Bridging the Gaps

Connecting Research Streams in Organizational Network Research

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Abstract

Apart from an introduction and conclusion, the present dissertation consists of four chapters in the form of three research papers and one essay. Each of these chapters revolves around organizational networks and attempts to bring research streams together that deal with the same – or similar – phenomena, yet are largely disjunct. In that sense, each chapter is attempting to *bridge gaps*. The first of these chapters investigates partner selection in business ecosystems and brings together the ecosystem and network literature. Second is an essay which introduces four new effects to a popular method for analyzing network dynamics, bringing together management science and mathematics. Third is a research paper analyzing the interdependence between corporate strategic actions and board interlock networks, bringing together the antecedents and outcomes of the latter. And finally, the fourth of these chapters brings together director- and firm-level research on board interlock networks by estimating the formation of such a network when introducing both levels into a stochastic model. The dissertation advances our understanding of organizational networks and the methods we can use to learn about them.

Keywords: Organizational Networks, Network Dynamics, Network Outcomes

“Dynamics of Organizational Networks in the Style of Edward Hopper”, created by Dall-E 2

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As in everybody's life, my life has seen a fair share of occurrences that I never planned for, but in retrospect am glad they happened. Near the top of the list of these unplanned occurrences that turned out to be a pretty good thing is probably writing a dissertation. I also can firmly attest to the fact that referring to *bridges* in the title of this dissertation has not been something that I had any plans for when I started my venture into academia. However, given that bridges are probably among the most meticulously planned structures one can imagine, I find it both a great reflection of academic research and an odd display of irony, two things I thoroughly enjoy.

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Steffen Triebel

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Chapter 1
Introduction

In early 2020, the World Health Organization declared the COVID-19 outbreak a pandemic (WHO, 2020) and with that, much of the world – including Western Europe and the United States – came to a grinding halt. The response in most industrialized countries was shaped by societal turbulence and political uncertainty and included a number of non-pharmaceutical inventions, such as school closures, mask mandates or lockdowns (Dahlquist and Kugelberg, 2023; Lionello, Stranges, Karki, Wiltshire, Proietti, Annunziato, Jansa, Severi, and group, 2022; Mader and Rüttenauer, 2022). Less than a year later, vaccine candidates were announced and, after trial, obtained emergency approvals in many countries (Rogers, 2022). Among all the turmoil, the speedy development, production, and distribution of effective vaccinations were a testament to a constant that is well-known to management researchers: the prevalence and importance of interorganizational relations (Parmigiani and Rivera-Santos, 2011; Shipilov and Gawer, 2020; Weck and Blomqvist, 2008).

Yet, while the collaborative efforts of firms will come as a surprise to neither layman nor management scholars, the latter have long established that interorganizational relations are much more complex than the seemingly dyadic effort to finding a joint solution to a problem – such as Pfizer collaborating with BioNTech to develop Comirnaty and bring it to market (BioNTech, 2020). In reality, organizations are rarely connected to only one other organization. Rather, they are regularly embedded into networks (Granovetter, 1985), which are "set[s] of actors connected by a set of ties" (Borgatti and Foster, 2003: 992). Depending on a firm's position in its network, this embeddedness provides the firm with various benefits and opportunities: Bridging the gap between different clusters of firms may allow a focal firm to become a broker and thus be able to either forward exclusive information to foster collaboration or withhold said information to benefit from it – effectively acting as the proverbial *tertius iungens* or *tertius gaudens* (Ahuja, 2000; Quintane and Carnabuci, 2016). As another example, firms may be very well embedded into their network and benefit from a high level of closure by accessing complementary capabilities and having trusted relationships (Gulati, 1995; Gulati, Sytch, and Tatarynowicz, 2012). Not all network effects are beneficial, however. Instead, networks may constrain a firm's opportunities or have unforeseen – and sometimes unwanted - consequences. For instance, Li and Berta find that low-status banks have to repeatedly trade with former partners instead of being able to extend their transaction opportunities due to the hierarchical nature of bank networks (Li and Berta, 2002). Knowledge and information have been shown to homogenize over time in networks, and, as such, rigid routines set in that potentially hamper creativity (Ferriani, Cattani, and Baden-Fuller, 2009; Soda, Usai, and Zaheer, 2004). Clearly, the question of what the consequences of interorganizational networks are (and if these consequences are always desirable from a firm's perspective) does not have an answer that is as clear cut as the exemplary success story of the Comirnaty vaccines. Such tensions between beneficial and detrimental outcomes of networks only scratch the surface of research on interorganizational networks. Research on the consequences of networks is complemented by research on the formation and dynamics of such networks (Chen, Mehra, Tasselli, and Borgatti, 2022; Kim, Howard, Pahnke, and Boeker, 2016), in which researchers are focused on how and why firms form or dissolve ties. In addition, interorganizational networks occur in many different forms, among them strategic alliances (Albers, Wohlgezogen, and Zajac, 2013; Gulati, 2017; Ryan-Charleton, Gnyawali, and Oliveira, 2022), board interlock networks (Chu and Davis, 2016; Hernandez, Sanders, and Tuschke, 2015; Mizruchi, 1996), supply chain networks (Humphrey, 2003; Ostrovsky, 2008; Su, Kao, and Linderman, 2020) or business ecosystems (Hannah and Eisenhardt, 2018; Kapoor and Lee, 2013; Zhang and Liang, 2011). Considering how rich and complex the field is and how many different aspects one can focus on when analyzing interorganizational networks, there is much to learn from the extant literature, while, at the same time, there are plenty of questions left to be asked that may advance our understanding of this every-day phenomenon.

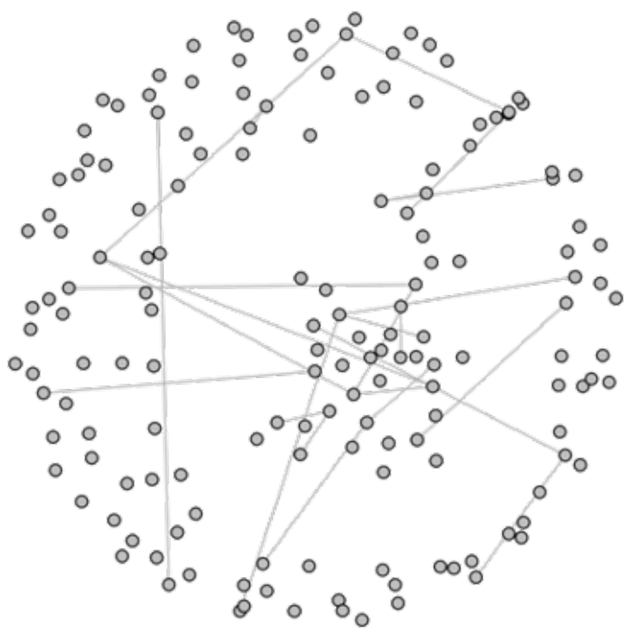
Apart from the following introductory passages and conclusion, this dissertation contains four chapters - three research articles as well as one essay -, each of which attempts to resolve some of these open questions. Each of these four chapters attempts to bridge different research streams while employing contemporary network research methods. The first of them, *Partner Selection in Business Ecosystems: A Network Approach*, links the business ecosystem literature and learnings from extant network research, using novel developments in stochastic actor-oriented models. While business ecosystems are typically not analyzed by the means of network research, my co-authors and I argue that both research streams are strongly related and can benefit from each other (Jacobides, Cennamo, and Gawer, 2018; Shipilov and Gawer, 2020). Using a unique dataset of value chains of the four largest US-based pharmaceutical firms, the paper presents a nuanced depiction of partner selection in business ecosystems and discusses the internal dynamics of such ecosystems. Second is the essay *Modeling Core-Periphery Structures in Management Research*, which introduces four non-linear rate effects for stochastic actor-oriented models that have been written during the course of this dissertation and by now have been implemented into the corresponding R library, *RSiena*. These effects allow management researchers to capture the core-periphery structure that is characteristic of many interorganizational networks based on in- and reciprocal degree distributions more accurately than previously possible. The essay illustrates the use of these effects and discusses potential cases in which their implementation may prove useful. It bridges management theoretical considerations regarding interorganizational networks and methodological advances in network research (Provan and Kenis, 2007). The third is a paper titled *The Coevolution of Board Interlock Networks and Corporate Strategic Action*, which bridges research on the dynamics and consequences of board interlock networks (Haunschild, 1993; Howard, Withers, and Tihanyi, 2017; Withers, Howard, and Tihanyi, 2020). The paper relies on the idea that the dynamics and consequences of board interlock networks are not disjunct phenomena – which is how they are typically treated in extant literature – but rather part of a recursive process. It takes on a structurationist perspective (Giddens, 1984) to develop hypotheses and, using a data set of board interlocks between large German firms, finds that a coevolution process is occurring. Fourth is a paper called *Integrating the Two Modes of Board Interlock Research*. Set in the context of board interlock networks between the Fortune 500, it deals with the problems that occur when treating multimodal phenomena as if they were only occurring on one mode – a technique that is commonly referred to as projection. Precisely, the paper bridges the contradicting results that stem from different theoretical perspectives on outside director selection between the firm and director level (Withers, Hillman, and Cannella, 2012). The results suggest that projected network models introduce considerable biases and that using a two-mode approach allows to resolve contradictory evidence in extant literature by providing detailed results. They further suggest that the director level, and thereby social processes, is dominant in explaining network formation, while the rational considerations that we typically attribute to firm level effects tend to be more spurious. Going forward, I present a brief history of organizational network research in management studies followed by a short overview of the tools available to network researchers and their characteristics. In line with the main themes of this dissertation, I emphasize interorganizational networks rather than intraorganizational networks. Subsequently, I present the four studies briefly introduced in the last paragraph and offer a conclusion as well as avenues for future research.

1.1 A Brief Overview of Research on Organizational Networks

While the general idea that network structures – the smallest of which is a triad – play an important role in the social sciences to explain observed phenomena can be traced back to Georg Simmel in the early 20th century (Freeman, 2004), this perspective only gained substantial popularity with management scholars when sociologist Mark Granovetter published his seminal work *Economic Action and Social Structure: The Problem of Embeddedness* (Granovetter, 1985). In it, he argues that "[u]nder- and oversocialized accounts are paradoxically similar in their neglect of ongoing structures of social relations" (1985: 481). In other words, Granovetter proposes that typical economic explanations fall short of taking the social structures under which economic actors act into account, whereas reformist economists and sociologists tend to neglect the agency of economic actors by overstating the role of the surrounding social structures. A network approach is instead neither under- nor over-embedded, but views "the world from a structural rather than (or in addition to) an autonomous lens, thus representing a distinct (and arguably more complete) worldview" (Zaheer, Gözübüyük, and Milanov, 2010: 62). The perspective that economic actors' actions are neither independent from social structure nor dictated by it has since found much resonance in the management research community. It has sparked much work that gradually moved away from atomistic explanations to a more relational understanding of why organizations act as they do. As noted by Borgatti and Foster, "[t]he volume of social network research in management has increased radically in recent years" (2003: 991), and this trend has continued in the past two decades. Almost four decades after *The Problem of Embeddedness* was printed, network research plays a significant role in the scholarly assessment of management processes as is evident by the many reviews of extant literature and roadmaps for future research published in high-ranked journals (Chen *et al.*, 2022; Jacobsen, Stea, and Soda, 2022; Shipilov and Gawer, 2020; Tasselli and Kilduff, 2021; Tasselli, Kilduff, and Menges, 2015).

