeholders may well be represented and interpreted in graphical terms, connecting stakeholding nodes (vertices) with their interactions (links or edges).

Even though both corporate governance and network science are well-grounded theories, their possible connections have been hardly investigated.

To the author's best knowledge, there are few specific studies about their joint analysis (the issue is partially addressed in Vermeulen, 2015 and in Bonacina et al., 2015). The research is so original and may ignite a new literature strand.

Consistently with this conceptual framework, the research question of this study is concerned with the (innovative) possibility to represent the interactions among stakeholders – a core corporate governance concern – through network patterns and their (mathematical) properties.

Each stakeholder represents a node that is linked through edges with other nodes. Nodes have different degrees of (hierarchical) importance, and pivoting stakeholders are the bridging vertices that connect a higher number of other stakeholders and vehiculate more "traffic" (information, decisions, transactions, etc.). Network theory may so represent the corporate governance interactions among composite stakeholders (both inside and outside the firm) in a complementary way, using an innovative interdisciplinary approach.

The expression "network governance" has already been used by Jones et al., 1997, referring to some interaction between transaction cost economics and social network theories. Assens and Lemeur (2016) show that to minimize uncertainty, enterprises try to organize their partner relationships into a network, in which the principles of trust and reciprocity prevail. By definition, a network is a collaborative structure, which depends neither on the market nor on the hierarchy. The perimeter of this study is, however, wider, as it considers further aspects (reported in the list below) that are traditionally included in the corporate governance perimeter of investigation.

To the extent that networks can be expressed in mathematical terms, through adjacency or incidence matrices, interactions among stakeholders may be measured, especially if they follow recursive patterns that may be interpreted with artificial intelligence through specifically designed algorithms.

The main corporate governance issues that can be interpreted using network theory may, for instance, concern:

1. Diffused versus concentrated ownership structure, and the consequent links between many or few "nodes" of shareholders with the firm and the other stakeholders;
2. Large versus fragmented creditors (the former represent bridging nodes with intense relationships with the firm and other smaller and scattered nodes);
3. The link between the (listed) firm, its stock market, and the worldwide markets, each representing a node correlated to the others;
4. A reinterpretation of the theory of the firm as a Coasian nexus (network) of contracts;
5. The spread of information among networked stakeholders;
6. Value creation with digital scalability, where intangible nodes grow exponentially, increasing the value of the network;
7. Value destruction due to (strategic) node deletion;
8. Interfirm coordination;
9. Interlocking directorship among board members of different firms;
10. The impact of network analysis and game theory on interactive agents;
11. Digital platforms that represent a "virtual" (intangible/figurative) stakeholder.

Network theory is important as an additional explanatory factor of corporate governance (this being the main research question of this study).

It is also worth investigating since it is likely to disrupt, together with digital platforms, artificial intelligence, and blockchains, traditional (analogic) business models. The impact on corporate governance (Brennan et al., 2019), albeit still under-investigated, is also likely to be meaningful.

The study is organized as follows: after an introductory section about network theory, the primary governance points will be synthetically analyzed, with emphasis on the open issues that are closer to a "networked" interpretation.

A discussion with indications for future research and some critical considerations precedes the concluding remarks.

2. NETWORK THEORY

Network theory (Barabási, 2016) is the study of graphs as a representation of either symmetric relations or asymmetric relations between discrete objects. In computer science and network science, network theory is a part of graph theory: a network can be defined as a graph in which nodes and/or edges have attributes (e.g., names).

An interdependent network is a system of coupled networks where nodes of one or more networks depend on nodes in other networks. Such dependencies are enhanced by developments in modern technology. Dependencies may lead to cascading failures between the networks, and a relatively small failure can lead to a catastrophic breakdown of the system (as shown in Section 7). Blackouts are a demonstration of the important role played by the dependencies between networks.

Networks represent a fundamental characteristic of complex systems whose connected structure may give an innovative interpretation of the interactions among (linked) stakeholders.

Network theory has applications in many disciplines, including statistical physics, particle physics, computer science, electrical engineering, biology, economics, finance, operations research, climatology, ecology, and sociology. Applications of network theory include logistical networks, the World Wide Web, Internet, gene regulatory networks, epidemiology, metabolic networks, social networks, epistemological networks, etc.

A scientific methodology often used in network theory is represented by induction: what can be shown for small networks may be intuitively extended to other networks (Estrada & Knight, 2015, p. 34). Pollination of well-established network theory applications (e.g., physics, computer science, electrical engineering, biology, epidemiology, climatology, etc.) may well address corporate governance issues with an interdisciplinary approach.

The links of a network can be directed or undirected. Some systems have directed links, like the www, whose uniform resource locators (URL) point from one web document to the other, or phone calls, where one person calls the other. Other systems have undirected links, like transmission lines on the power grid, on which the electric current can flow in both directions. A network is called directed (or digraph) if all its links are asymmetric, and cause-effect relationships are only one-way; it is called undirected if all its links are symmetric (one-to-one). Some networks simultaneously have directed and undirected links.

Most relationships in corporate governance are bi-directional and so undirected.

A vital property of each node is its degree, representing the number of links it has to other nodes. The degree is an important parameter even in corporate governance, as it identifies the connections among stakeholders and their intensity. Edges among nodes (i.e., stakeholders) represent (Estrada & Knight, 2015):

- Physical links (pairs of nodes can be physically connected by a tangible link);
- Physical interactions (connection determined by a physical force);
- Ethereal (intangible) connections (information or other immaterial links);
- Geographic closeness between nodes;
- Social connections (friendship, collaboration, family ties, etc.);
- Functional linking (actions that activate other activities).

Nodes may not be directly linked by an edge but still have some bridging relationships, through a walk (trail) among distinct edges.

The study of degree distribution is particularly suited to the analysis of complex networks (Estrada & Knight, 2015, p. 95).

Scale-free networks are consistent with corporate governance patterns and with the presence of hubs represented by pivoting stakeholders (large creditors; managers; key shareholders, etc.). Once the hubs are present, they fundamentally change the system's behavior.

