Corporate governance, digital platforms, and network theory: information and risk-return sharing of connected stakeholders

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Abstract

Corporate Governance, Digital Platforms, and Network Theory. Information and Risk-Return Sharing of Connected Stakeholders
Digital platforms are a technology-enabled transactional tool that facilitates connections between stakeholders. Their features are consistent with network theory applications where stakeholders are the nodes rotating around the platform. Platforms may be considered a new virtual stakeholder that, consistently with network theory, connects conventional partners (shareholders, managers, employees, lenders, clients, suppliers, etc.), representing a bridging node and edge in multilayer networks. Stakeholders are nodes that interact around the bridging (hub) node, sharing information, and co-creating value within a sustainable digital ecosystem. Shared information is fueled in real-time by big data and reduces asymmetries and risk, redesigning information systems. Corporate governance and managerial implications emerge as a critical, still under-explored issue.

Keywords: Theory of the firm, Digital Information Systems, Scalability, Ecosystem, Digital Governance, Multilayer Network, Sustainability.

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1. Introduction

The Coasian theory of the firm, considered as a nexus of contracts, shapes traditional corporate governance mechanisms about the interactions among composite stakeholders, in a context where ownership is separated from control. Digital platforms are, however, reshaping the firm's ecosystem, and they can be considered a digital stakeholder that fosters connectivity within and outside the firm.

Governance consequences of these innovative interactions appear meaningful, albeit under-investigated, as they primarily concern the sharing of information and of risk-return patterns among connected stakeholders. And connectivity may conveniently be interpreted applying network theory that derives from the mathematical investigation of graphs.

In graph theory, nodes are linked to each other through edges. In corporate governance, stakeholders (including the virtual digital platform) interact through mechanisms that may be described using graph (network) theory. The Coasian firm may so become a network of contracts through which connected node-stakeholders interact, exchanging digital information, and sharing risk and returns. This consequential reasoning is the framing context of this study.

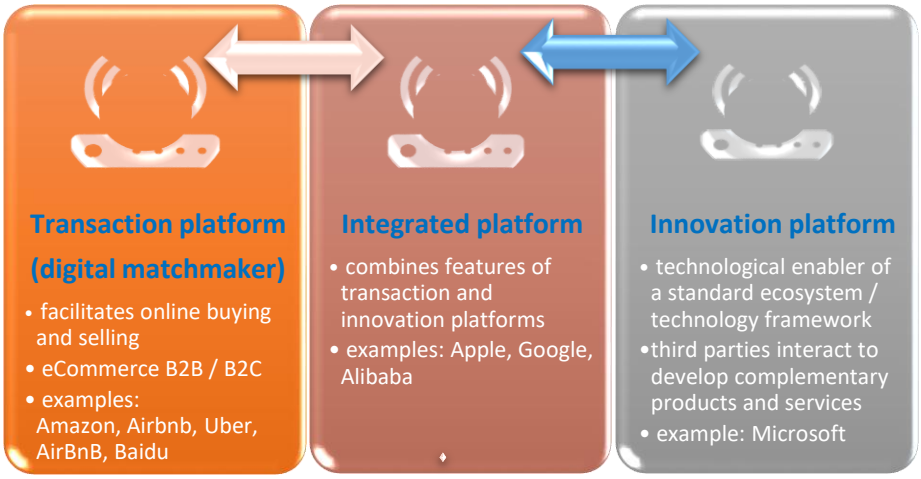
Consistently with these premises and definitions, *the research question of the paper focuses on the role of digital platforms (considered as a virtual stakeholder, and analyzed with network theory patterns) in reshaping corporate governance interactions among networking stakeholders*.

A short description of digital platforms is preliminary to further considerations, consistently with the research question. Platforms are facilitators of exchange (of goods, services, and information) between different types of stakeholders that could not otherwise interact with each other. Transactions are mediated through complementary players that share a network ecosystem (Rochet and Tirole, 2003; Armstrong, 2006). Due to their digital features, they have a global outreach that gives them potential to scale.

Digitalization is the process of converting data (not necessarily information) into a computer-readable format. Digital platforms are "software-based external platforms consisting of the extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate" (Tiwana *et al*., 2010). Software platforms are a technological meeting ground where application developers and end-users converge (Evans *et al*., 2006).

A taxonomy of the platform typologies is recalled in Figure 1.

Figure 1 – *Platform Taxonomy*



An analysis of the impact of digital platforms on corporate governance mechanisms can be conducted by first defining the core components of this architecture (digital platforms, stakeholders, and networks) and then fine-tuning some core findings in specific industries.

Digital platforms are at the basis of technology-enabled business models that facilitate exchanges between multiple groups – such as end-users and producers – who do not necessarily know each other. The generated value is proportional to the size of the community, with scalable network effects thanks to the Internet. Interaction within digital platforms follows innovative paradigms where stakeholders co-create and share value. Supply and value chains flatten and incorporate learning curves (economies of experience) that are fueled by real-time big data.

Traditional stakeholders (shareholders, managers, employees, suppliers, financial lenders, customers, etc.) whose interactions are examined by classic corporate governance literature are complemented by pivoting digital platforms which are a further "virtual" stakeholder.