First and foremost, network research is a research paradigm that allows scholars to analyze and evaluate the relationships actors entertain. Over the years, there have been many attempts to define what makes up a network and why studying them is worthwhile (Borgatti and Foster, 2003; Borgatti and Halgin, 2011). Mitchell, for example, offered a relatively comprehensive definition of what networks are as early as 1969: "Networks are a specific set of linkages among a defined set of actors, with the additional property that the characteristics of these linkages as a whole may be used to interpret the social behaviour of the actors involved." (Mitchell, 1969: 2) In organizational research, one of the earliest definitions of social networks stems from Tichy, Tushman & Fombrun, who state that "[t]he social network approach views organizations in society as a system of objects (e.g., people, groups, organizations) joined by a variety of relationships" (1979: 507). As a research paradigm, scholars often take on a structural perspective on networks. Thus, one may follow Freeman (2004), who proposes four principal foundations for network research: (1) Relationships between actors are a *relevant* phenomenon to perform research on, (2) relationships are *meaningful*, (3) they can be visualized, which allows researchers to see *patterns* and (4) they can be *formalized* through the use of graph theory. The common denominators in most – if not all – definitions, are that networks are made up of actors, which are often called *nodes*, and that these actors are connected through ties, which are often called *edges*. Networks are typically depicted by circles (or squares), which represent nodes, and lines, which represent edges. Figure 1.1 gives an example of a very simple network with a relatively low density, meaning that relatively few possible connections between nodes are realized.

Figure 1.1: A typical network visualization



Importantly, the way in which actors are tied to one another matters. To network scholars, it is of major interest what characterizes ties, and these characteristics span many facets of life, such as "friendship, advice, discussion, and dislike" (Tasselli *et al.*, 2015: 1364). Equally as important is the question of what goods flow through network ties, intangible goods, such as knowledge, or tangible goods, such as money (Borgatti, 2005). The aggregation of ties between actors forms a network, which is characterized by different patterns and structures, such as cliques (Gulati, 1999; Provan and Sebastian, 1998), and roles that actors take on, some of which they can only take on *because* of their specific position in the network. One of these roles would be brokerage (Burt, 2005), which allows actors that span disconnected cliques to either facilitate collaboration or separation between these cliques (Grosser, Obstfeld, Labianca, and Borgatti, 2019; Quintane and Carnabuci, 2016). There are many aspects that further complicate research on networks, for example if ties are directed or undirected, if ties are binary or valued, or if ties are multiplex and comprise multiple domains (Borgatti and Foster, 2003; Shipilov, Gulati, Kilduff, Li, and Tsai, 2014). In research on interorganizational networks, actors are typically organizations, such as firms. However, the same principles one would expect from research on networks of adolescent youths (Mercken, Snijders, Steglich, Vartiainen, and Vries, 2010) or colleagues in the workplace (Oksanen, Kouvonen, Kivimäki, Pentti, Virtanen, Linna, and Vahtera, 2008), still apply: Actors, which are connected via ties, form networks through their actions and the structure and composition of these networks influence what actions these actors take in the future.

1.2 Research Perspectives on Organizational Networks

Organizational networks are complex, dynamic phenomena made up of diverse sets of actors. Management research in the past decades has primarily taken on two different perspectives on organizational networks: Scholars broadly distinguish between the *theory of networks* and *network theory*, the former of which refers to the "processes that determine why networks have the structures they do" (Borgatti and Halgin, 2011: 1168), while the latter refers to "the mechanisms and processes that interact with network structures to yield certain outcomes for individuals and groups" (Borgatti and Halgin, 2011: 1168). In layman's terms, scholars studying organizational networks are interested in their *formation and dynamics* as well as their *consequences*. In more recently emerging research streams, management researchers also began theorizing about and analyzing multiplex connections – such as the simultaneous existence of dissonant and advice ties among colleagues (Brennecke, 2020) - and multilevel networks – such as affiliation networks between multiple levels, like work projects and individuals or actors and seasons of a TV show (Conaldi, Lomi, and Tonellato, 2012; Soda, Mannucci, and Burt, 2021). These more recently evolving research streams are not distinct from the analysis of network formation, dynamics, and outcomes. Rather, they form subthemes, in which researchers analyze the dynamics or consequences of said multiplex or multilevel networks (Shipilov *et al.*, 2014; Stadtfeld, Mascia, Pallotti, and Lomi, 2016). Notably, the seemingly distinct research perspectives that focus on either formation and dynamics or consequences are not as unrelated as they may seem at first glance. Instead, researchers recently began to put emphasis on the notion that networks dynamics and consequences often coevolve (Kalish, Luria, Toker, and Westman, 2015; Parker, Waldstrøm, and Shah, 2022; Tröster, Parker, Knippenberg, and Sahlmüller, 2019). Research that deals with coevolution processes in interorganizational networks, however, is still exceedingly rare (with exceptions, of course, such as Matous and Todo, 2017) and has yet to catch up with other contemporary studies from the field of organizational network research, which have so far focused on recursive processes between the dynamics and consequences of interpersonal networks.

1.2.1 Network formation and dynamics

Assessing the formation and dynamics of organizational networks is critical since overarching structures enable and constrain an organization's actions, and particular network structures can be beneficial or detrimental to an organization's goals. Thus, any "understanding of network outcomes is incomplete and potentially flawed without an appreciation of the genesis and evolution of the underlying network structures" (Ahuja, Soda, and Zaheer, 2012: 434). Scholars interested in the formation and dynamics of networks typically ask questions about which attributes, actions, and processes lead to certain structural patterns and the network positions of specific actors. While earlier network research often examined specific network properties, such as structural cohesion or the existence of small world-properties (Moody and White, 2003; Watts, 1999), the introduction of more complex network models, such as exponential random graph models or stochastic actor-oriented models allowed researchers to "examine multiple interdependent social processes involved in network formation" (Kim *et al.*, 2016: 23). These interdependent social processes do not only refer to the role of nodal attributes, for example assuming that larger firms will tend to have more ties to other firms than their smaller counterparts. Rather, there are endogenous mechanisms inherent in networks that "are thought to regulate the likelihood that particular relationships materialize" (Corbo, Corrado, and Ferriani, 2016: 324). Four of the most important endogenous network mechanisms are reciprocity, homophily, assortativity, and network closure. The first, reciprocity, describes "a form of interaction that essentially centers on mutuality" (Göbel, Vogel, and Weber, 2013: 34) and refers to the tendency of network actors to reciprocate existing ties. Next is homophily, which laymen know by the proverb birds of a feather flock together, refers to the tendency of actors in networks to associate with others with whom they share similar attributes (Ertug, Brennecke, Kovacs, and Zou, 2022; Lawrence and Shah, 2020). A third mechanism, assortativity, refers to the tendency of nodes to attach to others with a particular degree centrality, or in other words: the number of ties (Khanna and Guler, 2022; Rivera, Soderstrom, and Uzzi, 2010). This degree centrality might be similar between nodes, in which case assortativity would represent a form of structural homophily, or nodes might tend to be attracted to other nodes that exhibit a high degree centrality, in which case one would observe the mechanism proverbially known as the rich get richer, often also called the Matthew-effect. The final example of elementary network mechanisms is network closure. In its most simple and easily understandable form, this occurs in the form of transitive triads. These triads follow the tendency that a friend of a friend becomes a friend. Thus, for organizations partnering with another organization at a given time point, it is likely to also partner with a partner of that organization at one point in the future. For network closure, there have been many developments in the past decades that (often) more accurately capture the underlying social processes, for instance geometrically weighted depictions (Robins, Snijders, Wang, Handcock, and Pattison, 2007b; Snijders, Pattison, Robins, and Handcock, 2006).

Some examples of recent studies that deal with the formation and dynamics of organizational networks on the firm level include the works of Clough et al. (2020), Withers et al. (2020) as well as Hernandenz and Menon (2018). Clough and colleagues, for instance, examine how managers evaluate if they should continue or dissolve existing exchange ties. In the context of a firm building a Formula One racing car, they find that "a firm building a Formula One racing car is more likely to end an exchange relationship with an engine supplier after that supplier's other customers experience an episode of poor performance relative to their historic track record" (Clough and Piezunka, 2020: 972). The second aforementioned example analyzes how board interlock formation is influenced by financial restatements of firms. It finds that financial restatements disrupt a firm's network but that this disruption is mitigated through social status and that "restating firms build new ties through socially embedded processes, such as reciprocity and transitivity" (Withers *et al.*, 2020: 1). Hernandez and Menon theorize that acquisitions lead to what they call a node collapse and that such collapses "can radically restructure the network in one transaction, constituting a revolutionary change compared with the incremental effect of tie additions and deletions, which have been the focus of prior research" (Hernandez and Menon, 2018: 1). They use a simulation approach to support their assumptions. Even though interorganizational networks have been studied for decades and there has been a large variety of contexts and tested explanations, "the relative importance of the studied network drivers remains a puzzle" (Novoselova, 2021: 2). According to Novoselova

(2021), six dimensions can be distinguished that drive interorganizational connectedness: time, industry, geography, organization, networks, and agents. Research on interorganizational networks has been subject to many different theoretical perspectives, such as resource dependency theory or agency theory (Eisenhardt, 1989; Hillman, Withers, and Collins, 2009; Pfeffer and Salancik, 1978a) and, over decades, many different contexts and types of interorganizational networks, such as board interlocks or strategic alliances, have been studied (Gulati, 2017; Lamb and Roundy, 2016). Considering that hundreds of studies have not yielded a conclusive and comprehensive explanation of what drives interorganizational networks, it is perhaps unsurprising that the conclusion to the question of what drives interorganizational networks is, at least for the time being, "everything matters" (Novoselova, 2021: 21). Thus, more research is needed to further sharpen our view on interorganizational networks and provide more pieces to the puzzle of what drives their formation and dynamics.

1.2.2 Network consequences

Like there are multiple different drivers that shape how networks form and change over time, research has long established that the consequences that result from networks are manyfold. On the individual level, these include job entrance and exit (Fernandez, Castilla, and Moore, 2000; Tröster *et al.*, 2019), a tendency for homogenization across attitudes among members of organizations (Galaskiewicz and Burt, 1991; Umphress, Labianca, Brass, Kass, and Scholten, 2003) or power (Blau and Alba, 1982; Brass and Burkhardt, 1993), among many other aspects. Studies on networks between organizations have likewise found many different consequences of interorganizational networks. Perhaps one of the best-researched areas in this field is research on *imitation* as a consequence of interorganizational networks. Here, it is assumed that "[n]etwork ties transmit information and are thought to be especially influential information conduits because they provide salient and trusted information that is likely to affect behavior" (Brass, Galaskiewicz, Greve, and Tsai, 2004: 805). For example, Haunschild (1993) finds that "[t]here is a relationship between a focal firm's acquisition activity and acquisition activity by those firms that are tied to a focal firm through directorships" (Haunschild, 1993: 586), thus suggesting that firms imitate corporate strategic actions of their direct ties. Other studies find that firms are influenced in their decision to acquire high-tech ventures by prior acquisition experiences of other firms in their network (Ozmel, Reuer, and Wu, 2017) or that the adoption of stock option pay is influenced by a firm's board interlocks (Yoshikawa, Shim, Kim, and Tuschke, 2020). A second major area of research on network consequences in interorganizational networks is firm performance. For instance, the performance of startups in the Canadian biotechnology sector is significantly influenced by the configuration of their alliance networks at the time of their founding (Baum, Calabrese, and Silverman, 2000). Another study finds that firm performance may be enhanced through board interlocks, which help a firm to adapt when facing high levels of uncertainty (Martin, Gözübüyük, and Becerra, 2015). There are many other areas in which scholars have found support for the notion that interorganizational networks have important consequences, such as innovation (Ahuja, 2000; Khanna and Guler, 2022; Kumar and Zaheer, 2019) or firm survival (Hager, Galaskiewicz, and Larson, 2004). While "network scholars do not claim that network structure is the only, or even the primary, determinant of firm-level outcomes" (Zaheer *et al.*, 2010: 63), there is a broad consensus that networks have important consequences which warrant the continued interest of management scholars. In summary, for network consequences it can be stated that "(1) they transfer information that gives rise to attitude similarity, imitation, and generation of innovations; (2) they mediate transactions among organizations and cooperation among persons; and (3) they give differential access to resources and power" (Brass *et al.*, 2004: 807).