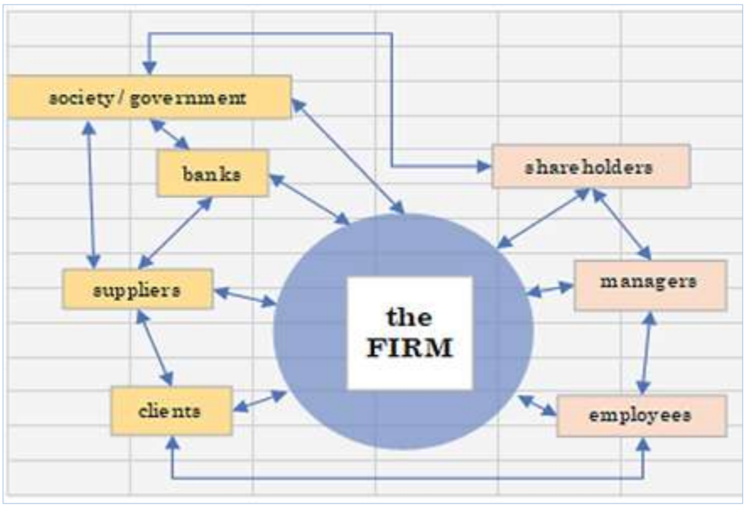
Networks can be interpreted in both static and dynamic terms that represent their evolution and may also be used for predictive purposes. Evolving networks can predict the growth rate of a node that may depend on its age and contribute to the interpretation of dynamic governance issues.

Another important concept is represented by internal links. In many networks, new links not only arrive with new nodes but are added between pre-existing nodes. For example, most new links on the www are internal links, corresponding to newly added URLs between pre-existing web documents. Similarly, virtually all new social/friendship links form between individuals that already have other friends and acquaintances.

Internal links represent an essential feature of the firm that has a strong bulk of inside stakeholders that are closely tied among them, with further links to other external stakeholders.

Figure 1 shows how internal and external stakeholders interact around the company that represents the pivoting hub.

Figure 1. External vs. internal stakeholders



2.1. Social networks

Social network analysis examines the structure of organizational networks and relationships between social entities that can be represented by interacting stakeholders.

(Social) networks are often used to interpret the behavior of communities. The employees of a company are more likely to interact with their co-workers than with employees of other companies. Consequently, workplaces appear as densely interconnected communities within the social network. Communities can be detected with hierarchical clustering that is based on a similarity matrix that measures the distance between two nodes. Communities can be dense or sparse, are typically overlapping and they have communicating and clustering links. Communities in social networks tend to be nucleated around strong ties that may be represented by hubs. These properties have evident governance implications.

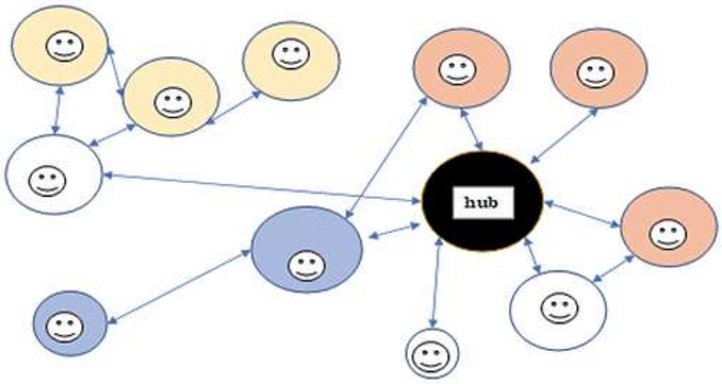
Assortativity (assortative mating) is a preference for a network's nodes to attach to others that are similar. Though the specific measure of similarity may vary, network theorists often examine assortativity in terms of a node's degree. The addition of this characteristic to network models approximates the behaviors of many real-world networks. Assortative mating reflects the tendency of individuals to date or marry individuals that are similar to them. In assortative networks, hubs tend to connect to other hubs and small-degree nodes to similar nodes. In a network environment, we can also encounter the traditional assortativity, when nodes of similar properties link to each other.

Correlations between nodes of similar degree are often found in the mixing patterns of many observable networks. For instance, in social networks, nodes tend to be connected with other nodes with similar degree values. This tendency is referred to as assortative mixing, or assortativity. On the other hand, technological and biological networks typically show disassortative mixing, or disassortativity, as high degree nodes tend to attach to low degree nodes (Newman, 2002).

In assortative networks, nodes of comparable degree tend to link to each other: small-degree nodes to small-degree nodes and hubs to hubs. In neutral networks, nodes link to each other randomly. In disassortative networks, hubs tend to connect to small-degree nodes and small-degree nodes to hubs. Social networks are assortative, and stakeholders typically behave accordingly.

Figure 2 shows an example of stakeholders (whose different colors represent an example of their belonging to specific clusters, e.g., suppliers) that interact following a social network pattern. Dyadic and triadic relationships become multi-sided thanks to the belonging to the systemic network. The (black) hub is represented by the networking firm, consistently with Figure 11.

Figure 2. Interaction among users of a social network

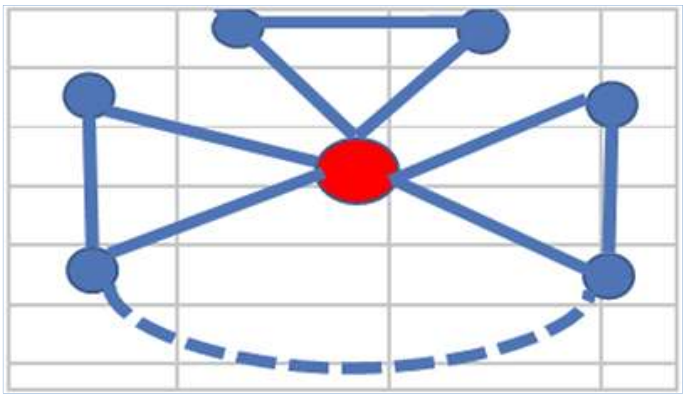


2.2. Clustering networks

Many real-world networks are characterized by the presence of a relatively large number of triangles.

A network formed by triangles joined at a central node (Estrada & Knight, 2015, p. 103) can be represented in Figure 3. Each triangle represents a theoretical cluster where a class of stakeholders (e.g., suppliers, clients, managers, and other employees, etc.) synergistically interact around the hub firm that constitutes the bridging node. Supplier network issues have been analyzed, for instance, in Hernawati and Surya (2019). Connections between each cluster are typically mediated by the firm.

Figure 3. Clustering triangular networks



This representation is consistent with a firm (hub at the center) and its stakeholders that can be grouped in converging triangles, each representing a category (shareholders, managers, employees, etc.). Adjacent triangles may well be linked among them.