This paper is to the author's best knowledge innovative, and it might shed light on traditional governance relationships, re-engineered around digital platforms. Implications for the sustainability and resilience of the supply and value digital chains are a promising research avenue.

The study is organized as follows: after these introductory notes, a literature review is contained in Section 2. Network theory concepts are applied in section 3 to the Coasian theory of (networked) firms. Section 4 addresses

the impact of networking scalability on a platform ecosystem, whereas section 5 is dedicated to digital governance implications. Smart (digital) supply and value chains are then shortly examined in section 6 and are followed in section 7 by an extension to multilayer networks. A discussion (section 8) precedes some concluding remarks (section 9).

2. Literature review

Since the topic is highly interdisciplinary, a synthetic literature review will consider first separately and then jointly the main streams that deal with each field, to find out how they can interact, and which are some possible research gaps. The main subdivisions concern: 1) Network theory (applied to corporate governance and interacting stakeholders); 2) Digital platforms; 3) Networked digital platforms and related governance issues (with interactive and value co-creating stakeholders).

2.1. Network theory

Network theory (see Bapat, 2011; Barabási, 2016, Caldarelli and Catanzaro, 2011; Erdős and Rényi, 1959; Estrada and Knight, 2015; Jackson, 2008; Van Steen, 2010), is the study of graphs as a representation of either symmetric 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. A summary of some basic network theory concepts is useful for a better understanding of the workings of (networked) digital platforms, consistently with the research question.

Networks are a fundamental feature 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 www, Internet, gene regulatory networks, epidemiology (even concerning pandemic patterns, like those of Covid-19 coronavirus), metabolic networks, social networks, epistemological networks, etc.

Induction is a scientific methodology often used in network theory: what can be proven for small networks may be intuitively extended to other networks (Estrada and 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.

Stakeholding nodes, as those depicted in Figure 4 are typically symmetric (i.e., bidirectional, or undirected), and this increases the informative and decisional value of the network, particularly when digital platforms are introduced, as they directly mediate the relationships among other stakeholders.

A key property of each node is its degree: its number of links to other nodes. The degree is an important parameter even in corporate governance, as it identifies the connections among stakeholders and their intensity.

In networks, physical distance is replaced by path length. A path is a route that runs along with the links of the network. A path length is the number of links it contains. Even the shortest path can be important, considering (digital or traditional) supply and value chains where each passage (or node) is presided by interacting stakeholders, who share marginal economic returns (and bear corresponding costs), co-creating value. Physical distance plays a key role in determining the interactions between the components of physical systems. In networks, distance is a challenging concept, and physical locations coexist with digital links where geographical location is not an issue. One of the main advantages of digitalization is that it minimizes time and space constraints.

In network science, paths play a central role. In corporate governance they are the interactions between stakeholders. Whereas traditional relationships among stakeholders typically occur through physical interaction, networking follows the path length rule, and "digital" distances are typically negligible. Connections are important as they enable interactions among stakeholders. Disconnections may happen in case of failures or other value-destroying occurrences. In highly sensitive industries as healthcare, even temporary disconnections may cause severe damages to patients. Digitalization is a double-edged sword, as it increases connections, consequent possible disconnections, while also helping to fix them in real-time.

The clustering coefficient captures the degree to which the neighbors of a given node link to each other. Clusters are relevant for interfirm coordination when companies cooperate within an industrial district, joint ventures or other forms of cooperative competition - coopetition in shared markets (Klein *et al*., 2019). The degree of a node contains no information about the relationship between a node's neighbors. Do they all know each other, or are

they perhaps isolated from each other? The answer is provided by the local clustering coefficient that measures the density of links in node immediate neighborhood.

The concept of node centrality (Estrada and Knight, 2015, Chapter 14) is used in the determination of the most critical nodes in a network, acting as hubs. They can 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 – and/perhaps indispensability - of central nodes is fully consistent with the Coasian nature of the firm as a nexus (network) of contracts and ties among composite stakeholders. Node centrality is also applicable to digital platforms due to their bridging features.

Degree centrality measures the ability of a node to communicate directly with others. This is of key importance in firms, which also have a closeness centrality, having the shortest path distance with surrounding stakeholders being the other nodes. Furthermore, firms are characterized by their betweenness centrality that detects nodes that serve as a bridge from one part of a graph to another. Closeness to other nodes is important even in terms of higher influence.

Communities in networks (Estrada and Knight, 2015, chapter 21) are 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 that coalesce around the hub-firm or the bridging digital platform, as it will be shown in Figure 4.

2.2. Digital Platforms

Digital platforms refer to a variety of complementary concepts that still need comprehensive systematization in the literature. A synthetic outlook of this recent research strand is important to make some critical remarks, consistent with the research question of this study.

A literature review on digital platforms is contained in Asadullah *et al*. (2019) and in Sutherland *et al*. (2018) that analyze sharing economy platforms. Spagnoletti *et al*. (2015, p. 364) 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 businesses are those which carry out transactions that are digitally mediated or involve products or services that are experienced digitally (Weill

and Woerner, 2013). Platforms are facilitators of exchange (of goods, services, and information). Transactions are mediated through complementary players that share a network ecosystem (Rochet and Tirole, 2003; Armstrong, 2006). This interpretation is consistent with the transaction cost theory that can be applied as a constructive stakeholder theory (Ketokivi and Mahoney, 2015).