Management scholars researching network consequences either include network measures in traditional statistical approaches (Ahuja, 2000; Beckman and Haunschild, 2002; Connelly, Johnson, Tihanyi, and Ellstrand, 2011) or network models, which allow for scholars to "narrow the gap between theoretically grounded mechanisms of social contagion, and empirical data on organizational networks" (Parker, Pallotti, and Lomi, 2021: 2). These include, but are not restricted to auto-logistic actor attribute models, which "afford direct modeling of a variety of dependencies that may be of general theoretical interest or contextual empirical relevance" (Parker *et al.*, 2021: 2) and are derived from exponential random graph models, or the co-evolution variant of stochastic actor-oriented models (Kalish, 2020; Snijders, Bunt, and Steglich, 2010), in which the notion that "networks create outcomes that are, in turn, antecedents for further network development" (Brass *et al.*, 2004: 809) is inherent.

1.3 A Compendium of Network Models

As has been laid out above, network research has seen a steady increase over the past decades in management research, including but not restricted to research on interorganizational networks. Much of this success rests on the advent of computational social network analysis that started with the so-called *Harvard revolution* starting in the 1970s. In the following years, scholars such as Harrison White, Mark Granovetter and Barry Wellman worked on the formalization of social networks, allowing quantitative measurements to be integrated into types of analyses that were more familiar to sociologists and business scholars at the time (such as logistic regressions), while also developing early versions of more complex network models, such as block models (Freeman, 2004). Today, scholars interested in researching social networks have a large compendium of increasingly complicated but also increasingly capable statistical models to choose from, which typically either treat the network as the dependent variable or derive the network's influence on attributes of interest. In this section, I will present five models in total, two of which have become commonplace in management research and three, that, while offering great potential for future research, have seen relatively little application in the field. Table 1.1 presents a classification of this compendium presented in the following section.

Table 1.1: Overview of the network model compendium

Model Name / Characteristic		*Stochastic actor-oriented model (SAOM)*	*Exponential random graph model (ERGM)*	*Dynamic network actor model (DyNAM)*	*Relational event model (REM)*	*Auto-logistic actor attribute model (ALAAM)*
Logic	Actor-based	x		x		
	Tie-based		x		x	x
Time	Cross-sectional		x			x
	Longitudinal	x		x		
Perspective	Network as outcome	x	x	x	x	
	Network as antecedent	x				x
Network foundation	Relational states	x	x	x		x
	Relational events			x	x	

The columns in Table 1.1 represent the five most capable models for network research at the time of writing. Two of these – SAOMs and ERGMs – are relatively common in management studies, while DyNAMs, REMs and ALAAMs offer a large potential that management scholars studying networks have so far left largely untapped, bar some exceptions (Parker *et al.*, 2021; Quintane and Carnabuci, 2016). The rows in Table 1.1 represent the characteristics of these models, which are divided into four foundational categories: First is *logic*, where it can be distinguished if network models are actor-oriented or tie-based. For the former, it is assumed that "the nodes of the graph are social actors having the potential to change their outgoing ties" (Snijders, 2016: 344). For tie-based models, the analysis "examines tie formation at the network level" (Kim *et al.*, 2016: 23) and is thus not based on actor preferences. Second is *time*. This category distinguishes if the models are based on cross-sectional or longitudinal data, thus if they model the likelihood of a given network state or the dynamics of a network. It should be noted that there are extensions available that allow for longitudinal analysis using models that are typically thought of as cross-sectional, such as temporal ERGMs and REMs (Leifeld, Cranmer, and Desmarais, 2018; Meijerink-Bosman, Leenders, and Mulder, 2022). The categorization presented here, however, is based on the basic principles that the presented models are built on. Third is *perspective*, which distinguishes between networks as outcomes and thus being the dependent variable and networks as antecedents, thus, being the explanation behind an actor's behavior or action. Fourth and last is *network foundation*, which can be separated into relational states and relational events. Relational states refer to semi-permanent connections such as "the formation, transformation, or dissolution of a friendship tie" (Chen *et al.*, 2022: 1604), while relational events refer to sequences of more or less concerted actions such as "emails exchanged over time among a set of actors" (Chen *et al.*, 2022: 1604). Although the five models presented above seem the most promising for future endeavors in management research, the compendium is by no means comprehensive. Instead, there are more methods available, such as quadratic assignment procedures or the integration of network measures into regressions, which is still the most common application of a network perspective, though often limited to the analysis of dyadic connections (Chen *et al.*, 2022).

1.3.1 Stochastic actor-oriented models

The most widely used model for the analysis of network dynamics in management research, but also adjacent fields, are stochastic actor-oriented models, often also called SIENA models. They take on the philosophy that "[s]ocial networks are dynamic by nature" and have the purpose "to represent network dynamics on the basis of observed longitudinal data, and evaluate these according to the paradigm of statistical inference" (Snijders *et al.*, 2010: 44). From a SAOM-perspective, actors can control how and when they change their outgoing ties. To estimate and understand these changes, SAOMs then take structural properties as well as nodal and dyadic attributes into account. Ties in SAOMs are generally thought of as relational states. Thus, they are semi-permanent connections, and their existence has meaning. Existing (and non-existing) ties then influence the decision of an actor to create, maintain or dissolve ties, which is modeled through an objective function (*which* change is made) and a rate function (*how often* a change is made). Importantly, SAOMs allow for the modeling of coevolution processes, meaning that networks can be antecedents in addition to outcomes. They feature a high number of options for the specification of network constraints as well as effects on the actor, dyad, and network level. Over the past decades, developments in SAOMs have been rapid, and various functionalities have been added, for example, the option to model two-mode data, assess time heterogeneity, and include non-discrete attributes as network outcomes (Lospinoso, Schweinberger, Snijders, and Ripley, 2011; Niezink, Snijders, and Duijn, 2019; Snijders, Lomi, and Torló, 2013). Together with their capability to model coevolution processes, the flexibility of SAOMs makes them a high-ranking choice among management scholars interested in studying networks. This is evident by the wide range of topics covered across different areas of management research, such as rivalry between neighborhoods competing in the horse race Palio di Siena (Sgourev and Operti, 2019), the relationship between film school students and institutional logics (Ebbers and Wijnberg, 2019) or how knowledge dependence leads to the formation of board interlocks (Howard *et al.*, 2017).

1.3.2 Exponential random graph models

While SAOMs are actor-oriented and longitudinal by nature, ERGMs form a tie-based, cross-sectional counterpart (Kim *et al.*, 2016). In contrast to stochastic actor-oriented models, exponential random graph models are not concerned with how attractive an actor deems another actor as a partner. Rather, "ERGMs model which configurations are more likely to exist" (Stadtfeld, Hollway, and Block, 2017: 6). Like the previously described SAOMs, ERGMs allow network researchers to specify models "to be built from a more realistic construal of the structural foundations of social behavior" (Robins, Pattison, Kalish, and Lusher, 2007a: 173), meaning that they account for the interdependences between actors and allow scholars to incorporate structural effects into their analysis. In general, ERGMs aim to explain the likelihood of observing network patterns and substructures. Estimated parameters thus express if these patterns "are more commonly observed in the network than might be expected by chance" (Robins *et al.*, 2007a: 175). Although fundamentally different in their approach, ERGMs, like SAOMs, feature a large variety of effects that can be included to obtain a wellfitting model (Robins *et al.*, 2007a, 2007b; Robins, Pattison, and Wang, 2009). Over the past two decades, multiple extensions to ERGMs have been developed and these models now allow for the analysis of two-mode networks or the inclusion of time, to name two examples (Robins and Pattison, 2001; Wang, Sharpe, Robins, and Pattison, 2009; Wang, Pattison, and Robins, 2013). Management scholars have taken a liking to ERGMs due to their flexibility and the ability to use cross-sectional data, which allows to view networks as reaching a state close to equilibrium, thus answering questions about network formation instead of network dynamics. Studies using ERGMs deal, for instance, with the role of dissonant ties for individuals who seek problem-solving assistance (Brennecke, 2020), interorganizational collaboration networks in economic development policy (Lee, Lee, and Feiock, 2012) or the drivers behind the formation of board interlock networks (Kim *et al.*, 2016).

1.3.3 Dynamic network actor models

Different from the aforementioned two model types, the primary aim of DyNAMs is to explain the creation or dissolution of relational events rather than relational states. In other words, DyNAMs aim "for the study of coordination networks through time" (Stadtfeld *et al.*, 2017: 2). As their internal logic is loosely related to SAOMs, they are dynamic (in the sense that they rely on longitudinal data) and actor-oriented. A network of relational states, such as friendship ties, is necessary to explain the dynamics of relational events with DyNAMs. The relational event data needs to be time-stamped and thus be much more granular than regular panel data. This data structure then allows for the analysis of the role of time windows (for example: sending a complaint about a misbehaving colleague is more likely in the three days after the incident than afterward) but also for the role of network structures on relational events (for example: strategic alliances in which participating firms form transitive triads are quicker to register patents than firms that organize their strategic alliances in separated dyads). The introduction of DyNAMs to the network model compendium has been relatively recent. Thus, only very few management studies that apply them have been published as of yet (Bianchi and

Lomi, 2022). Given their unique place in the network model compendium and extensive capabilities, among them the inclusion of weighted and signed ties, they offer a promising tool for future research in the field of management.

1.3.4 Relational event models

A second class of models that aims to explain relational events rather than relational states are relational event models, or REMs for short (Butts, 2008). These have been available considerably longer than DyNAMs but are tie-based and thus related to ERGMs rather than SAOMs. REMs model relational events as discrete occurrences and, like all network models presented here, allow researchers to incorporate complex dependencies and network patterns into the analysis. Data points in REMs need to be time-stamped. Thus, REMs are longitudinal by nature, but traditional panel data, which is often more readily available than time-stamped data, is not sufficient. REMs have seen considerably less application in management studies than SAOMs and ERGMs. The published applications, however, cover a wide range, from board interlock networks (Valeeva, Heemskerk, and Takes, 2020) to patient transfers among hospitals (Kitts, Lomi, Mascia, Pallotti, and Quintane, 2017; Vu, Lomi, Mascia, and Pallotti, 2017) or information brokerage (Quintane and Carnabuci, 2016).

1.3.5 Auto-logistic actor attribute models

The last network model type of the selection presented here are ALAAMs, which do not aim to explain network formation or dynamics but instead focus on offering "a principled analytical framework for modeling social contagion that predicts the presence of an individual attribute (or behavioral outcome)" (Parker *et al.*, 2021: 2). Like all network models, they do so by taking social structures and network patterns into account. ALAAMs are closely related to ERGMs and have been derived from their undirected variant (Robins, Elliott, and Pattison, 2001). Thus, they model social contagion processes based on cross-sectional data and are tie-based, not actor-oriented. Even though ALAAMs, at least in their initial formulation, have been around for more than two decades, applications in settings relevant to management research remain exceedingly rare (Kashima, Wilson, Lusher, Pearson, and Pearson, 2013; Parker *et al.*, 2021). Given that longitudinal data is often difficult to obtain and that there are limited options to model network outcomes with proper network models, ALAAMs offer exciting prospects for future research in management studies.

1.4 Overview of the Main Chapters

The following chapters take the format of three research articles as well as one essay and represent the core of this dissertation. Each chapter deals with a different research question and, with the exception of the essay presented in chapter 3, features a different empirical setting and data set. All chapters, however, can be allocated to concepts that have been introduced in prior sections of this dissertation, such as the research perspective (network dynamics and formation versus consequences) or model choice. Tables 1.2 to 1.5 present a short overview of the main chapters, including their research objective, full lists of authors, and additional acknowledgments not reflected in the lists of authors. More details are, of course, found in the corresponding chapters.

Table 1.2: Overview of chapter 2

Partner Selection in Business Ecosystems – A Network Approach

Format	Research article
Research motivation	Over the past decades, interest in business ecosystems has steadily increased. However, it is unclear how the dynamics of business ecosystems unfold and what role salient resources play in these changes.
Research objective	Explain which partner selection mechanisms are dominant regarding different salient attributes by using a network modeling approach.
Research perspective	Network dynamics
Level of analysis	Organization
Model type	Stochastic actor-oriented model
Network data	Value chains between four large US-based pharmaceutical firms
Main contribution	The chapter contributes to research on business ecosystems by showing that aspiration is the dominant partner selection mechanism in regard to firm size and homophily is dominant in regard to the inventiveness of firms. Based on the results, the chapter provides a nuanced discussion of how firms in business ecosystems select potential partners.
Authors	Steffen Triebel, Julia Brennecke, Christiana Weber, Insa Kramer
Additional acknowledgments	The manuscript benefitted from feedback by participants of the Sunbelt 2021, the Duisterbelt 2021 and the Academy of Management Conference 2022.