3. DIFFUSED OR CONCENTRATED OWNERSHIP STRUCTURE? PUBLIC COMPANIES VERSUS FAMILY BUSINESSES

The ownership structure considers two corner solutions where shareholders are either diffused (mainly in listed public companies) or concentrated in family businesses. The number of the shareholders (each representing a node) and the links among them and with other stakeholders are entirely consistent with network theory.

Diffused ownership is typical of large corporations that are listed and are characterized by a high degree of separation between ownership and control: atomized shareholders act like principals that delegate the management of the firm to professional agents.

In family businesses, principals and agents tend to overlap and, in many cases, coincide.

Internal ties are stronger within the family firm, whose dimensions are typically smaller than that of public companies. The obsession of keeping control under the family limits growth opportunities. Under a network theory interpretation, this is a case where dominating hubs, expressing the control over the company, are willing to persist over time, up to the point of limiting any expansion of the family firm network. Cohesion and concentration of ties may prevail over the sharing with external value co-creators. This model may be challenged by trendy business models that reshape companies around their customers, decentralizing its barycenter.

Diffused ownership in public companies can be interpreted in terms of networking links among stakeholders (nodes), without (Figure 4) or with (Figure 5) the intermediation of institutional investors. Professional investors often act as proxy-collectors, concentrating the voting power and acting as a networking hub linked to otherwise uncorrelated nodes.

Figure 4. Networking stakeholders in a public company

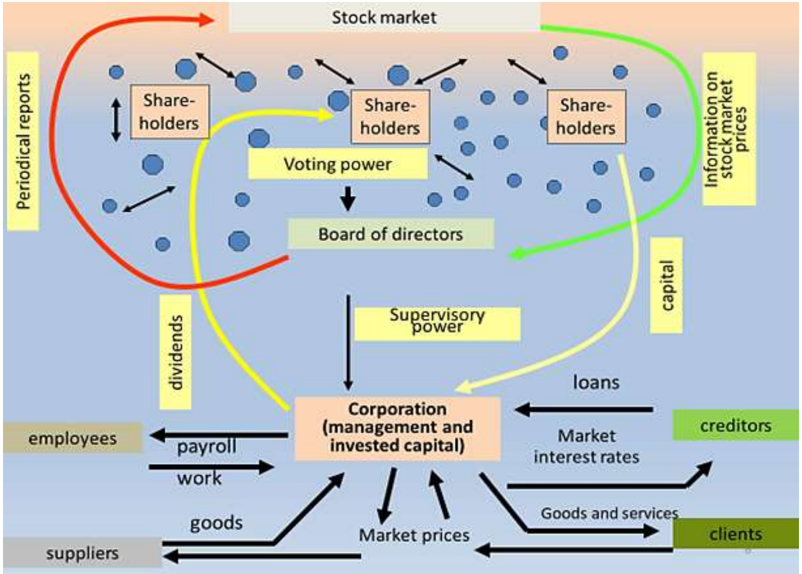
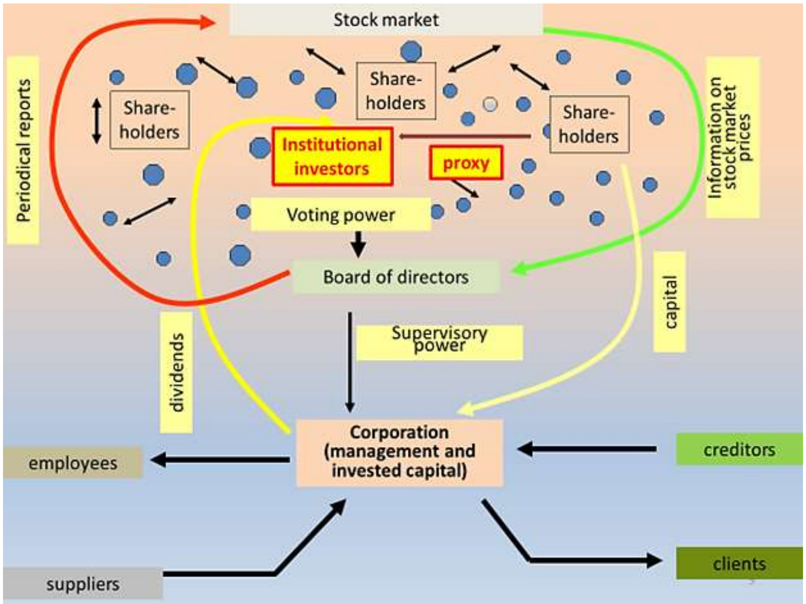


Figure 5. Institutional investors (proxy-holders) in a public company



Family businesses or even public companies may be part of a group that can be pyramidal or take the shape of a "comb" and develops horizontally, as shown in Figures 6 and 7. In the former case, there is stock leverage, according to which the ultimate shareholders of the holding company minimize the equity-holding necessary to control the operating companies. This brings to well-known opportunistic behaviors.

Both structures can be conceived in terms of networks, where each firm is the node, and shareholdings represent the edge.

Figure 6. Pyramidal group

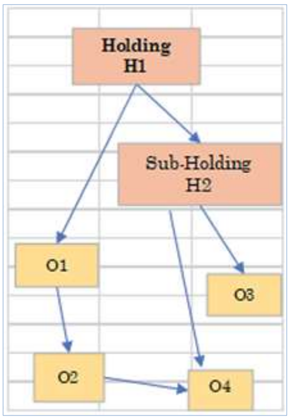
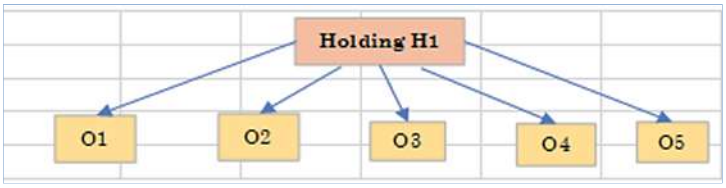
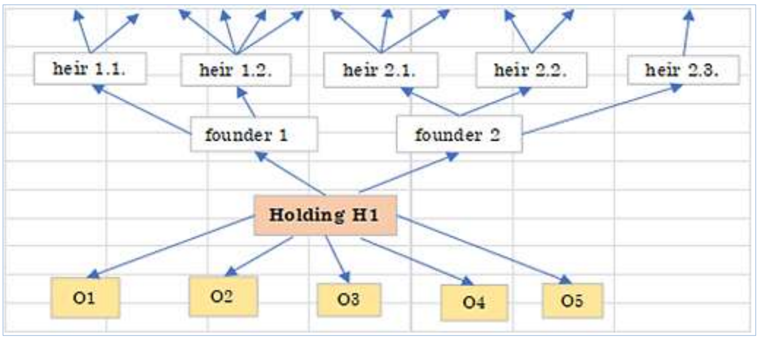


Figure 7. Horizontal group



Shareholders are fragmented in family businesses that get articulated along with generations, for inheritance reasons. Common control can be kept through unifying holding companies that are positioned at the vertex (hub node) of the group. If the tree ramification of the family grows above the holding company, then control over the operative firms is preserved, as shown in Figure 8. Trees are graphs lacking cycles, and they are rooted if they have a single vertex (van Steen, 2010; Chapter 5), for instance, represented by the holding company that serves as a bridging hub, concentrating otherwise dispersed shareholders.