Digital platforms are multisided digital frameworks that shape the terms on which participants interact. Digital platforms are also complex mixtures of software, hardware, operations, and networks (De Reuven *et al*., 2018; Gawer and Cusumano, 2014; Gawer, 2014). They provide a set of shared techniques, technologies, and interfaces to a broad set of users; social and economic interactions are mediated online, often by apps (Kenney and Zysman, 2016). Digital platforms are complementarily defined as ‘‘software-based external platforms consisting of the extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate’’ (Tiwana *et al*., 2010). Software platforms are a technological space where application developers and end-users converge (Evans *et al*., 2006).

Digital platforms have become a major mode for organizing a wide range of human activities, including economic, social, and political interactions (e.g., Tan *et al*. 2015; Kane *et al*. 2014). Platforms leverage networked technologies to facilitate economic exchange, transfer information and connect people (Fenwick *et al*., 2019). Studies sharing this view focus on the technical developments and functions upon which complementary products and services can be developed i.e., building on the top of the technical core that a platform owner offers and facilitates (Tiwana *et al*. 2010; Ghazawneh and Henfridsson 2015; Ceccagnoli *et al*. 2012).

Other studies have conceptualized digital platforms based on a non-technical view that presents platforms as a commercial network or market that enables transactions in the form of business-to-business (B2B), business-to-customer (B2C), or even customer-to-customer (C2C) exchanges (Tan *et al*. 2015, Koh and Fichman 2014, Pagani 2013). Digital platforms may include crowdfunding and P2P stakeholders (Majchrzak and Malhotra, 2013) which are innovative ways of raising equity. Crowdfunding issues are a new frontier of corporate governance (Cumming *et al*., 2019).

As anticipated, a holistic representation of digital platforms is still missing in the current literature, due also to its recent origin. The flexible nature of digital platforms is an important feature (improving its usefulness, for instance in making supply and value chains more resilient) but also an obstacle for comprehensive systematization.

The literature about digital platforms is inspired by an interdisciplinary approach (mainly technological and managerial) that hardly considers the mathematical aspects connected to the network (graph) theory. Corporate governance implications, illustrated in section 2.3., are – to the author's best knowledge – still not investigated, as anticipated in the introduction. They are a research gap which this study tries to partially fill. Governance issues consider digital platforms as a pivotal virtual stakeholder.

2.3. Networked Governance

Corporate governance is going to be deeply affected by innovation. According to Brennan et al. (2019), a revolutionary paradigm shift is well underway on how we think about business structures and governance because of disruptive technology and innovations. Networked governance, ignited by digital innovation, can become a cornerstone of this technological revolution. Whereas a holistic conceptual interpretation of corporate governance goes far beyond the scope of this study, some narrower considerations will be made. Consistently with the research question, the relationships among traditional and digital stakeholders will be examined. These stakeholders represent an innovative subset of the more general corporate governance issues.

Networked (corporate) governance originates from the interactivity of network theory with corporate governance principles. The topic has been illustrated in Fenwick *et al*. (2019) and Moro Visconti (2019), according to which this connection is still under-investigated.

Networked governance, as it will be proven in Section 3, is consistent with a re-interpretation of the classic (Coasian) theory of the firm (see Holmstrom and Tirole, 1989; Williamson, 1979). Value co-creation patterns (Akaka *et al*., 2012; Beirão, *et al*., 2017; Blaschke *et al*., 2019; Ceccagnoli *et al*., 2012; Galvagno and Dalli, 2014; Moro Visconti *et al*., 2017) exploit the network governance properties of digital platforms.

The survey of Pedrini and Ferri, 2019 shows that stakeholder management is increasingly important in corporate activities, and the rise of the internet, social networking, and big data have put more pressure on companies to develop new tools and techniques to manage stakeholders online. This is consistent with this study, according to which Internet-connected stakeholders increasingly use digital platforms (and related social networking) to interact, sharing big data.

The relationships among the stakeholders that interact around the digital platform may be eased by new intangibles (Moro Visconti, 2020, chapter 3) such as:

- Big (and small) data and IoT as input factors of decision-making;
- Collection, storage, and analysis of data through cloud computing, interoperable databases and artificial intelligence patterns;
- Interaction with digital platforms with smartphones, tablets, notebooks, M-Apps;
- Validation of data through blockchains (that may be considered as a specific digital platform).

A complete analysis of these interactions goes far beyond the scope of this study, which considers them as a facilitator for networking stakeholders.

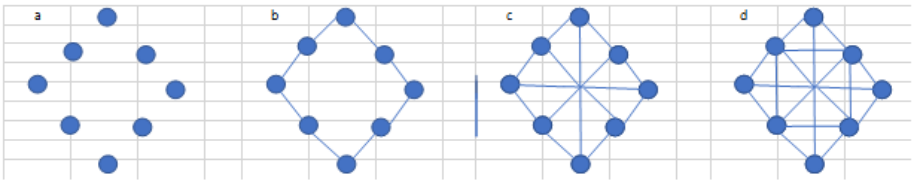
3. The Firm as a Coasian Network (Nexus) of Contracts

Digital platforms facilitate the interaction of networked stakeholders. An interpretation of the firm as a network (nexus) of contracts is then useful to understand its relationship with the virtual digital agent.