Table 1.3: Overview of chapter 3

Modeling Core-Periphery Structures in Management Research

Format	Essay
Research motivation	Organizational networks are often characterized by core-periphery structures in which one organization takes on a coordinating role at a network's center. Such a structure provides considerable challenges when modeling networks.
Research objective	Alleviate modeling issues caused by extreme core-periphery structures by providing options to respect these structures in the model specification.
Research perspective	Network dynamics
Level of analysis	Organization
Model type	Stochastic actor-oriented model
Network data	Value chains of one US-based pharmaceutical firm
Main contribution	The chapter introduces four effects to SAOMs that can help with skewed in- and reciprocal-degree distributions in a non-linear fashion, potentially aiding model convergence and leading to results that are more accurate.
Authors	Steffen Triebel
Additional acknowledgments	Tom Snijders offered extremely helpful and patient guidance and has implemented the proposed effects into the RSiena package, for which I am very grateful.

Table 1.4: Overview of chapter 4

The Co-Evolution of Board Interlock Networks and Corporate Strategic Actions

Format	Research article
Research motivation	Research has shown that corporate strategic action influences board interlock networks and that board interlock networks influence corporate strategic actions. Both research streams have been treated as separate, even though they are clearly related.
Research objective	Theorize and empirically assess if corporate strategic actions and board interlock networks coevolve.
Research perspective	Network dynamics and outcomes
Level of analysis	Organization
Model type	Stochastic actor-oriented model
Network data	Board interlocks between large German firms
Main contribution	Utilizing structuration theory, the paper hypothesizes and empirically shows that board interlock networks and corporate strategic actions coevolve and are not separate phenomena.
Authors	Steffen Triebel, Julia Brennecke, Christiana Weber
Additional acknowledgments	The manuscript benefitted from feedback by participants of the EGOS 2020, the Sunbelt 2020 and the Academy of Management Conference 2021. My coauthors and I are also grateful to Andrew Parker and Wolfgang Sofka, who provided friendly peer reviews.

Table 1.5: Overview of chapter 5

Integrating Two Modes of Board Interlock Research

Format	Research article
Research motivation	Board interlock research typically either takes on a firm- or director-level perspective. These perspectives, which are based on different theoretical premises, have led to contradictory results.
Research objective	Integrate both modes of board interlock research and thereby help to resolve the contradictory results in extant literature as well as assess the prevalence of problems occurring due to the omission of either the firm- or director-level.
Research perspective	Network formation
Level of analysis	Organization and individual
Model type	Exponential random graph model
Network data	Board interlocks between the Fortune 500
Main contribution	The chapter provides a two-mode analysis of board interlocks between the Fortune 500, empirically showing that social explanations tend to dominate the rational considerations research often attributes to firms forming board interlocks.
Authors	Steffen Triebel
Additional acknowledgments	The manuscript benefitted from feedback by participants of the Sunbelt 2022 and Duisterbelt 2022. I am also grateful to Eric Quintane who provided a friendly peer review and David Hunter, with whom I have had many fruitful conversations about the model in the paper.

Chapter 2
Partner Selection in Business Ecosystems: A Network Approach

Abstract

Scholarly interest in business ecosystems has steadily increased over the past decades. While many studies have dealt with theoretical approaches, the architecture or outcomes of business ecosystems, literature on their internal dynamics remains scarce. Without understanding these dynamics, however, our understanding of business ecosystems remains incomplete. In this paper, we investigate the dynamics of business ecosystems in the American pharmaceutical sector, arguing that firms exhibit different partner selection mechanisms depending on which attribute they consider in partner selection. Applying a longitudinal network approach, we find that firms will show tendencies for homophily when considering the inventiveness of potential partners, tendencies for aspiration when considering their size, and tendencies for domination when considering their profitability. Our study makes three contributions: First, we contribute to the literature on ecosystems and networks by bridging the gap between both research streams, opening up a fruitful conversation that benefits both fields. Second, we complement the business ecosystem literature by providing a nuanced analysis of partner selection mechanisms in business ecosystems. Third, we add to the broader field of interorganizational relations by showing how partner selection mechanisms compete with each other and strongly depend on the attributes exhibited by both firms in the partnership.

2.1 Introduction

Business ecosystems are a specific form of interorganizational relations and have become a prominent topic in the debate on how organizations navigate the tension between collaboration and competition (Hannah and Eisenhardt, 2018). Past research in the field of ecosystems has focused on their emergence and architecture (Kapoor and Lee, 2013; Thomas, Autio, and Gann, 2014; Thomas and Ritala, 2021), their role in value creation (Adner and Kapoor, 2010; Kapoor, 2018; Toh and Miller, 2017) or their precise definition (Adner, 2017; Jacobides *et al.*, 2018; Valkokari, 2015). However, scholars have largely neglected the dynamics of business ecosystems, although recent studies have pointed out their importance and begun to assess them. For example, Thomas and Ritala (2021) propose a dynamic framework that helps explain how ecosystems gain legitimacy over time. In a longitudinal case study, Ansari and colleagues have shown how the introduction of disruptive innovations into TiVos ecosystem led to the challenge of keeping the support of its ecosystem incumbents. Incumbents may leave the ecosystem in response to such disruptions, thereby causing dynamic changes in it (Ansari, Garud, and Kumaraswamy, 2016). Dattée et al. (2018) show how generative technological innovations shape the context and constellations in which firms in an ecosystem operate and how this leads to changes in the value proposition. In other examples, Adner and Kapoor (2016) examine how the speed of adoption of new technologies is depending on the progress of singular technologies already present in an ecosystem. Even though all these studies deal with the role of dynamics in ecosystems, i.e., regarding their outcomes or emergence, literature that structurally approaches such dynamics and deals with the question of "what sort of resources and capabilities could be valuable for firms in this dynamic context" (Jacobides *et al.*, 2018: 2270) remains sparse. Instead, "it is still unclear what valuable resources and/or capabilities mean within the ecosystem setting" (Gueler and Schneider, 2021: 158). To address this, we propose to use network methodology to analyze the role of important company resources for partner selection processes in business ecosystems, which are characterized as being dynamic by nature (Moore, 1993). Business ecosystems, which "[center] on a firm and its environment" (Jacobides *et al.*, 2018: 2256) are particularly suited to be assessed from a network perspective[1], as they represent hub firms and their direct environment, with which they must interact. Using network methodology is not uncommon when studying business ecosystems (Azzam, Ayerbe, and Dang, 2017; Iyer, Lee, and Venkatraman, 2006; Pellinen, Ritala, Järvi, and Sainio, 2012), with scholars sometimes even using the terms ecosystem and network interchangeably (Ansari *et al.*, 2016; Dhanaraj and Parkhe, 2006).

Our paper aims to help understand how the resources of potential partners and the internal characteristics of business ecosystems lead firms to select and deselect partners. To this end, we analyze changes in the business ecosystems of four major US-based pharmaceutical firms between 2016 and 2019. As a means of systematically understanding how firms in business ecosystems choose their partners, we investigate three partner selection mechanisms commonly used in management research: homophily (Ertug *et al.*, 2022; Lawrence and Shah, 2020), aspiration (Clough and Piezunka, 2020; Lant, 1992) and conformity (Bernheim, 1994; Philippe and Durand, 2011). These three selection mechanisms are well-suited to represent the main mechanisms driving business ecosystem compositions (Jacobides *et al.*, 2018): Strategic alignment (represented through homophily), accessing non-generic complementary resources (represented through aspiration) and exerting power in a non-hierarchical setting (represented through conformity). Whereas these partner selection mechanisms have so far been treated as rather isolated in management research, we draw on learnings from network analysis literature and argue that these partner selection mechanisms compete (Snijders and Lomi, 2019). We link these partner selection mechanisms to three firm resources that capture relevant aspects of business ecosystem incumbents: *Inventiveness*, representing strategic alignment in a highly innovative sector, *size*, representing available resources, and *profitability*, representing success

[1] This is in comparison to innovation and platform ecosystems, both of which offer a different focus: Innovation ecosystems often focus on specific products, while platform ecosystems focus on the role of a provider linking suppliers and customers, i.e., Apple providing developer toolkits and the iOS store.

and reliability. Drawing on the business ecosystem literature, we hypothesize which of the three proposed partner selection mechanism will be dominant for each resource and empirically test our assumptions using novel developments in stochastic actor-oriented models (Snijders *et al.*, 2010; Snijders and Lomi, 2019). Our results show that the roles that inventiveness, size and profitability play for partner selection differ greatly and that various selection mechanisms need to be considered to accurately capture the internal dynamics of business ecosystems. More precisely, firms in our sample look for similar firms as partners regarding inventiveness (homophily), while they will try to partner with larger firms regarding size (aspiration). We find no evidence for conformity in partner selection. Instead, dominance appears to be the dominant partner selection mechanism regarding profitability. Our results give a detailed account of how a firm's attribute values (i.e., being a large firm) relate to the values of potential partners, showing that a one-size-fits-all interpretation often falls short and does not accurately explain observed changes in a business ecosystem. Lastly, our results indicate that business ecosystem hubs facilitate collaborations between firms within their ecosystem, while at the same time fostering the dissolution of connections to different ecosystems.

We make three key contributions: First, we contribute to the ecosystem and network literature by integrating both research streams in a novel way. While a network perspective on business ecosystems is not inherently new (see for example Azzam *et al.*, 2017; Pellinen *et al.*, 2012), this perspective usually remains static. In contrast, we engage with business ecosystems in a dynamic way. Given the dynamic nature of business ecosystems (Moore, 1993), this integration is a necessary step to advance our understanding of how such ecosystems evolve over time. We shine a light on the structural drivers of business ecosystems and explore the role of crucial resources, thereby answering the corresponding call of Jacobides et al. (2018). To that end, we are explaining how inventiveness, size and profitability are related to firms making changes in their business ecosystem. Regarding network research, we directly leverage our knowledge of business ecosystems to "help build better models of network dynamics" (Shipilov and Gawer, 2020: 115). We do so by acknowledging that, from a network perspective, hub firms in ecosystems are primarily characterized by incoming ties. To represent this, we created an adequate effect for stochastic actor-oriented models, which can now be incorporated into studies on the dynamics of networks characterized by a highly skewed indegree distribution.

Second, our study contributes to research on business ecosystems by providing detailed insights into the mechanisms behind partner selection and, to an extent, deselection. We show that different partner selection mechanisms play different roles in relation to different salient attributes. Specifically, we show how homophily, aspiration, and conformity relate to the inventiveness, size, and profitability of firms when selecting or deselecting partners in business ecosystems. By shining light on the partner selection mechanisms aspiration and conformity, which have so far received little attention in research on interorganizational relations, alongside homophily, we paint a detailed picture of how partner selection unfolds in the four business ecosystems we sampled. More generally, our findings help to unravel the logics of change in business ecosystems. To that end, we show that firms prefer partners that exhibit a similar innovation strategy over those that are more inventive and that the smaller firms are, the more they are attracted to large firms that offer potential resources such as logistic capabilities or market access, while the size of potential partners does hardly matter to firms which are large themselves. We also show how firms in ecosystems will try to avoid partnering with firms that are successful, potentially to be able to leverage more negotiation power in the non-hierarchical setting of business ecosystems. Third, we add to the broader field of research on the dynamics of interorganizational relations, by allowing the aforementioned partner selection mechanisms to compete with each other. Using the approach of Snijders & Lomi (2019), our study provides a nuanced investigation of homophily, aspiration, conformity and, as we find in our results, dominance. By empirically investigating their relation to crucial resources, we show that more simple representations of partner selection often fall short and are easily misinterpreted. We show that the strength of a partner selection mechanism for specific resources differs dependent on the available resources of the ego and alter firm. This leads to two conclusions: It is insufficient to analyze the attributes of firms independently. Rather, the interplay of the firm's attributes needs to be considered when analyzing partner selection. It is also insufficient to represent partner selection tendencies in a single value, as the preference for, e.g., aspiration may be very pronounced for small firms, but irrelevant for larger firms. These findings advance our understanding of interorganizational relations, and business ecosystems in particular, by shifting the focus away from the firms at their core – which is often the starting and ending point in extant literature (Ansari *et al.*, 2016; Li, 2009).