Figure 8. Ascendant generational ramification (preserving the "hub/bridging" node - holding company)



Group companies may be represented by articulated networks in the case of the interlocking Japanese keiretsu or the Korean chaebol (Han, 2016), synthetically recalled in Section 8.

The separation of ownership from control is a classic corporate governance concern. As Tirole (2006, p. 15) points out "in 1932, Berle and Means wrote a pathbreaking book documenting the separation of ownership and control in the United States. They showed that shareholder dispersion creates substantial managerial discretion, which can be abused. This was the starting point for the subsequent academic thinking on corporate governance and corporate finance". Shareholder dispersion may well be explained and mapped with network theory.

4. CORPORATE GOVERNANCE AND THE FINANCIAL MARKETS

When a firm is listed, its ownership is diffused (see Section 3), and the market value of its shares reflects the stock market price. The market price of the firm is sensitive to the domestic stock market that hosts the firm, and the sensitivity parameter is expressed by the beta (β) of the listed stock against the volatility of the market.

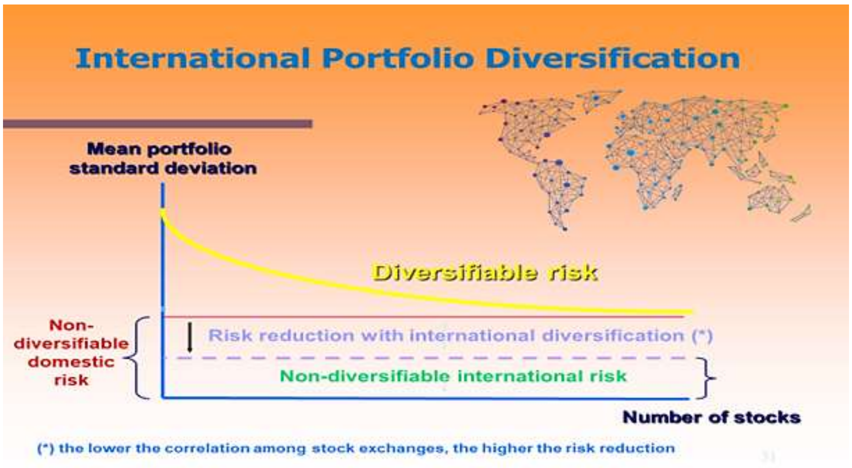
But stock markets are also linked among them and so the intrinsic volatility of each market is transmitted to other markets through their correlation: the higher the correlation, the bigger the risk-sharing through contagion.

The interactions between the listed firm and the other firms of the same (domestic) market contribute to the overall market volatility. Interconnectivity among stock markets brings to overall volatility (systemic risk) that cannot be further reduced through international diversification.

These well-known properties can be interpreted in network terms that represent the macro-links between the stock exchanges and the micro-links within domestic stock markets. Spreading phenomena and epidemic modeling of contact networks can explain the propagation of risk among different stock markets.

Figure 9 contains an example of the link between a networked world's map and the impact of international portfolio diversification on diversifiable and idiosyncratic risk. This is consistent with an interpretation of the volatility and correlation among the global stock markets that might be explained using network theory (Baumohl et al., 2018).

Figure 9. International portfolio diversification



Connections among firms may have undesired side-effects when they propagate risk. Contagion works at a macro level, for instance, through the interaction of stock markets whose correlation (that is increasing due to globalization) is a transmission factor of volatility sharing. At a meso or micro level, a domino effect propagates risk among different firms, especially in sensitive industries (like the financial sector, where defaults may quickly become systemic, as shown in Section 7).

Contagion is eased by systemic networking that, in this case, shows its negative externalities. Increased globalization, even due to technological advances that make communication easier and faster, fosters correlation and so transmission of volatility.

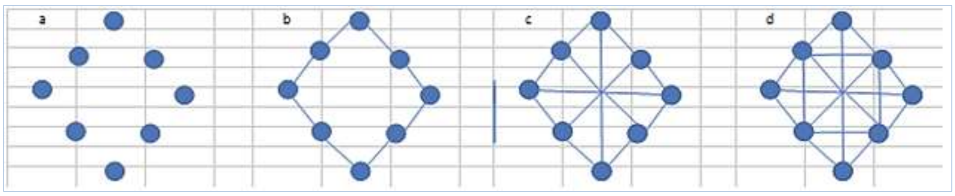
Governance consequences may be relevant. Within this framework, technology is a double-edged sword that may reduce information asymmetries but also increase the speed of contagion, fake news, and overreaction.

5. THE FIRM AS A COASIAN NEXUS (NETWORK) OF CONTRACTS

The firm can be considered as a nexus of contracts both internally, so justifying in a Coasian way its very existence, and externally, should agreements with third parties be considered within a broader framework.

This interpretation is entirely consistent with the network theory since nexuses are the links among different nodes (here represented by composite stakeholders, in a multilayer framework). Consider an initial situation where there is no firm. Each node represented by a blue circle can have different links with the others. Figure 10 shows an increasingly linked framework where the network (a) is initially empty (since there are no links among the different nodes) and then becomes increasingly linked with more and more edges (b → c →d).

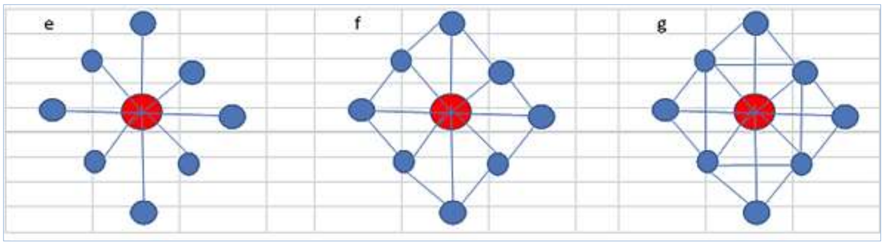
Figure 10. Network (without a firm)



A different situation occurs when, at the center of the "crossroad" among the different nodes, there is a hub represented by the firm.