The firm can be considered as a nexus of contracts both internally, justifying in a Coasian way its very existence, and externally, considering agreements with third parties. This interpretation is fully consistent with the network theory since nexuses are the links among different nodes (here represented by composite stakeholders, in a multilayer framework).

Consider a situation where there is no firm to start with. Each node represented by a blue circle can have different links with the others. Figure 2 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).

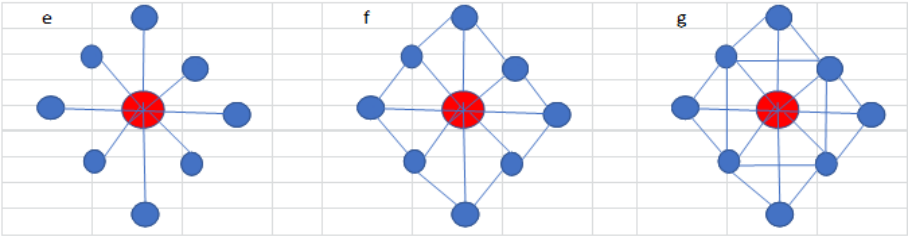
Figure 2. - *Network (without a firm)*



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 3, 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 become (increasingly) linked to each other, without necessarily passing through the hub.

Figure 3. - *Network with a hub firm*



From Figures 2 and 3, it becomes evident 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 open database with a pattern of sharable and unmodifiable data that are sequenced in chronological order. Due to their decentralized nature, they can reduce the importance of concentrating (monopolistic) hubs. Governance consequences are many: blockchains 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, and interconnected. Platforms leverage networked technologies to facilitate economic exchange, transfer information and connect people (Fenwick *et al*., 2020). Networks are frequently horizontal, open and autonomous: the way stakeholders interact is deeply 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 stakeholders;
- personalized consumer experience becomes increasingly important 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. External nexuses of contracts typically involve external stakeholders such as contractors. While stakeholders always include shareholders, they also include debtholders, clients, suppliers, workers, public authorities, and the external community.

Vertical integration is a well-known form of networked cooperation, within the "make it or buy" strategic decision that stands out as one of the basic 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 is a management control system where companies within a vertical supply chain are controlled by a common owner. The specialization of each firm within the vertical value chain allows a synergic combination of products and services, linking upstream buyers with downstream suppliers.

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 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) make some key 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 in 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 and Knight, 2015, Chapter 14) is used in determining the most important nodes in a network, acting as hubs. Their features include the ability to communicate directly with other nodes, their closeness to other nodes, and their role as communicators between different parts of a network. Usefulness – up to indispensability - of central nodes is fully consistent with the Coasian nature of the firm as a nexus (network) of contracts and ties among composite stakeholders.

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

4. Networking effects and scalability of digital platforms

As anticipated in the introduction, *the focus of this research is the impact of digital platforms on networking stakeholders and their corporate governance interactions.*

Networks become more valuable and important if they increase in size and interconnections, following the 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 (n^2). Metcalfe's law (for critical analysis, see Odlyzko and Tilly, 2005) describes network effects typical of communication technologies and networks such as the Internet, social networking, and the World Wide Web. Metcalfe's Law expresses mathematically the number of unique possible connections in a network of nodes. If a network is composed of n people and each of them assigns to the network a value proportional to the number of other participants, then the value that all n people assign to the network is:

$$n * (n-1) = n^2 - n \qquad [1.]$$

Digital platforms increase scalable profitability by offering exponential ecosystem growth. Scalability is an essential feature of any business. It 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 revenue accompanied by a less than proportional increase in variable costs. Scalability is the ability of a device to adapt to a changing environment with changing customer needs. In broader terms, scalability means flexibility (so incorporating real options to expand, postpone, abandon businesses), which allows us to better address and achieve specific needs of clients with a customer-centric approach. People's interests and tastes, as well as environmental conditions, evolve continuously. Scalability is therefore vital as it contributes to competitiveness, efficiency, and quality (Moro Visconti, 2020). Scalability helps the system work without any delay and resource waste, making efficient use of available resources (Gupta et. al., 2017). As described by Gander (2015), drivers of scale for digital business models are analyzed in Table 1, reported in the Appendix on the SIDREA website (www.sidrea.it/digital-network-information).

5. Networked governance around digital platforms

The previous sections have proven how the firm, thanks to digitalization, can be considered as a network of contracts. Some corporate governance implications have already been anticipated, consistently with the research question that is focused on the impact of digital platforms on the networking stakeholders. This section investigates in further detail how internal and external stakeholders interact around two bridging nodes: the networked firm and the digital platform.

Digital networks use a common platform as a pivoting (bridging) node which centralizes information sharing and transactions. Innovation is continuously proposing new paradigms for value creation, reshaping governance interactions.