2.2 Theoretical Foundations

2.2.1 Business ecosystems

The term ecosystem has first been applied to the business context by Moore (1993), who defined ecosystems as an "economic community supported by a foundation of interacting organizations and individuals (…, which) coevolve their capabilities and roles, and tend to align themselves with the direction set by one or more central companies" (Moore, 1993: 26). Businesses in ecosystems form a complex network of interdependences in which they interact and balance competition and cooperation (Basole, 2009). Research on business ecosystems has focused on the design, emergence, and outcomes of these ecosystems, but rarely touched on their dynamics. For instance, studies propose that the emergence of ecosystems depends on value discovery, collective governance, and contextual embedding (Thomas, Autio, and Gann, 2022). Kapoor and Lee (2013) show that the complementarity of organizational forms influences the engagement of firms in complementary activities, more specifically: the decision to invest in new technologies. Additionally, Toh and Miller (Toh and Miller, 2017) find that the extent of complementary technologies in an ecosystem leads to increases and decreases in disclosure inclinations. Other research deals with the crucial role of bottlenecks and how these may hinder ecosystem growth (Hannah and Eisenhardt, 2018; Masucci, Brusoni, and Cennamo, 2020). Although scholars have emphasized the importance of understanding ecosystem dynamics and some initial studies on the topic have been conducted (Cennamo and Santaló, 2019; Gómez-Uranga, Miguel, and Zabala-Iturriagagoitia, 2014; Mäkinen and Dedehayir, 2014), research so far has neglected how potential partners' resources shape the internal dynamics of business ecosystems.

In recent studies, scholars commonly differentiated between business, innovation and platform ecosystems (Jacobides *et al.*, 2018) but also sometimes entrepreneurial (Autio, Nambisan, Thomas, and Wright, 2018) and industry ecosystems (Ansari *et al.*, 2016; Best, 2015). *Business ecosystems*, on which we focus our study, can be "conceived as an economic community of interacting actors that all affect each other through their activities, considering all relevant actors beyond the boundaries of a single industry" (Jacobides *et al.*, 2018: 2257). Within business ecosystems, the links between actors and their joint activities positively contribute to the firms' joint value propositions (Kapoor, 2018). A premise of business ecosystems is the simultaneous existence of interdependencies and non-generic complementarities between firms in ecosystems – regularly called ecosystem incumbents (Jacobides *et al.*, 2018; Kapoor, 2018). To be considered non-generic, these complementarities must be either unique or highly modular (Jacobides *et al.*, 2018). Non-generic complementarities are multi-lateral and can be provided by distributors, advertisers, and research institutions as well as standard-setting bodies, judiciaries, and companies along a firm's value chain (Iyer and Davenport, 2008; Li, 2009; Meyer, Gaba, and Colwell, 2005; Pierce, 2009). Business ecosystems, "[a]s a new means of inter-organizational cooperation" (Gueler and Schneider, 2021: 158), are notably different from other forms of such cooperation. For one, value chains may be vertical as well as horizontal, and each value chain needs to generate a value surplus (Oh, Phillips, Park, and Lee, 2016). While business ecosystems consist of diverse interdependent firms, they commonly have a hub firm at their center, which coordinates standards used in the ecosystem and fosters collaboration between its incumbents.

Even though the hub firm at a business ecosystems core takes on an orchestrating role, ecosystems are not hierarchically governed. Instead, all ecosystem incumbents have a significant amount of autonomy. Thus, coordination in business ecosystems is facilitated by providing an alignment structure. Said alignment structure can be defined as "the extent to which there is mutual agreement among the members regarding positions and flows" (Adner, 2017: 47). Since alignment structures may regularly change, incumbents must constantly adapt their position within a business ecosystem (Lingens and Huber, 2021; Moore, 1993). Therefore, unlike partner selection in strategic alliances, it is not sufficient for firms to consider a dyadic relationship with another firm if they want to select suitable partners for their business ecosystem. Instead, they need to consider all influencing connections and further prospective possibilities arising from their partnerships (Adner, 2017). Thus, firms in ecosystems must navigate dyadic partner selection and, simultaneously, consider changes to the whole business ecosystem when selecting partners. Some of these characteristics are similar to other forms of interorganizational relations: For example, management scholars have long established the concept of central coordinating actors in firm networks, coined focal firm, hub, or orchestrator (see for example Chou and Zolkiewski, 2012; Kaartemo, Coviello, and Nummela, 2020; Provan, Fish, and Sydow, 2007). Many forms of interorganizational relations also have the primary goal of generating some sort of value for participating firms or are based on the integration of complementary resources, for example, strategic alliances (Chung, Singh, and Lee, 2000; Gulati, 2017). However, the combination of the characteristics listed above, especially the exclusion of generic goods and services and the non-hierarchical governance structure, makes business ecosystems unique and distinct in comparison with other forms of interorganizational relations.

2.2.2 Selection mechanisms

Questions of what drives partner selection by organizations have been one of the core interests of scholars researching the dynamics of interorganizational relations since the field emerged (Chen *et al.*, 2022) and have since been the subject of countless studies (Ahuja, Polidoro, and Mitchell, 2009; Baum, Rowley, Shipilov, and Chuang, 2005; Kim and Higgins, 2007; Lincoln, Gerlach, and Takahashi, 1992; Powell, White, Koput, and Owen-Smith, 2005). Yet, business ecosystem scholars so far mainly focused on ecosystem emergence (Best, 2015; Thomas and Ritala, 2021), leaving out the question of ongoing internal dynamics. Studies researching partner selection between organizations typically focus on a combination of firm resources and selection mechanisms (Ahuja *et al.*, 2009; Kim and Higgins, 2007; Thornton and Ocasio, 1999). In other words, researchers usually consider the role of specific salient resources and try to explain which mechanism then leads to the creation of a partnership based on said attributes. To systematically approach the dynamics of business ecosystems, given that "it is still unclear what valuable resources […] mean within the ecosystem setting" (Gueler and Schneider, 2021: 158), we first introduce three partner selection mechanisms: homophily, aspiration and conformity. As mentioned earlier and according to Jacobides (2018), business ecosystems have a couple of typical features. Three of the most important features are: First, an alignment structure or a sort of common ground. This is reflected by homophily. Next, firms engage with business ecosystems to access non-generic complementary resources. This is reflected by aspiration. And third, a way to negotiate power and align partners for a common cause in a non-hierarchical setting. This is reflected by conformity. We link these three partner selection mechanisms to salient resources: inventiveness, size, and profitability. Based on the logic of business ecosystems, we then build our hypotheses.

Homophily. Homophily is a concept that is well known both in and out of academia, reflected by the popular proverb *birds of a feather flock together*. First introduced to social science by Lazarsfeld & Merton (1954), it refers to the idea that actors tend to choose partners to whom they are similar, be it structurally or regarding certain attributes. The relevance of homophily for management studies can be underlined by the large number of studies (for example Pallotti and Lomi, 2011; Singh, Hansen, and Podolny, 2010; Steffens, Terjesen, and

Davidsson, 2012) as well as two recently published review articles that deal with homophily as a concept (Lawrence and Shah, 2020) and its respective consequences (Ertug *et al.*, 2022). In the more specific context of interorganizational relations, homophily has been studied in various settings (Gulati, 1995; Lincoln *et al.*, 1992; Nohria and Garcia-Pont, 1991; Powell *et al.*, 2005; Traoré, 2007; Voelker, McDowell, and Harris, 2013). For instance, Ahuja et al. (2009) look at the role of structural homophily, by analyzing the alliance activities of 97 global chemical firms. They find that great performance differences between firms hinder alliance formation, indicating that firms in their study show homophilic behavior regarding their performance. Kim and Higgins show how the formation of alliances in the biotech industry "is related to status homophily and role-based homophily between young and established organizations" (2007: 499). Other scholars find that organizational similarities, along with resource dependencies and transaction costs, play a significant role in predicting collaboration choices between actors that pursue regional economic development (Lee *et al.*, 2012). Consequences of homophily on the organizational level "ha[ve] been linked to classical organizational outcomes, such as productivity and innovation, as well as valuation and financial performance" (Ertug *et al.*, 2022: 33).

Aspiration. Aspiration can be defined as a comparison of oneself with the value of a given attribute obtained by other actors (Cyert and March, 1963; Festinger, 1954). In management terms, this would refer to "desired performance levels in specific organizational outcomes" (Shinkle, 2012: 416). In contrast to homophily, aspiration is a mechanism that management research has so far mainly linked to questions of internal performance, goal-setting or personal traits (House, 1971; Hu, Zhang, Song, and Liang, 2019; Knudsen, 2008; Lant and Montgomery, 1987; Wehrung, 1989), with only relatively few studies linking aspiration to partner selection. As a partner selection mechanism in business ecosystems, aspiration can be understood as the desire to partner with another firm that exhibits a high value of a desirable attribute (i.e, the desire of a firm to partner with another company that is larger than itself). A few studies that take aspiration into account help illustrate this: For instance, research has recognized the importance of peer performance for setting goals and reference points (Shinkle, 2012). Podolny (1993) shows that the highest-status banks are the ones most able to successfully establish innovations in the market and, in doing so, additionally improve the perception of their superior quality. Hence, firms tend to cooperate with higher-status firms linking a higher status with a higher probability of success. Covering a more structural aspect of research on firm partnerships, Ahuja finds that "poorly embedded firms are more likely to participate in ties characterized by social asymmetry" (Ahuja *et al.*, 2009: 941), meaning that companies in a peripheral position will be less likely to attempt partnering up with companies that inhabit a similarly peripheral position, but rather aspire to connect with more central firms.

Conformity. Like aspiration, conformity as a mechanism has received considerable attention in management research, but less prominently so in the study of interorganizational relations. Originally referring to a *social norm*, the idea of conformity has its origins in social psychology, i.e., in the works of Sherif (1935) and Asch (1951). In management research, conformity can be defined "as an objective modification of organizational behavior that accedes to the requests or expectations that resource holders formulate" (Durand and Jourdan, 2012: 1296). In past studies, management researchers have approached conformity from various theoretical lenses: Institutionalists acknowledge that organizations conform to their environment by adopting common practices and accommodating other demands, providing them with legitimacy (Fiss and Zajac, 2004; Miller and Chen, 1996; Oliver, 1997; Suchman, 1995). As an example, Thornton & Ocasio (1999) examined how American publishing houses enforce structural change (focusing on the core business versus recruiting MBA graduates) due to them conforming to financial market logics. Building on these findings, Thornton (2002) indicates that conforming to changes in institutional logics leads to the emergence of unknown resource dependencies and competition. Miller et al. (2013) find that family involvement in businesses is related to greater conformity in many aspects of strategy, leading to a superior return on assets. Strategy theorists view conformity less as a positive resource, but more as a mechanism that limits a firm's ability to effectively compete (Chen and Hambrick, 1995; Oliver, 1997; Teece, Pisano, and Shuen, 1997). For example, research shows how CEOs' negative emotions lead to more conformity in the choice of strategy (Delgado-García and Fuente-Sabaté, 2010). Importantly, conformity does not only lead to consequences *within* a firm. Rather, other firms listed on the stock market are pressured to conform to a single institutionalized market category (Zuckerman, 1999). Philippe and Durand (2011) demonstrate that firms choose strategically between different norm-conforming behaviors to influence their reputation. These studies make it clear that conformity is not restricted to dyadic relations between a firm and a partner but indicate that the influence of conformity is defined by the firm's whole environment and its expected behavior (Tolbert and Zucker, 1997). As is the case with aspiration, studies that assess the role of conformity in interorganizational relations remain few, with notable exceptions. For instance, researchers find that companies in interorganizational networks in an industrial district tend attach to firms that conform to this district's code of conduct to not jeopardize their business (Chetty and Agndal, 2008). Another study found that conforming to fads and fashions in industries increases the likelihood of board interlock formation in firms (Yue, 2012). From a partner selection perspective, conformity would then not inflict a behavioral change, but rather reflect a preference to connect to others who exhibit conformity through a recognizable attribute (i.e., the desire to connect with firms which exhibit profitability around a perceived norm).