Nodes are increasing. In the situation represented by (e) in Figure 11, the hub is the only pivoting entity: each stakeholder must pass through the hub to communicate with another node; in situation (f) or (g) nodes are also (increasingly) linked among them, without necessarily passing through the hub.

Figure 11. Network with a hub firm



From Figures 10 and 11, it intuitively appears that the hub/firm adds value to the whole network. This may be considered a "graph-theory" interpretation of the theory of the firm.

Blockchains are likely to reshape networking interactions. The blockchain is a decentralized and distributed digital ledger that corresponds to an open database with a pattern of sharable and unmodifiable data that are sequenced in chronological order, following a networked pattern.

Due to their decentralization characteristics, they may reduce the importance of concentrating (monopolistic) hubs. Governance consequences are many: they can help promote transparency, build trust and reputation, and enhance efficiency in transactions, reducing information asymmetries and moral hazard (di Prisco, 2019).

Corporate governance structures and firms connected through digital platforms become decentralized, unmediated (Fenwick et al., 2017), and interconnected. Networks are frequently horizontal, open, and autonomous: the way stakeholders interact is profoundly reshaped, with disruptive governance consequences:

- vertical hierarchies (typical of family businesses or multinational firms) are replaced by sharing mechanisms;
- stewardship changes accordingly and is replaced by horizontal cooperation among interacting stakeholders;
- personalized consumer experience increasingly matters in unmediated transactions;
- relationships become flat and inclusive;
- peer-to-peer transactions replace traditional supply chain patterns.

Nexuses of contracts are also consistent with supply and value chains, where stakeholders interact to co-create shared value. These aspects will be synthetically examined in Sections 9 and 12.

External nexuses of contracts typically involve synergic stakeholders, linked to the firm with pass-through contracts or other cooperation agreements. While stakeholders always include shareholders, they are also represented by debtholders, clients, suppliers, workers, and public authorities, up to the civil society surrounding the company and interested in its well-being.

Vertical integration represents a well-known form of networked cooperation, within the "make it or buy" strategic decision that stands out as one of the essential elements of the theory of the firm, as illustrated by Williamson (1985), Holmstrom and Tirole (1989), and Hart (1995, Part I). In microeconomics, vertical integration describes a management control system where a common owner controls companies within a vertical supply chain. The specialization of each firm within the vertical value chain allows a synergic combination of products and services, cementing upstream buyers with downstream suppliers.

The value chain is consistent with the networking stakeholders that rotate around it.

The Coasian rationale behind the ontological existence of the firm, considered as a nexus of contracts, may tentatively be extended to a wider framework where the firm is analyzed within its broader legal "web". The internal nexus of contracts may so be expanded to consider also external legal agreements. The firm is the "glue" that brings together many heterogeneous stakeholders.

The Coasian theory of the firm is linked to transaction economics. Ketokivi and Mahoney (2017) ask some critical questions about the issue: "Which components should a manufacturing firm make in-house, which should it co-produce, and which should it outsource? Who should sit on the firm's board of directors? What is the right balance between debt and equity financing? These questions may appear different on the surface, but they are all variations on the same theme: how should a complex contractual relationship be governed to avoid waste and to create transaction value? Transaction Cost Economics is one of the most established theories to address this fundamental question".

The concept of node centrality (Estrada & Knight, 2015, Chapter 14) is used in the determination of the most critical nodes in a network, acting as hubs. Their characteristics include the ability to communicate directly with other nodes, their closeness to other nodes, and their role to act as a communicator between different parts of a network. Usefulness – up to indispensability - of central nodes is entirely consistent with the Coasian nature of the firm as a nexus (network) of contracts and ties among composite stakeholders.

Degree centrality measures the ability of a node to communicate directly with others, this being a founding characteristic of the firm. Firms also have a closeness centrality, having the shortest path distance with other nodes represented by surrounding stakeholders. Furthermore, firms are characterized by their betweenness centrality that represents a vital communication node between other pairs of nodes. Closeness to other nodes is important even in terms of higher influence.

Communities in networks (Estrada & Knight, 2015, Chapter 21) represent an explanation of the organization of nodes in complex networks. Communities are groups of nodes more densely connected amongst themselves than with the rest of the nodes of the network. Communities may be represented by social networks (see Section 2.1) and may be magnetized by hub-nodes represented by the firm that clusters stakeholders with its gravitational centrality.

The firm is seen as a contract among a multitude of parties (Holmstrom & Tirole, 1989), and this vision is consistent with an interaction of networked stakeholders.

6. THE SPREAD OF INFORMATION (BIG DATA) AMONG NETWORKED STAKEHOLDERS

Communicability accounts for the volume of information transmitted from one node to another in a network by using all possible routes (direct links, paths, trails, etc.) between them. Shorter linking routes are given more weight than longer ones (Estrada & Knight, 2015, Chapter 19).

Information asymmetries – a key concept in corporate governance and a primary source of conflicts of interest among stakeholders – arise when communicability is interrupted or non-existent and are more frequent in directed networks, where information flows are not reciprocal between two connected nodes.

Information asymmetries traditionally arise in a corporate governance context where borrowers have better information about their creditworthiness than the lending bank. They originate conflicts of interest that might seriously prevent an efficient allocation of finance: the liquidity allocation problem derives from the fact that although money is abundant, it is nevertheless not easy to give it to the right and deserving borrowers. Managers, for instance, incorporate informative privileges that are discounted with other stakeholders (Myers, Majluf, 1984), increasing the cost of capital and eventually destroying value.

Adverse selection is another typical problem in money lending, and it occurs when banks – not knowing who is who – cannot easily discriminate between good and risky borrowers, who should deserve higher interest rate charges.

Moral hazard is a classical "take the money and run problem" since borrowers might try to flee with the bank's money or try not to fully engage them in the project for which they have been financed.

These classical corporate governance problems are well-known in traditional banking and they naturally bring to sub-optimal allocation of financial resources. The consequent capital rationing problems frequently affect potentially sound borrowers, if they are not able to differentiate themselves from those who bluff. The theory of signaling states that information asymmetry between a firm and outsiders leads the former to make specific changes in its capital structure. Ross (1977), Myers & Majluf (1984), and John (1987) have shown that under asymmetric information, firms may prefer debt to equity financing.