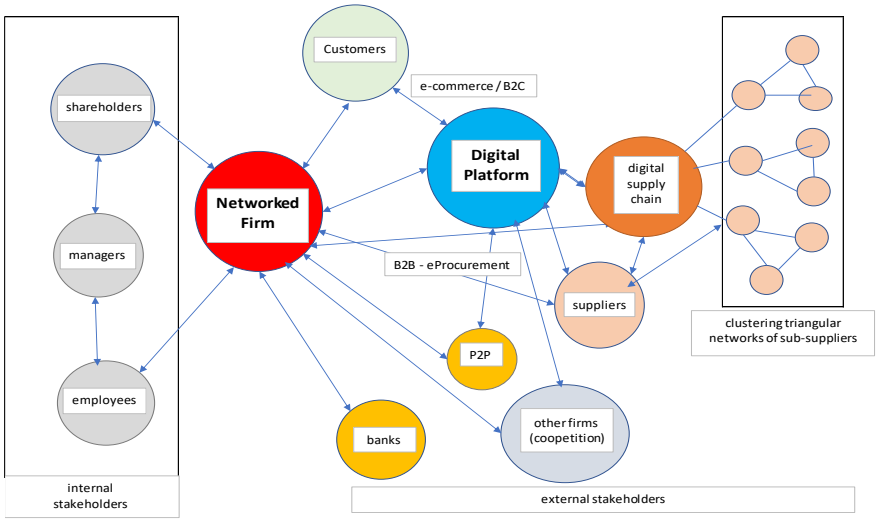
As described in de Reuven *et al*., 2018, digital technologies imply homogenization of data, editability, reprogrammability, distributedness and self-referentiality (Yoo *et al*., 2010; Kallinikos *et al*., 2013). Such features of digitality can lead to multiple inheritances in distributed settings, meaning there is no single owner of the platform core who dictates its design hierarchy (Henfridsson *et al*., 2014). This suggests that digital platforms, with their socio-technical features, may have "horizontal" features with interesting corporate governance implications in terms of value co-creation and sharing incentives. This feature is also consistent with the nature of distributed blockchains, where secured data are created and shared by cooperating stakeholders.

Internal stakeholders (mainly shareholders, managers, employees) are the core part of the networked firm whereas external stakeholders are customers, suppliers, financial institutions (banks) and other players (P2P investors; competitors; partners, etc.). The firm may also be considered an "internal" platform (Gawer, 2014).

The digital platform is the bridging node between the firm and the external stakeholders (that may also have a direct link with the firm, bypassing the intermediating function of the platform) and it can be linked to a digital supply chain where suppliers interact with B2B transactions and e-Procurement.

Figure 4 shows a case where players (stakeholders) are interacting nodes.

Figure 4 – *Internal and External Stakeholders linked to the Firm and the Digital Platform*



The two bridging (hub) nodes shown in Figure 4 are the networked firm and the digital platform. Internal stakeholders (shareholders, managers, employees, etc.) are a cohesive ecosystem within the firm that is linked to other external stakeholders (customers, suppliers, banks, interacting firms, etc.). These traditional internal and external stakeholders are complemented by the digital platform which is an innovative bridging node, linked also to P2P lenders, and digitized supply chains, following B2B or B2C transactional patterns.

The digital supply chain is a further bridging node between the digital platform, the traditional suppliers and a further sub-network of e-suppliers that exchange information and trade in real-time (24 hours / 7 days a week). B2B2C stakeholders that make transactions through the platform exchange data and so fuel big data stored in the cloud. This information then feeds interoperable databases, with consequent artificial intelligence interpretation (and possible blockchain validation). The digital platform acts as an intermediating hub, increasing the number of nodes (vertices) as well as the quantity and quality of the links. For instance, any interaction between two agents that is mediated through the platform is digitally recorded.

A digital platform that mediates different groups of users (such as buyers and sellers) may be denoted as multi-sided (Boudreau and Hagiu, 2009). In

two-sided markets, two distinct groups have a relationship where the value for one group increases as the number of participants from the other group increases (Evans, 2003; Eisenman *et al*., 2006). As platforms bring together multiple user groups, they create the so-called network effects or network externalities (de Reuver *et al*., 2018). This is consistent with the Metcalfe's property of networks and with the interpretation of platforms in networking terms.The added value of the eco-systemic network arises mainly from two synergistic features:

a) The "architectural" value of the network itself (depending on the outlay of the nodes and links), measurable in numbers;
b) The functional value of the network (including the platform as a bridging node), which depends on the intensity of the interactions among the different links (exchange of information; transactions, etc.). Architectural links are important to the extent that they incentive "traffic" among nodes (stakeholders).

Smart products in combination with innovative data-driven supply chain services help rethinking supply chain management, leading to more self-organizing and self-optimizing systems. Digitization will play a growing role in global supply chains due to reasons such as the shift in values from the physical artifact to the data created by smart products, the emerging importance of services, the displacement of industry borders, the radical change of competitive structures, the transformation of business models and more in general, the symptomatic creative destruction of established structures and behavior patterns (Pflaum *et al*., 2017).

6. Digital (smart) supply chains

Digital supply (and value) chains is a further extension of the above considerations, consistently with the framework and aim of this study. Within a networked governance ecosystem, the information patterns and risk-return sharing of connected stakeholders are deeply affected by digitalization. This has an important impact on corporate governance.