2.2.3 Salient resources

As has been stated above, it is typical for researchers that assess the dynamics of interorganizational relations to link partner selection mechanisms to salient resources, for example size to homophily (Amati, Lomi, Mascia, and Pallotti, 2019; Matous and Todo, 2017; Withers *et al.*, 2020). We include three different firm attributes that reflect salient resources to examine partner selection processes in business ecosystems: Inventiveness, size, and profitability. All three of these are relevant for firms in business ecosystems to assess how likely it is for a partnership to lead to value co-creation and, thus, how attractive said partnership appears. Additionally, all three of these resources are commonly used in research on the dynamics of other forms of interorganizational relations (Gilding, Brennecke, Bunton, Lusher, Molloy, and Codoreanu, 2020; Jacobs, Kraude, and Narayanan, 2016).

Inventiveness. Innovation is essential for firms to remain competitive. This is especially true for firms in fast-moving industries, such as biopharmaceutics (Gilding *et al.*, 2020; Powell *et al.*, 2005; Powell, Koput, and Smith-Doerr, 1996). In business ecosystems, inventiveness, which can be typically seen as a proxy for strategic orientation towards innovation, plays a crucial role in strategic alignment (Ferreira and Teixeira, 2019; Lingens and Huber, 2021; Masucci *et al.*, 2020). Strategic alignment in terms of similar innovation strategies and goals may facilitate co-creation without challenging goal setting or communication within the partnership. Considering that creating a value surplus is the primary goal of business ecosystems, comprehensible strategic aims are key for reducing coordination difficulties and helping to generate increased value for the involved firms (Shah and Swaminathan, 2008). When considering potential partners, firms are likely to pay attention to these potential partners' inventiveness, interpreting this as potential access to innovative resources and capabilities and to create a joint value surplus (Li, Eden, Hitt, and Ireland, 2008). We assume that firms in business ecosystems will preferably partner with other firms whose inventiveness is similar to their own since this reflects similar strategic aims and potential for fruitful exchanges. These similar strategic aims might manifest themselves through a comparable willingness to spend available resources or an equal organizational commitment to successfully implement inventions in the market (Lee *et al.*, 2012).

Hypothesis 1 (H1): *Firms in business ecosystems tend to select firms as partners who exhibit a similar inventiveness as they do over other firms (Homophily).*

Size. The overall amount, variety, and availability of resources – tangible and intangible - are a second key firm characteristic in business ecosystems, which is evident by the hub firms in business ecosystems often being large firms at the ecosystem's core (Basole, 2009; Best, 2015; Li, 2009). For ecosystem incumbents considering which firms to partner with, size will act as a proxy for capabilities and resource allocation capacities. Firm size has been positively associated with the ability to build the necessary dynamic capabilities to bring products to market in highly competitive markets (Jeng and Pak, 2014), the ability to entertain reliable supply chains with less dependency on collaboration between suppliers (Cao and Zhang, 2011) or entering foreign markets (Agarwal and Ramaswami, 1992). Especially to smaller firms, who lack these resources, things like access to specific foreign markets can be viewed as a non-generic complementarity. Internal resources such as knowledge may be defined as non-generic complementarities if they reflect unique technologies or processes relevant to the business ecosystem. Such resources are less dependent on firm size, as smaller firms in ecosystems may provide key technologies in a similar manner as large firms do.

Emphasizing the purpose of achieving a value surplus in business ecosystems, we expect an overall aspiration tendency, meaning that firms will tend to prefer partnering with larger firms. This is especially true for smaller firms, who are less able to substitute these resources on their own. Among other things, a collaboration with a larger firm provides small firms with access to foreign markets and internal production resources and provides valuable contacts. An overall higher availability of resources may increase large firm *A*'s attractiveness, since the combination of these resources with the non-generic complementarity offered by smaller firm *B*, offers the possibility to generate a joint value.

Hypothesis 2 (H2): *Firms in business ecosystems tend to select firms as partners who are larger in size than they are over other firms (Aspiration).*

Profitability. Profitability is one of the most common attributes when examining partner selection in interorganizational relations. While a given firm will generally strive for high profitability, network theory suggests that actors - in this case, firms – are embedded into their surroundings and will be aware of the exhibited attribute values of their peers (Granovetter, 1985). Thus, firms will have a general idea of the profitability of firms that they already partner with or are considering partnerships with. Moreover, they know what can be considered *normal* in their direct environment. When considering profitability as a salient attribute, we assume that firms will compare potential partners' profitability with the social norm exhibited in their environment. By using the social norm as a point of comparison, selecting firms not only consider potential partners' performance but also take characteristics of the business ecosystem into account. On the one hand, profitability above the social norm may be perilous for selecting firms. A partner that is outstandingly successful may occupy too much power within the partnership, dictating the division of revenue streams or negotiating unfavorable licensing agreements. This might decrease the value that is accessible for the weaker firm. On the other hand, profitability below average may signal a lack of reliability of the potential partner. Selecting a firm with profitability much lower than expected in a firm's direct environment may bear the risk of investing in a partnership that ends in unsuccessful joint value, and hence is a sunk cost risk for the selecting firm. This ties in with the business ecosystem literature, which stresses the importance of negotiation power and coopetition, since business ecosystems are organized non-hierarchically (Gueler and Schneider, 2021; Hannah and Eisenhardt, 2018). Partnering with firms that exhibit profitability around the business ecosystem's norm will help alleviate power disparities. Thus, we expect conformity to be the dominant selection mechanism regarding profitability.

Hypothesis 3 (H3): *Firms in business ecosystems tend to select firms as partners who exhibit profitability close to the social norm over other firms (Conformity).*

2. 3 Method and Data

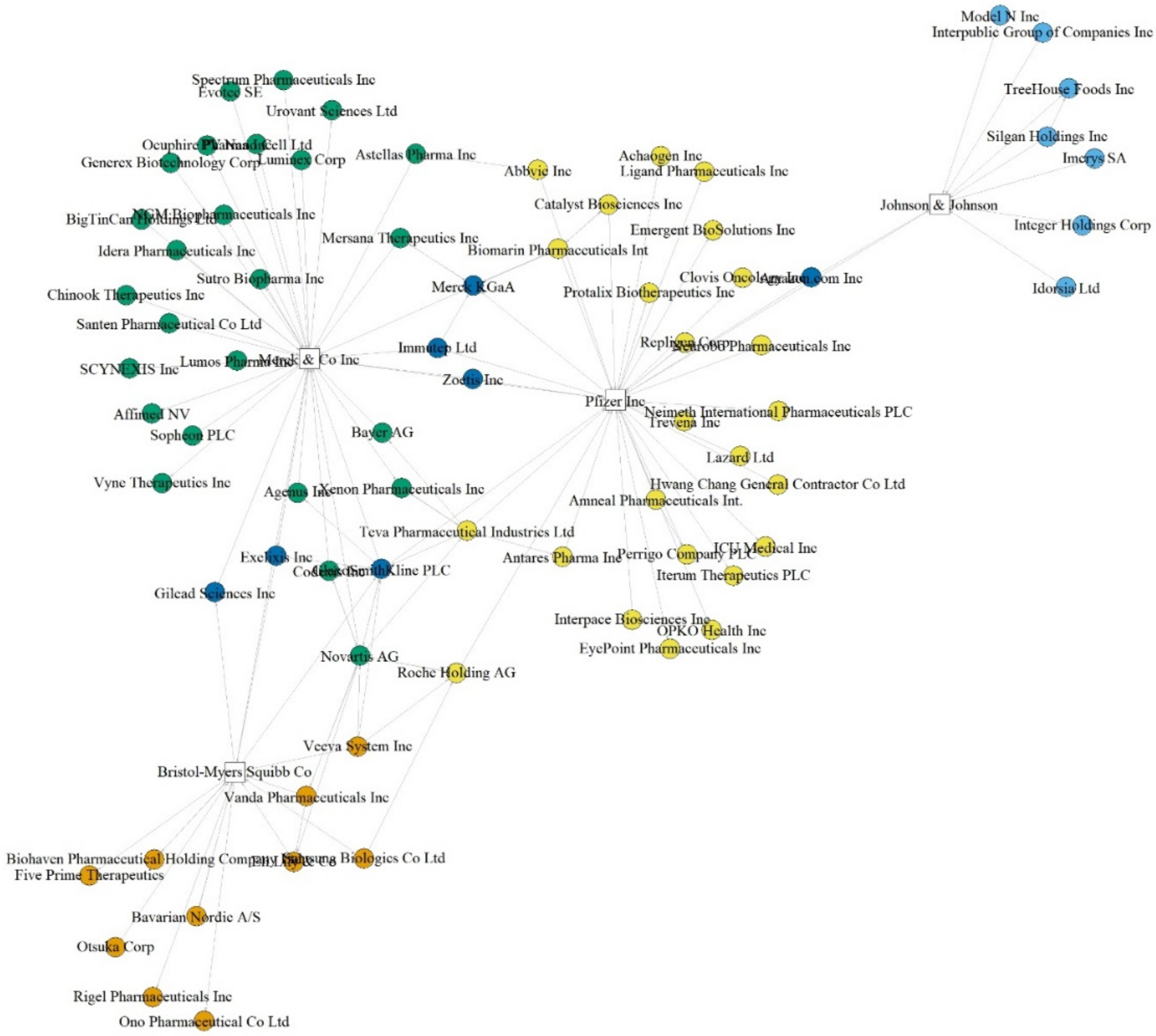
2.3.1 Sample

Our sample consists of four business ecosystems based on the four American pharmaceutical companies which had the highest turnover in 2019: Pfizer, Merck & Co, Bristol-Myers Squibb, and Johnson & Johnson. Referring to studies of Xu et al. (2020) and Adner and Kapoor (2010), these ecosystems are constructed by collecting data on the four focal firms value chains and on the value chain connections between their partners. To ensure the comparability of firms and the availability of data on value chains and attributes, we restricted our sample to publicly traded firms, as there is no available data for private firms and government institutions on attributes such as profitability. After capturing all value chain members of the four focal firms, we analyzed how all companies in the value chains of Pfizer, Merck & Co, Bristol-Myers Squibb, and Johnson & Johnson are connected among each other, thereby constructing a network. Companies in our sample are connected through a variety of activities. All of these activities share the requirement that they represent non-generic complementarities and lead to the co-creation of value. Activities include research-oriented activities such as the licensing of patents or development cooperation, strategy-oriented activities such as marketing or distributing, and, to a lesser extent, manufacturing-oriented activities such as relationships with suppliers or agreements about outsourced production of specialized goods (i.e., specific proteins). As business ecosystems revolve around non-generic complementarities, generic complementarities were excluded and thus do not constitute ties. To be specific, complementarities needed to be either unique, meaning that "[j]oint consumption generates greater utility than separate consumption, and these complements have less value when not consumed together" or supermodular, meaning there are "increasing returns of joint consumption of complements" (Jacobides *et al.*, 2018: 2266).

While the business ecosystems in our sample differ in size, they show structural characteristics well-known from organizational network research. All four ecosystems are partly connected to the other business ecosystems in our sample at some point of our observation period via so called bridging ties, which refer to actors spanning mostly disconnected cliques (Halevy, Halali, and Zlatev, 2019). In this sense, they resemble a part of the pharmaceutical industry ecosystem. Empirical data, however, shows, that the business ecosystems are very distinct and bridging ties between ecosystems are rare. Apart from bridging ties, several triadic relationships can also be identified in the sample. Such triads are a cornerstone of network theory, and their existence can basically be considered a prerequisite if one wants to assess data from a network perspective. The four business ecosystems can be differentiated clearly in the corresponding network visualization, Figure 2.1. The figure shows all companies directly connected to one of the four business ecosystems in 2017 with the focal firms being represented by white squares. All other firms are circles in different colors: Firms exclusively connected to Pfizers ecosystem are colored yellow, firms exclusively connected to Merck & Co are colored green, firms exclusively connected to Johnson & Johnson are colored light blue and those exclusively connected to Bristol-Myers Squibb are colored orange. Lastly, those companies that have been part of two or more of the four sampled business ecosystems during 2017 have been colored dark blue[2].