Information is conveyed through interactive networks, and so its representation and analysis are entirely consistent with network theory.

The network data that most impacts on information sharing is represented by the World Wide Web and the Internet.

While the terms www and internet are often used interchangeably in the media, they refer to different systems. The www is an information network, whose nodes are documents and links are URLs. In contrast, the Internet is an infrastructural network, whose nodes are computers called routers and whose links correspond to physical connections, like copper and optical cables or wireless links. The degree distribution of both networks is well approximated by a power-law, and so these networks are scale-free. On the Internet, a few highly connected hubs hold together numerous small nodes.

Network theory can be linked to big data, primarily through digital platforms that convey information in real-time. Value chains based on traditional databases become networked when they are linked to other chains through value-adding networks. Value chain networks are more resilient and able to cope with risks of failure, enabling alternatives.

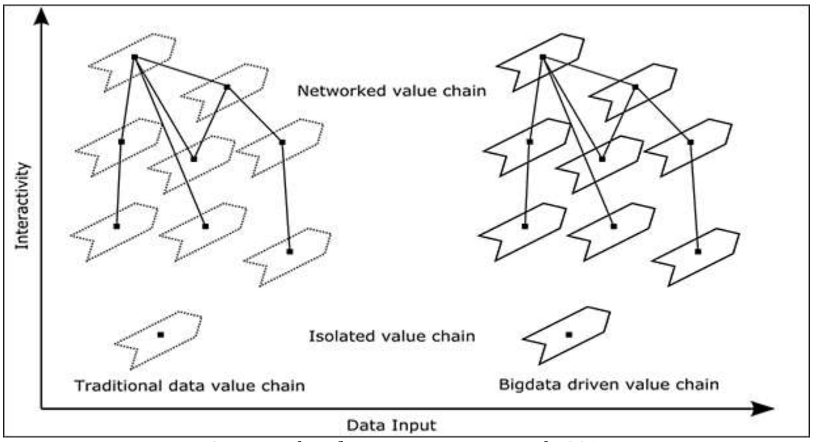
Networked value chains fueled by big data stand out as the best value-maximizing option, as illustrated in Figure 12.

Degree, correlations, clustering, and centrality provide information on single nodes, their immediate surroundings, and their position concerning the overall network (Caldarelli & Catanzaro, 2012). These features are networked informative nodes. Edging big data correlated to nodes disseminate extensive information in real-time.

The topology of networks, so crucial for their interpretation, is based on computing the edge betweenness that finds the edges through which most of the shortest paths pass.

Websites and the internet can be interpreted in terms of network science, being represented by relations among vertices and their connecting edges.

Figure 12. Network of value chains



Source: taken from Moro Visconti et al., 2017

Social networks, continuously fuelled by big data collection and processing, show the dynamic relationships among social entities (persons, groups, etc.). Along the value chain, they mainly develop the sharing phase. Big data processing of social network contents is quite complicated since the wording is semantically hard to interpret and classify.

7. FROM NODE DELETION TO VALUE DESTRUCTION

Whenever a node is deleted (see Section 2.3), the value is destroyed. If the node is central, due to its strategic importance and its bridging intermediation function, its removal may severely impair the firm and its internal/external nexuses, up to a default scenario.

Contagion is a process whereby the collapse of a node in a network leads to the destruction of neighboring nodes and thereby sets off a chain reaction in the network. It thus creates a special type of time-dependent network. Such processes are studied in various applications, for example, in financial network analysis, infection diffusion prediction, supply-chain management, or gene regulation (van Landesberger et al., 2013). This confirms that network theory is a highly interdisciplinary discipline.

Destruction or removal of a node may cause cascading implications due to domino effects, especially in bi-directional (undirected) networks where links are one-to-one.

Examples may be given by the disappearance of a strategic supplier, default of an important client with economic and financial drawbacks that can undermine the survival chances of the firm, abandonment of critical employees and managers (especially in small firms), withdrawal of a significant creditor (bank), etc.

The resilience of the firm and its ability to cope with adversities can be measured even in terms of capacity to rebuild the network when key nodes disappear.

Node deletion may disrupt the supply (and the value) chain that after being broken might be re-arranged substituting disappearing nodes or broken links. Not all nodes are equally essential and whenever a strategic node-firm is deleted, consequences are harder and networked contagion sours. This is, for instance, the case in the banking industry, where defaults are often systemic, as shown by the 2008 subprime crisis. Interconnections among financial institutions create potential channels for contagion and amplification of shocks to the financial system (Glasserman & Young, 2015).

Node deletion and its analysis in terms of network theory may give a complementary explanation of bankruptcy issues and contagion externalities that destroy stakeholder value. Interpretation, prevention, and mitigation of defaults through dynamic network theory may contribute to mitigate the devastating effects of a crisis, detecting its domino impact on related firms.

Timely prevention and identification of "patient zero" before contagion are consistent with big data velocity and alert processing in real-time. Tracking of possible interactions through network mapping is also useful to prevent unwanted transmission of contagious criticalities.

8. INTERLOCKING DIRECTORSHIP

A keiretsu (系列), literally system, series, a grouping of enterprises, an order of succession) is a set of companies with interlocking business relationships and shareholdings. It is a type of informal business group. The keiretsu maintained dominance over the Japanese economy for the second half of the 20th century.

Interlocking rotates around corporate centrality, a concept with two components, many interlocks, plus the degree to which those interlocks are with other companies with many interlocks. In the past, banks were invariably the most central organizations in the corporate network (Domhoff, 2016).

Interlocking is entirely consistent with a networked representation of related directors that link different firms. Each director in a firm that is also present in other boards represents a node intertwined with specular director-nodes. Network theory can help to map these relations and measure their intensity, easing the prevention of abuses and conflicts of interest.

Networks are likely to deeply reshape the workings of the board of directors, easing distant and timely meetings, and the assortative selection of board members. Artificial intelligence applications may envisage "virtual" directors, and foster big data analysis, with an impact on decision-making and strategic execution. The synergistic interaction of big data sources and artificial intelligence applications may also allow for processing massive information in real-time, improving the effectiveness and depth of monitoring functions.

Interlocking directorates and corporate networks are examined in Sapinski & Carroll (2018). Each type of interlock goes along with unique knowledge-based, social influence-related and institutional benefits and costs (Brennecke & Rank, 2017). The corporate governance concerns that they raise, first due to the concentration of power in the hands of large firms and banks, may be mapped with graph (network) theory.