A supply chain is a (physical) network between a company and its suppliers to produce and distribute a specific product to the final buyer. These links among the stakeholders shape their governance interactions and are reengineered by digitalization. Network theory and its digital extension are consistent with the architectural framework of the supply chain. To the extent

that the single steps ("rings") of the chain are affected by digitalization (e.g., thanks to a disintermediation process that shortens the chain), it can be inferred that the digitalization process produces savings – in the form of lower transactional costs – that improve the risk-return profile of the stakeholders that also benefit from the softening of information asymmetries.

What makes supply chains resilient is:

- A mix of complementary intangibles (e.g., big data and IoT that fuel patented processes and in-cloud artificial intelligence applications);
- A scalable network of expanding nodes and linking edges (consistent with network theory and its digital applications), incorporating growth real options, and B2B2C relationships;
- Digital platform services (cloud computing platforms where customers can develop, run, and manage applications without the requirement of building and maintaining the infrastructure typically needed when developing and launching an app) (Butler, 2013).

Network theory is mainly related to digital platforms, which are in turn catalyzers of scalable intangibles. The most powerful active platforms nowadays are Amazon, Alibaba, Apple, Google, and Facebook. Their common features are technologies not based on physical assets. They benefit from innovative ecosystems with core interactions between platform participants as consumers, producers, and third-parties (Jacobides *et al*., 2018).

Korpela *et al*. (2017) show that digital supply chain integration is becoming increasingly dynamic. Access to customer demand needs to be shared effectively, and product and service deliveries must be tracked to provide visibility in the supply chain. Business process integration is based on standards and reference architectures that should offer end-to-end integration of product data. Companies operating in supply chains integrate processes and data through the intermediating companies, who establish interoperability by mapping and integrating company-specific data for various organizations and systems. This practice has high integration costs, and adoption is still low. Business to business (B2B) integration within the supply chain refers to the exchange of electronic data over the internet between business partners and value-added service providers.

The principal value drivers of digital supply chains are:

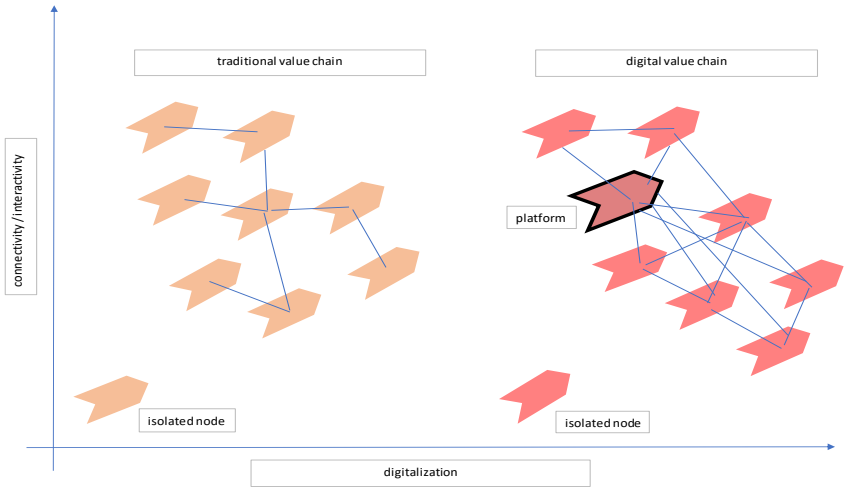
- Fast (just-in-time) end-to-end integration through digital enablers;
- Traceability and visibility of deliveries through smart logistics partners;
- Cost-effective cloud solutions provided by ICT partners;
- Sharing of real-time information in the cloud;

- Standardized transactions and collaboration through digital platforms accessed by supply chain members;
- Networking with geo-localized e-commerce customers.

Digital (smart) supply and value chain technologies combine information, computing, communication, and connectivity innovation in applications or devices like: Augmented reality; Big data; Cloud computing; Social media; Mobile, (cognitive) analytics or embedded devices; Cognitive technologies (machine learning, neural networks, robotic process automation, NPL, AI, etc.); IoT, wearables and Sensor technology; Nanotechnology; Omni-channel (to improve customer experience); Robotics; Self-Driving Vehicles and Unmanned Aerial Vehicles; 3D printing.

The interactions among the networked firm, the digital platform, and the other external stakeholders can be examined with a value chain analysis that outlines its networked and digital features. The value chain is digitized by the devices / technologies reported above. An example is shown in Figure 5.

Figure 5 – *From Traditional to Networked Digital Value Chains*



Digital value chains tend to be flatter (more horizontal and less hierarchical) than traditional value chains and the bridging platform acts as a coordinating hub, as shown in Figure 4. The digital network is intrinsically more valuable due to its highly interconnected architecture (higher number of links); value also depends on the increasing traffic of data or transactions

among the linked nodes. This incremental value can be estimated using a with-or-without approach (consistent with the International Valuation Standard 210), according to which the value chain is estimated with and without its networked digital features, using the difference as a proxy for value.