[2] Firms that have been part of no ecosystem in 2017 (but in other years), either by being total isolates or by being tied to non-focal firms, are not pictured to provide a more intuitive visualization of the four different cliques.

Figure 2.1: Visualization of business ecosystems



2.3.2 Measures

Firm connections. To objectively measure information about the existing value chains, we exported them from the Refinitiv Eikon-database for all four pharmaceutical firms and then exported the value chains of all firms that Pfizer, Merck, BMS and Johnson & Johnson were connected to between 2016 and 2019[3]. Precisely, Pfizer´s ecosystem consists of 64 firms, Merck & Co's includes 38 firms, Bristol-Myers Squibb's ecosystem consists of 22 firms and Johnson & Johnson's ecosystem spans 22 firms. We then analyzed how all firms participating

[3] These connections will subsequently be called *ties*, as is custom in network studies.

in these ecosystems are interconnected through their respective value chains and coded these connections as four 111x111 adjacency matrices, with each matrix representing one year. Subsequently, we went through each connection by hand and analyzed corresponding press releases to see if they represent *non-generic complementarities*, are subject to some form of standard-setting by the hub firm, and define their precise start- and end-dates. During data collection, we removed negative value chain connections, i.e., lawsuits about pending patents, and gained detailed insights into the connections. As such, we were able to ensure that the deletion of ties was primarily due to firms electing to end the partnership (i.e., when Pfizer ended their partnership with BioNTech in early 2021, apart from the continued joint development of Covid-19 vaccines), not due to external factors such as legal disputes. Table 2.1 provides some general information about the network, such as its centralization or density, as well as information about the tie changes between the time periods. The Jaccard Index mentioned in the table indicates the stability of the connections within ecosystems, with higher values indicating higher stability (e.g., fewer changes from one observation period to the next).

Table 2.1: Network descriptives

Information/Year	*2016*	*2017*	*2018*	*2019*
General Information				
Centralization	0.089	0.139	0.169	0.169
Density	0.007	0.011	0.014	0.014
Average Out-Degree	0.76	1.26	1.50	1.57
# of Ties	84	140	166	174
Tie Changes between Years				
No tie → tie	-	60	33	33
Tie → no tie	-	4	7	25
Tie → maintain tie	-	80	133	141
Jaccard Index	-	0.556	0.769	0.709

Attributes. Our hypotheses are based on company attributes that are often found in the analysis of interorganizational relations: Inventiveness, firm size, and profitability. To measure these categories, we employ commonly used proxies. Inventiveness is represented via the *total R&D spending of a company divided by its sales* (Hung and Chou, 2013; Laursen and Salter, 2014), firm size is represented via *total assets* (Kitts *et al.*, 2017; Zhu and Westphal, 2021), and profitability is represented via *return on assets* (Hernandez *et al.*, 2015; Zhu and Westphal, 2021). Like the business ecosystem data, we extracted these attributes from the Refinitiv Eikon database. Missing data for size and profitability was low, with 3.3% and 5.4% missing across all periods, respectively. Inventiveness shows missing values of 20.1%. Due to the relatively high number of missing values for inventiveness, we imputed the data using the sample algorithm implemented in R's *mice* package[4]. Later estimation results only changed in terms of statistical power but led to similar parameter estimates when comparing imputed and non-imputed data for robustness. Values for size have been exported as absolute numbers (in $US), while profitability and inventiveness are exported as relative values (i.e., a company may spend 80% of its sales on R&D). Since our dependent variable is a network varying over a set time period, with 2019 being the last observed time point, we include attribute data for the years 2016-2018, with each time period $t_{(n)}$ being the basis for estimation of the network at $t_{(n+1)}$. Additionally, we have included four constant attributes, each representing if a firm has been part of the ecosystem of either Pfizer, Merck & Co, Bristol-Myers Squibb and/or Johnson & Johnson at any given time during our observation period. These take the format of dummy variables with values being either 0 or 1. Table 2.2 gives an overview of the means, standard deviations, and correlations of all attributes.

[4] Collecting the data by hand became increasingly unreliable due to firms not reporting all necessary numbers to calculate inventiveness, a lack of transparency requirements before firms went public and bankruptcys or acquisitions during the sample period.

Table 2.2: Descriptive statistics

	Mean	*SD*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1. Firm Size T1	13.71	3.21	-							
2. Firm Size T2	13.71	3.21	0.97***	-						
3. Firm Size T3	13.76	3.01	0.97***	0.99***	-					
4. Profitability T1	-0.79	2.79	0.74***	0.74***	0.73***	-				
5. Profitability T2	-0.77	2.78	0.73***	0.73***	0.73***	0.88***	-			
6. Profitability T3	-0.58	2.85	0.57***	0.66***	0.65***	0.80***	0.77***	-		
7. Inventiveness T1	3.73	2.35	-0.56***	-0.56***	-0.55***	-0.66***	-0.63***	-0.63***	-	
8. Inventiveness T2	3.68	2.16	-0.61***	-0.64***	-0.64***	-0.67***	-0.68***	-0.68***	0.88***	
9. Inventiveness T3	3.63	2.48	-0.54***	-0.59***	-0.59***	-0.63***	-0.61***	-0.62***	0.84***	0.93***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; $n = 111$

2.3.3 Method

Our sample shows properties one would typically expect from networks (e.g., triadic relationships and bridging ties that connect one business ecosystem to another) and sufficiently high Jaccard indices (above 0.3 at all times). Thus, we are able to apply network methodology to model the dynamics of said business ecosystems, while specifying our model in a way that reflects the particularities of business ecosystems. One of the most comprehensive approaches for the analysis of network dynamics are *stochastic actor-oriented models* (SAOMs). The main purpose of these models is to estimate the likelihood of actors in a network *creating*, *maintaining,* or *deleting* a tie to another actor (Snijders *et al.*, 2010). They assume that, while time is continuous, the networks are observed at discrete points in time. Our study observes four time points, which are the end dates of the years 2016-2019. This means that if two firms entered a partnership in March 2017 and ended it in August 2018, the partnership would appear in 2017, but not 2018. Firms that have not been publicly listed during the whole observation period, were founded after 2016, or went bankrupt before 2019, have been set to *structural zeroes* for the respective time periods, meaning that ties could not have occurred at the time (Ripley, Snijders, B'oda, Preciado, and Voros, 2022). SAOMs assume that firms control their outgoing ties. For example, Pfizer proposing the joint licensing of a patent to Emergent BioSolutions places the initiative on Pfizer. To model network dynamics, SAOMs estimate a rate function, which represents the rate at which change in a network occurs as well as an evaluation function, which represents the way actors evaluate which changes to make. SAOMs enable researchers to incorporate endogenous effects present in networks, such as reciprocity or the popularity of a focal actor, but also offer different ways for attributes – or exogenous effects - to be included[5]. These attributes may be on the firm level (i.e., size) or dyadic (i.e., belonging to the same ecosystem).

Modeling selection mechanisms. To test our hypotheses, we include several parameters that correspond to the respective attributes of interest: Inventiveness, size, and profitability. To this end, we make use of recent advances in SAOMs by Snijders & Lomi (2019), combining the included parameters in a function that allows us to model attribute-based selection mechanisms as competing drivers of network change. For reference, the role of attributes in partner selection in SAOMs is typically modeled through the inclusion of the attribute values of the *sender* β_1, *receiver* β_2 and their *similarity* β_3. The attraction function a_1 of a sending firm i and a receiving firm j would then be represented by the equation:

$$a_1(v_i \mid v_j) = \beta_1 v_i + \beta_2 v_j + \beta_3 |v_i - v_j|$$

However, "homophily and aspiration are not readily combined in this model, and attachment conformity cannot be represented" (Snijders and Lomi, 2019: 6). Instead, a model specified as described above only adequately represents homophily *or* aspiration. Snijders and Lomi (2019) propose a four parameter-model that allows for the representation of different competing mechanisms: homophily, aspiration and conformity. These four parameters are based on the attribute value of the sending firm θ_1, that of the receiving firm θ_2, the squared attribute value of the receiving firm θ_3 and the squared difference of the attribute values of both

[5] An exhaustive list of the available effects as well as their mathematical specification can be found in the RSiena – the name of the R package used to model SAOMs – manual (Ripley *et al.*, 2022).

companies θ_4. These parameters are then represented by a quadratic function, which we illustrate in attraction function a_2:

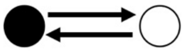
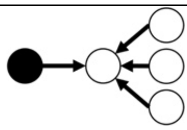
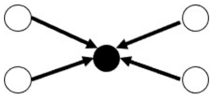
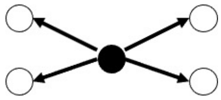
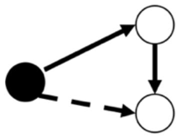
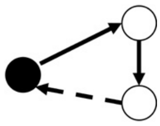
$$a_2(v_i \mid v_j) = \theta_1 v_i + \theta_2 v_j + \theta_3 v^2{}_j + \theta_4 (v_j - v_i)^2$$

After model estimation, we test the joint significance of the four parameters for each respective attribute with a multi-parametric test. All three attributes have been logarithmized, as it is advised that co-variates have a standard deviation between 0.1 and 10 and their values would have otherwise exceeded these thresholds (Ripley *et al.*, 2022).

Structural effects. Network models account for endogenous, structural effects, for example, the role of a firm's popularity. We include those structural effects that are commonly seen as the "standard for SAOMs" (Snijders and Lomi, 2019: 11). First, the *outdegree (density)* effect, which is similar to the intercept found in regular regression models and *reciprocity*, which reflects the tendency of firms to reciprocate ties – i.e., Merck being connected to Achaogen at *t1* influences the likelihood of Achaogen sending a tie back to Merck in *t2*. We control for three degree-related effects: *indegree popularity*, which reflects the popularity of firms based on their in-coming ties, *indegree activity*, which reflects the tendency of firms to send ties *because* of their high number of incoming ties and *outdegree activity*, which reflects the tendency of firms to send ties *because* of their high number of outgoing ties. All three degree-related effects have been transformed by their square root, which often leads to a better fit and is recommended (Ripley *et al.*, 2022). Finally, we control for *transitivity* (or *network closure*) by including the *transitive triplets*-effect. As an example, let us assume that Pfizer is connected to Abbvie and Abbvie is connected to Codexis at *t1*. A tendency for transitive closure would mean that Pfizer is likely to send a tie to Codexis during subsequent observations. The business ecosystem literature has made several assumptions on how ecosystems are structured, which require additional effects. Jacobides et al. (2018) argue that ecosystems, despite their focus on a focal firm or product, are not hierarchically organized. SAOMs allow us to control for the presence of hierarchical organization by including the *3-cycles*-effect alongside the already included *transitive triplets*-effect. Moreover, our sample includes four different business ecosystems. To account for this, we included four attributes, each representing one of the four business ecosystems in our sample. Ecosystem literature suggests that hub firms will facilitate collaboration within their business ecosystem. To capture this, we included a *within group-transitivity*-effect for each business ecosystem[6]. This effect captures the tendency to form transitive triplets *within* each group. *Within-group transitivity* is a relatively comprehensive effect as it encompasses lower-order effects, for example, differences in tendencies to send or receive ties within the same ecosystem. Finally, business ecosystems revolve around the hub firms at the center, which will generally be interested in incorporating certain goods (i.e., licenses or specific goods such as proteins) into their value chains. This interest is represented through incoming ties, rather than outgoing ties. To represent that the observed network is more important to some companies than to others (mainly the four hub firms), we included a *logarithmized indegree* effect influencing the rate of network change[7]. We provide a visualization of all effects for which visualization is feasible in Table 2.3. The black dots indicate agency:

[6] There are multiple effects that deal with within- and between-group effects in the RSiena library. To be specific, we use the *homXTransTrip*-effect.
[7] The inRateLog-effect was written for this paper and serves the purpose of depicting non-linear relationships between in-degree values and the rate function. See chapter 3 of this dissertation for more details on it.