9. INTERNATIONAL GROUP GOVERNANCE: A NETWORKED RATIONALE BEHIND THE MULTINATIONAL FIRM

A multinational corporation is a corporate organization that owns or controls the production of goods or services in at least one country other than its home country. The rationale of multinational enterprises has long been debated (Contractor, 2012).

A graphical representation of the linked firms, typically with a holding company located in one country and several subsidiaries located elsewhere, is entirely consistent with the network theory. Figure 13 shows a simple example of how firms belonging to a multinational group are linked among them. There are three main hubs in North America, Europe, and Africa. In the graph, some nodes are not directly linked to the other (e.g., Europe must use the pass-through North American node to reach Africa). The architecture of the group and its governance might be modified to allow for more intense networking, so improving the overall value of the network (according to Metcalfe's law, examined in Section 12).

Figure 13. Geographical network of firms belonging to the same group

Source: adapted from Shutterstock.com

Geographical networks and geolocalization issues may contribute to the explanation of multinational concerns that impact on governance, like for example, transfer pricing issues or antitrust concerns (that increasingly address tech-giants and their monopolistic digital platforms).

Digital supply chains and horizontal interactions among scattered stakeholders reshape traditional business models, with profound implications on multinationals with hierarchical governance structures.

Inclusive platform companies endanger incumbent multinationals, challenging consolidated value propositions with decentralized strategies. Network externalities that threaten consolidated family businesses affect even multinationals and their hierarchical structure. Disintermediation through networked blockchains reshapes consolidated businesses and industries, challenging their resilience to digital market trends.

10. SOCIAL NETWORKS AND CROWDFUNDING

A social network is a social structure made up of a set of social actors (such as individuals or organizations), sets of dyadic ties, and other social interactions between actors. The social network perspective provides a set of methods for analyzing the structure of whole social entities as well as a variety of theories explaining the patterns observed in these structures (Wasserman & Faust, 1994). The study of these structures uses social network analysis to identify local and global trends, locate influential entities, and examine network dynamics. Social media reshape and disintermediate the firm communication and are a core component of strategies that look for viral scalability of revenues and shared trust-building.

Crowdfunding is the practice of funding a project or venture by raising small amounts of money from many people, typically via the Internet and through social network platforms. In crowdfunding, a digital platform is a connecting hub (bridging node) among the different equity-holders.

P2P lending follows networked value co-creating patterns that reshape traditional ownership & control mechanisms. Even the cost of collected capital and its embedded risky component follow innovative paths where upside potential is shared since inception. Trendy monitoring is secured by continuous feedbacks that nurture big data and artificial intelligence, softening information asymmetries.

To the extent that differences between expectations and real outcomes are reduced by timely evidence, risk should also decrease (so reducing the cost of capital and improving Discounted Cash Flows), softening governance conflicts.

Social networking around digital platforms also contributes to reshaping digitized supply and value chains, easing e-commerce B2B/B2C transactions, and the value co-creation patterns of the involved stakeholders.

11. GAME THEORETIC NETWORKS AND CORPORATE GOVERNANCE

Network game theory is the combination of network analysis and game theory to the study of situations of interdependence between adaptive agents. Network game theory builds upon and expands classical game theory by incorporating the network of connections within which agents make their choices. In so doing it offers a richer model of the behavior of agents within games.

Game theory is the study of mathematical models of strategic interaction between rational decision-makers (Aumann, 1987). Game types can be:

1. Cooperative / Non-cooperative. A game is cooperative if the players can form binding commitments externally enforced (e.g., through contract law). A game is non-cooperative if players cannot form alliances or if all agreements need to be self-enforcing (e.g., through credible threats).
2. Symmetric / Asymmetric. Asymmetric game is a game where the payoffs for playing a particular strategy depend only on the other strategies employed, not on who is playing them. If the identities of the players can be changed without changing the payoff to the strategies, then a game is symmetric.
3. Zero-sum / Non-zero-sum. Zero-sum games are a special case of constant-sum games, in which choices by players can neither increase nor decrease the available resources. In zero-sum games, the total benefit to all players in the game, for every combination of strategies, always adds to zero (more informally, a player benefits only at the equal expense of others).

4. Simultaneous / Sequential. Simultaneous games are games where both players move simultaneously, or if they do not move simultaneously, the later players are unaware of the earlier players' actions (making them effectively simultaneous). Sequential games (or dynamic games) are games where later players have some knowledge about earlier actions. This need not be complete information about every action of earlier players; it might be very little knowledge.

The link between game and network theories is evident. Still, even the connections with corporate governance can be easily evidenced if the patterns of interaction among different stakeholders are carefully analyzed.

Game theory can improve the interpretation of reciprocal and contractual governance patterns.

Game theory applications to finance discriminate between uninformed and informed agents, with applications to corporate control, capital structure, dividends, and stock repurchases, external financing, and financial intermediation (Thakor, 1991). Corporate finance applications concern also the signaling model, agency costs, and other vital issues (Allen & Morris, 2014) that have strong links with corporate governance concerns.

12. DIGITAL PLATFORMS AND SCALABLE VALUE

Internet digital platforms are represented by a web browser where software interfaces interact. By using Internet platforms, businesses can create a competitive advantage and are a source of scalable value.

Digital platforms enhance scalability, which indicates the ability of a process, network, or system to handle a growing amount of work, or its potential to be enlarged to accommodate growth. It enables a growth in revenues accompanied by a less than proportional increase in variable costs. Since scalability enhances growth, it has essential side-effects on governance issues.

Digital scalability follows Metcalfe's law, according to which the effect of a telecommunications network is proportional to the square of the number of connected users of the system (n2).

Digital transformation concerns both traditional companies that are undergoing a digitalization upgrade and native digital businesses. These complementary businesses interact and are part of complex ecosystems populated by composite stakeholders (Bonollo & Poopuu, 2019).

Web platforms may be considered an "intangible stakeholder" that acts as an intermediating link among "physical" (traditional) stakeholders, representing the architectural framework of the firm's virtual network. Multi-stakeholder interactions in digital settings are examined by Viglia et al. (2017). Platforms reengineer supply and value chains, acting as digital hubs, and contributing to value-adding disintermediation.