Digital supply and value chains may be represented by two separated initially network ecosystems that eventually interact, within a multilayer network (Bianconi, 2018). This interpretation is consistent with the cloud manufacturing paradigm, an advanced form of networked manufacturing. This process is based on a combination of existing manufacturing systems and emerging technologies, such as cloud computing, virtual manufacturing, agile manufacturing, manufacturing grid, IoT, and service-oriented technologies (Akbaripour *et al*., 2015). Global supply chains (and related value chains) are becoming increasingly connected due to the increased globalization in terms of network size, strength and connectivity, showing significant intertemporal changes, and higher clustering (Tsekeris, 2017).

7. Multilayer Networks

The world is more complex than conventional economic models traditionally assume. Many real-world complex systems are accordingly best modeled by multiplex (multidimensional) networks of interacting layers (Lee *et al*., 2015). These interconnected systems are very sophisticated and may explain better the applications in the field of social network analysis, economics, operations management, finance, etc., being consistent with corporate governance concerns.

Multilayer networks are an extension of the traditional networks synthetically illustrated in section 2.1. and are fully consistent with the framing and research aim of this study. Multilayer networks are intrinsically fit for leveraging the scalability features examined in section 4, since they host bridging (replica) nodes, digital networks or firms (consistently with the basic representation of figure 4) that are simultaneously present in several layers. These properties have deep, albeit non investigated, governance consequences.

Complex multidimensional networks host multiple kinds of relations (multiplex, multilayer, multilevel, multi-relational, interconnected, interdependent, etc.), and may yield valuable insight in many interdisciplinary fields. These networks of networks may affect social networks that involve different types of connections, networks of airports connected by different air carriers, multiple infrastructures of a country that are mutually connected, etc.

Nodes which simultaneously belong to different layers (networks) can be represented mathematically by adjacency tensors with inter-layer edges that connect each network to the other. These links enhance the overall value of the network of networks, boosting Metcalfe's formulation.

Whereas the sophisticated mathematics that explains these relations (see Bianconi, 2018) goes far beyond this preliminary study, some economic implications may be worth considering.

The inter-layer edges (links) between the different nodes go beyond every single layer and connect two (or more) adjacent layers, resulting in a network of networks with multiple subsystems and connectivity properties. If the links between the nodes increase (both in the same layer and thanks to an inter-layer connection), there is a corresponding value growth of the systemic network of networks that might be estimated with Metcalfe's law.

Figure 6 – *Multilayer Networks*

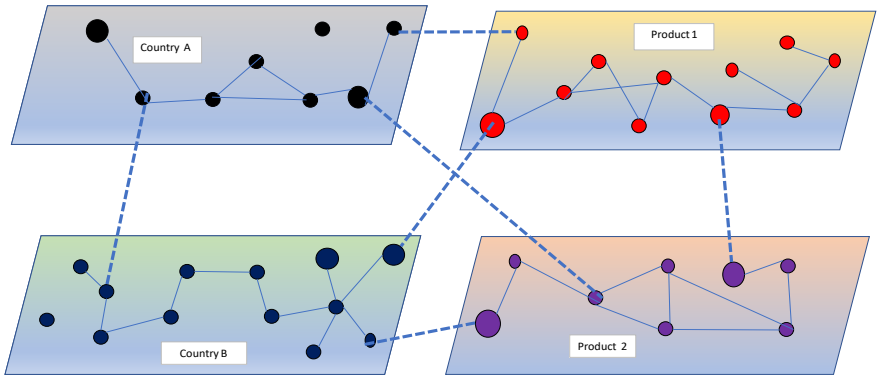


Figure 6 shows at first sight that inter-network bridging edges (that link nodes in country A with country B, product 1 and product 2) add value to the whole network ecosystem. This incremental value may be tentatively estimated (with a differential without/with approach) by comparing unrelated networks with linked ones. An economic interpretation of multiplex networks is – to the author's best knowledge – still underexplored and may be generalized (including further interacting layers in a dynamic ecosystem), giving an innovative explanation of the interactions between e-supply and e-value chains. As anticipated, digital platforms may once again act as the virtual linking edge among the networks.

8. Discussion

The interdisciplinary analysis of the implications of networked digital platforms on corporate governance raises essential questions that require deeper analysis. A first consideration, consistent with the research study, is that the link between traditional corporate governance issues and innovative digital platforms (that reshape the theory of the firm, to be considered as a network of contracts) can be better understood using network theory. Network (graph) theory is intrinsically fit to describe and measure (in mathematical terms) the relationships among nodes that are connected through edges.

An exact mathematical measurement – in economic terms – of the interactions among the traditional and digital stakeholders is still unavailable. Relational governance patterns, linked to social networking and human resource interactions, are for instance difficult to measure, despite being the "psychological glue" that ties stakeholders together.

Stakeholders can innovatively be interpreted as interacting nodes that exploit digital links (platforms) to improve their cooperation. As a result, (big) data sharing improves, softening information asymmetries which are a major corporate governance concern. Risk-return sharing also benefits from better and more timely joint information. Trendy applications of this interaction may include artificial intelligence patterns, nurtured by big data stored in the cloud.

The interpretation of digital platforms through network theory (Moro Visconti, 2020, chapter 3) is consistent with scalability features. Economies of scale and experience are a fundamental features of networks and intangible (digital) business models. And whenever traditional stakeholders interact with virtual digital platforms, the networked firm is enabled to create scalable value, boosting information sharing, especially with value co-creating customers that share returns, minimizing risk even through timely feedback. More specifically, the online interaction of stakeholders (with social networking and big data sharing) reshapes corporate governance patterns. Using big data, firms gather information and data on the needs and wants of stakeholders without requiring direct interaction (Pedrini and Ferri, 2019).

Corporate governance structures and firms connected through digital platforms become decentralized, unmediated (Fenwick *et al*., 2017), and interconnected. Networks follow iterative patterns and are frequently horizontal, open, and independent; the way stakeholders interact is drastically reshaped, with disruptive consequences on governance:

- vertical hierarchies (typical of family businesses or multinational firms) are replaced by sharing mechanisms; The current discussion about corporate governance ignores the transition from a centralized to a decentralized, unmediated, and interconnected world and from a world of vertical hierarchies to a world of horizontal, open, and autonomous networks. (Fenwick *et al*., 2017);
- stewardship changes accordingly and is replaced by horizontal interaction among stakeholders;
- personalized consumer experience (with real-time feedbacks that fuel value co-creation patterns) becomes increasingly important;
- peer-to-peer (P2P) transactions replace traditional supply chain patterns;
- Stakeholders interact via contract nexuses to co-create shared value.

External contract nexuses typically involve synergic stakeholders connected to the firm with pass-through contracts or other cooperation agreements.

Both the networked firm and the digital platform(s) can be considered a bridging node, as shown in Figure 4. According to the Granovetter (1973) theorem, strong ties are unlikely to be the sources of new information since they already share data. Bridges are weaker ties (as they tend to have little if any link with indirect nodes) and are consequently the best potential sources of novel information. Governance implications, as shown in the preceding sections, are still largely unexplored and may confute some of the Granovetter theses, considering the pervasive impact of digitalization that may strengthen weak ties. Even this issue deserves further theoretical and practical analysis.

New research avenues may for instance include:

- The architecture of the digital ecosystem (see Wareham *et al*., 2014) to balance the different interests (with a trade-off between centralized versus distributed control), bypassing vertical hierarchies, favoring horizontal interaction of stakeholders and their incentives to co-create and share value;
- The relationships between platform providers and mobile app developers (see Eaton *et al*., 2015);
- Vulnerability of the network (to cyber-attacks, etc.) due to interconnectivity;
- The features of networked / digital supply and value chains (exemplified in Figure 5) and their incremental (differential) value, compared to traditional supply / value chains;
- Competition between platforms (dominant versus newcomers, etc.) in multi-sided markets (Rochet and Tirole, 2003), especially in the presence

of tech giants (in e-commerce; social networking, etc.) and other keystone firms able to extract monopolistic rents;
- The issue of how to govern digital platforms and their ecosystem, balancing the different interests of the networked stakeholders (Darking *et al*., 2008);
- Innovative ways (following digital/networking patterns) to interpret the current relation between environmental, social, and governance (ESG) criteria and corporate financial performance (Friede *et al*., 2015; Bellavite Pellegrini *et al*., 2019);
- The corporate governance implications of smart working, an organizational process that rotates around digital platforms.

9. Conclusion

This study analyzes the impact of digital platforms (whose properties are enhanced by the scalability of network theory) on the corporate governance interactions among the composite stakeholders. It has been proven, consistently with the research question of the paper, that when traditional stakeholders become digitally connected through bridging platforms, they improve their risk-adjusted return proceeds. This is also due to better and more timely circulation of "digitized" information.

Digitalization is the process of transforming information or physical products into digital form, allowing businesses to "go paperless". Thanks to digital solutions new forms of innovation and creativity are conceived while traditional business models are revised. Old-fashioned firms interact with digital startups, with a cross-pollination process that drives the analogic-to-digital transition. Digital links enable real-time exchange of information or e-transactions (B2B2C), reducing information asymmetries and other frictions. Real-time interaction between stakeholders helps to minimize risk and enhance returns by win-win value co-creation paradigms.

Digital platforms are emerging as a virtual stakeholder that bridges nodes among players inside and outside the firm. The platform, as well as firm interactions, may conveniently be interpreted with network theory, showing which are the links among the stakeholders and how they concretely work.

The interactions among composite stakeholders raise conflicts of interest that threaten the dynamic equilibrium of ecosystems. Interfacing digital platforms deeply reshape these relations via a better sharing of (big) data. The challenge is to design sounder ecosystems that converge interests and make

the digital supply and value chain more resilient. Improved flexibility to endogenous conflicts and exogenous shocks reduces risk, minimizing governance criticalities.

The dialectic interplay between the physical world and its digital mirror is still under-investigated and may be interpreted with Plato's allegory of the cave, wondering if the shadows perceived by the prisoners are the real or the digital world.

The interdisciplinary interpretation illustrated in this study fills a gap in the literature and has profound implications on some critical corporate governance issues. In this way it may inspire a new literature strand which addresses the still under-explored digital interactions between physical and virtual stakeholders.

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