Web platforms perform their action in many ways, acting as:

- An e-commerce site;
- A P2P lending platform;
- A FinTech enabler;
- A blockchain backbone (for governance implications, see Yermack, 2017);
- A mobile-App intermediary;
- A social network interface, etc.

Platforms are typically owned by IT or TLC giants, and catalyze information from users, collecting big data that can be stored and processed. Information asymmetries and their related conflicts of interest may be reduced, although sharing of data is often impaired, and dominant players (the interface owner) may extract monopolistic rents.

13. DISCUSSION

The breadth of the topic and the width of its applications represent a major cause of the study limitations that are also due to the novelty of the topic and to the lack of empirical evidence. Closer scrutiny of the different topics that have been synthetically described might be conducted, possibly using the mathematical background of the network (graph) theory as a unifying paradigm for systemic analysis.

This preliminary study is still pioneering and is demanding for additional investigation, possibly igniting new literature strands. Some vital questions that may inspire future research remain largely unexplored:

- Which are the links that represent the firm's network? What happens around the stakeholding nodes and their links? How strong are the links among different nodes (stakeholders)? Can they be measured and modelled mathematically?
- Which are the changes in firm networks due to technology (digitalization; decentralization with blockchains; information sharing and processing with big data and artificial intelligence, etc.)? And how traditional firms that are "going digital" interact with digitally native companies?
- Which are the hub nodes (the firm itself, and key stakeholders, etc.) and how they react to network/blockchain-driven decentralization?
- Which are the dynamics that start from the "photography" of the network to estimate its outlook, even in terms of trendy sustainability?
- Which is the impact on the cost of collecting capital for networked firms with value-sharing patterns? And to which extent the risky cost of capital incorporates sustainability patterns?
- Which is the impact of networks on value creation (and co-creation), even considering the impact on volumes and economic/financial margins of digital scalability?
- Which is the impact of horizontal networks and P2P stakeholders on hierarchy, ownership & control (that represent traditional corporate governance milestones)?
- To which extent traditional stakeholders interact with digital platforms and networking backbones to co-create shared value?
- Which are the interactions of networked firms with climatic changes and circular economic patterns within an overarching natural eco-system? And which are the network differences between standard supply/value chains, and circular economy chains, in terms of sustainability and impact on Customer Social Responsibility?

Another trendy issue concerns digital platforms that work as bridging entities among networking stakeholders who use the platform to exchange information. Platforms may be considered as a new "virtual" actor, and interactions with traditional stakeholders are still under-investigated. Platforms are algorithmic intermediaries nurtured by big data stored in the cloud that fuel artificial intelligence patterns. "Virtuality" derives from the intangible (fictitious) nature of the (digital) platform that may act as a bridging node among the different nodes-stakeholders that rotate around the firm, considered as a nexus (network) of contracts. This topic is dealt with in Moro Visconti (2019), where digital platforms are considered as a virtual stakeholder that acting as a bridging node favors the interaction among other nodes/stakeholders that are incentivized to co-create value.

Digital connections are intrinsically intertwined with IT platforms. Spagnoletti et al. (2015, p. 364) accordingly define a digital platform as "a building block that provides an essential function to a technological system and serves as a foundation upon which complementary products, technologies, or services can be developed".

Digital platforms represent a cornerstone for e-commerce, B2B and B2C transactions, and they reshape the architectural design of the digital ecosystem (see Wareham et al., 2014), to balance the different interests (with a trade-off between centralized versus distributed control), bypassing traditional vertical hierarchies. Corporate governance implications are meaningful, albeit under-explored.

Linkages among different stakeholders can increasingly follow artificial intelligence patterns with deep corporate governance implications (Grove & Lockhart, 2019). Lasting and resilient networking may reduce short-termism and strategic myopia.

A further issue is represented by network externalities that concern the effects a product or service have on a user while others are using the same or compatible products or services. These properties may well be extended to corporate governance investigation, even in terms of value co-creation paradigms or contagion (should the externalities be negative).

14. CONCLUSION: BEYOND NETWORK THEORY - THE DARK SIDE OF CORPORATE GOVERNANCE

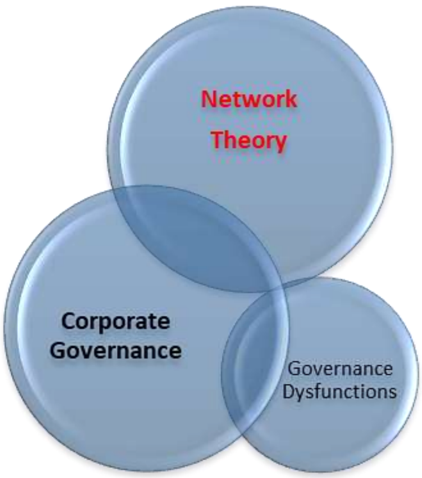
This study contains a preliminary analysis of two classical issues – corporate governance and network theory – in a combined and innovative way that shows unexplored interactions. The main theme is that stakeholders represent the founding block of corporate governance and their intricate interactions can intuitively be represented by networks.

Networks not only contribute to a better explanation of traditional corporate governance mechanisms but also, through their digital platform applications, disrupt traditional business models. Unmediated and technology-based corporate governance is deeply reshaped. If the firm dynamics is represented by more horizontal interactions of cooperating stakeholders, the difference between top-down dirigisme and bottom-up participated feedback is reduced, creating shareable wealth through value co-creation paradigms.

These pioneering topics (that may be easily extended, addressing additional issues) need further analysis and may ignite new literature strands with interdisciplinary pollination – networking – of ideas and solutions that embrace technology, network theory, and corporate governance concerns.

Even if network theory is extremely flexible and easily adaptable to many corporate governance issues, there are many concerns that may hardly be comprehensively interpreted with a network theory approach. This is reflected in Figure 14.

Figure 14. Network theory, corporate governance, and its dysfunctions



Governance failures are driven by agency problems (e.g., lack of managerial accountability; insufficient managerial effort; extravagant investments; entrenchment strategies; weak board of directors; moral hazard; adverse selection; self-dealing; strategic failure to avoid debt service, etc.) that may cause severe conflicts of interest among the stakeholders.

Networks may partially record these dysfunctions (e.g., if they are originated by information asymmetries that can be traced within the network) and their negative externalities, for instance, if they reduce the "traffic" among specific nodes but can hardly be used to provide comprehensive explanations and solutions.

The dark side of corporate governance that still puzzles investors is so far from being solved, even if an interdisciplinary approach that embodies network theory may substantially improve the comprehension of the governance conundrum.

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