Table 2.3: Visual representation of network effects

Effect	*Visual representation*	*Summary*
Density (out-degree)		Overall tendency of firms to send outgoing ties; akin to intercepts in regular regressions
Reciprocity		Tendency to reciprocate incoming ties
Indegree Popularity		Represents popularity of firms based on their in-degree
Indegree Activity		Represents tendency of firms to send outgoing ties *because* they already receive many ties
Outdegree Activity		Represents tendency of firms to send outgoing ties *because* they already send many tieso
Transitive Triplets		Tendency for network closure through the formation of transitive triplets.
3-cycles		Tendency for generalized network closure, represented by 3-cycle structures
Sender Effect		Influence of the sending firms attribute
Receiver Effect		Influence of the receiving firms attribute

2.4 Results

We divide the estimated parameters into two sections, presented in Table 2.4: First, the included structural effects, such as degree-related effects or within-ecosystem transitivity and second, the parameters depicting the selection mechanisms for inventiveness, size and profitability. The dependent variable is the combined network of all four business ecosystems. Positive parameters indicate a tendency for actors to maintain or create new ties, while negative parameters indicate a tendency for actors to dissolve existing ties or not create ties where no ties are currently present.

Table 2.4: Results of SAOMs on change in business ecosystems

Effect Name	Estimate	SE
Rate Parameter		
Period 1	0.54	(0.08)
Period 2	0.28	(0.05)
Period 3	0.34	(0.05)
Log. Indegree Effect on Rate	0.67***	(0.10)
Intercept		
Outdegree (density)	-5.74***	(0.57)
Structural Effects		
Reciprocity	1.33***	(0.33)
Indegree popularity (sqrt)	0.51***	(0.12)
Indegree activity (sqrt)	-0.98*	(0.44)
Outdegree activity (sqrt)	0.97***	(0.29)
Transitive Triplets	-1.32**	(0.49)
3-cycles	-0.51	(0.36)
Merck – Within-Ecosystem Transitivity	0.60	(0.32)
Pfizer – Within-Ecosystem Transitivity	1.04**	(0.39)
J&J – Within-Ecosystem Transitivity	0.93**	(0.34)
BMS – Within-Ecosystem Transitivity	0.80*	(0.34)
Hypothesized effects: Selection Mechanisms		
H1: Homophily - Inventiveness		
Sender	0.28*	(0.14)
Receiver	0.12	(0.09)
Receiver (squared)	-0.00	(0.03)
Difference Sender-Receiver (squared)	-0.07**	(0.03)
H2: Aspiration - Size		
Sender	0.75***	(0.19)
Receiver	0.53***	(0.11)
Receiver (squared)	-0.01	(0.02)
Difference Sender-Receiver (squared)	0.04***	(0.01)
H3: Conformity - Profitability		
Sender	-0.19	(0.11)
Receiver	-0.22**	(0.08)
Receiver (squared)	-0.01	(0.03)
Difference Sender-Receiver (squared)	-0.01	(0.01)

Significance levels are two-tailed. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Overall maximum convergence ratio: 0.11. All convergence t-ratios are below 0.04. $n = 111$

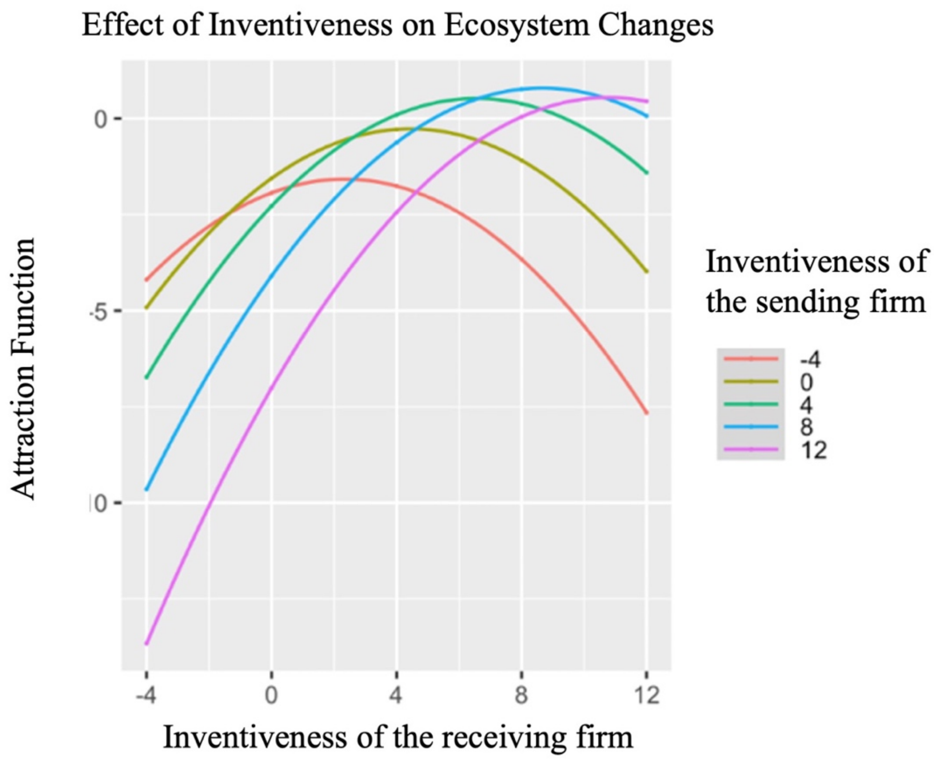
2.4.1 Structural effects

We find several significant structural effects. First, we see a strongly significant effect for *reciprocity* ($\theta = 1.33$, $p < 0.001$), indicating that firms will tend to reciprocate an outgoing connection. Next, all three included degree-related effects are significant: *Indegree popularity* ($\theta = 0.51$, $p < 0.001$), *Indegree activity* ($\theta = -0.98$, $p < 0.05$), and *Outdegree activity* ($\theta = 0.97$, $p < 0.001$). *Indegree popularity* indicates that companies will try to connect to firms that already have a high number of incoming ties (or are popular, in the proverbial sense). The negative *indegree activity* parameter indicates that firms that already have many incoming ties tend to dissolve more partnerships than their less active counterparts. On the other hand, the high parameter of *outdegree activity* indicates that firms, which have been active in the past (e.g., sending many ties), tend to continue to be more active in forming partnerships than others. While we find no significant effect for *3-cycles*, we find a negative effect for *transitive triplets* (θ = -1.32, $p < 0.01$). Combined, this suggests that the business ecosystems are not hierarchically organized and that there is a tendency for triads to dissolve. The included effects on the ecosystem level allow us to analyze this tendency in more detail: While the overall tendency of firms is to dissolve transitive triplets, we can see that there is a tendency to create or maintain transitive triplets in the ecosystems of Pfizer (θ = 1.04, $p < 0.01$), Johnson & Johnson (θ = 0.93, $p < 0.01$) and Bristol-Myers Squibb (θ = 0.80, $p < 0.05$), indicated by the respective significant positive parameters. We do not find a significant effect for the tendency to form transitive triplets within the ecosystems of Merck. The significance of the *logarithmized indegree* effect on the rate function (θ = 0.67, $p < 0.001$) indicates that the rate of network change is more strongly influenced by firms who have a higher indegree and that this relationship is non-linear.

2.4.2 Hypothesized effects

We model selection mechanisms through a combination of parameters for each company attribute: *Inventiveness, size,* and *profitability*. These parameters cannot be interpreted by the *all else being equal* paradigm but need to be interpreted together. To that end, they are represented by an *attraction function*, which we described in detail above. Hence, the question if single parameters are significant is not adequate on its own, but rather serves the purpose of providing more detail. We performed Wald tests to see if the combined influence of multiple parameters on the business ecosystem network, specifically the combination of the jointly included parameters per attribute, is not 0 (Wald, 1943). Previously, we hypothesized that the dominant selection mechanism for partner selection based on *inventiveness* would be *homophily*. The Wald test across the four included parameters yielded a significant result of $p = 0.01$. We also observe a significant effect for *Receiver* ($\theta = 0.28$, $p < 0.05$) as well as for the *squared difference between Sender and Receiver* ($\theta = -0.07$, $p < 0.01$). Figure 2.2 shows a visualization of these results:

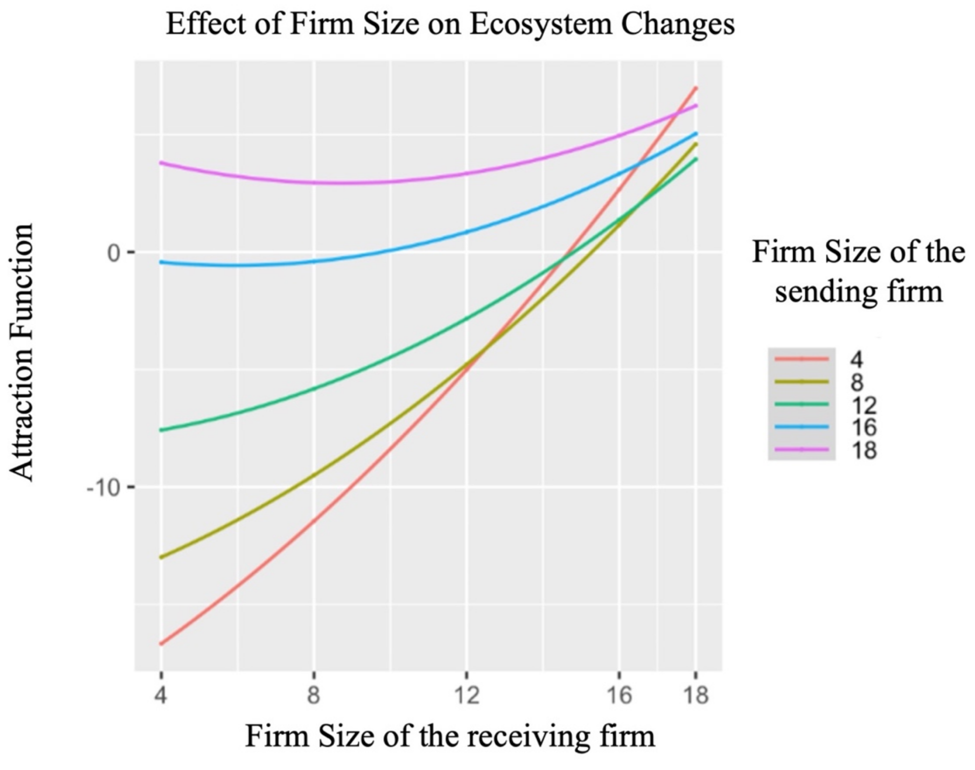
Figure 2.2: Attraction function visualizing the effect of inventiveness on partner selection



The visualization shows a clear *homophily* preference across all inventiveness values of the sending firm. This is indicated by the fact that the depicted slopes, which represent the partner preference of the selecting firm categorized by different inventiveness values, have their maxima at the same value – or at least close to the same value – as the receiving firm. Looking at the graph in more detail, we further observe that only inventiveness around the same value will positively influence the likelihood of creating a new partnership or maintaining an existing partnership (indicated by values higher than 0 on the y-axis). In contrast, stark differences in inventiveness increase the likelihood of dissolving an existing partnership or maintaining its *non-existence*. In sum, we see a clear preference for homophily. This allows us to confirm H1: Regarding inventiveness, the dominant partner selection mechanism for firms in business ecosystems is homophily.

Next, we hypothesized that the dominant selection mechanism for partner selection based on *size would* be *aspiration*. For *size*, this multi-parametric test was significant at a level of $p < 0.001$. We also observe a significant effect for *Sender* ($\theta = 0.75$, $p < 0.001$), *Receiver* ($\theta = 0.53$, $p < 0.001$) as well as for the *squared difference between Sender and Receiver* ($\theta = 0.04$, $p < 0.001$). Figure 2.3 shows which values of a receiving firm a sending firm is attracted to, depending on the sending firm's own values.

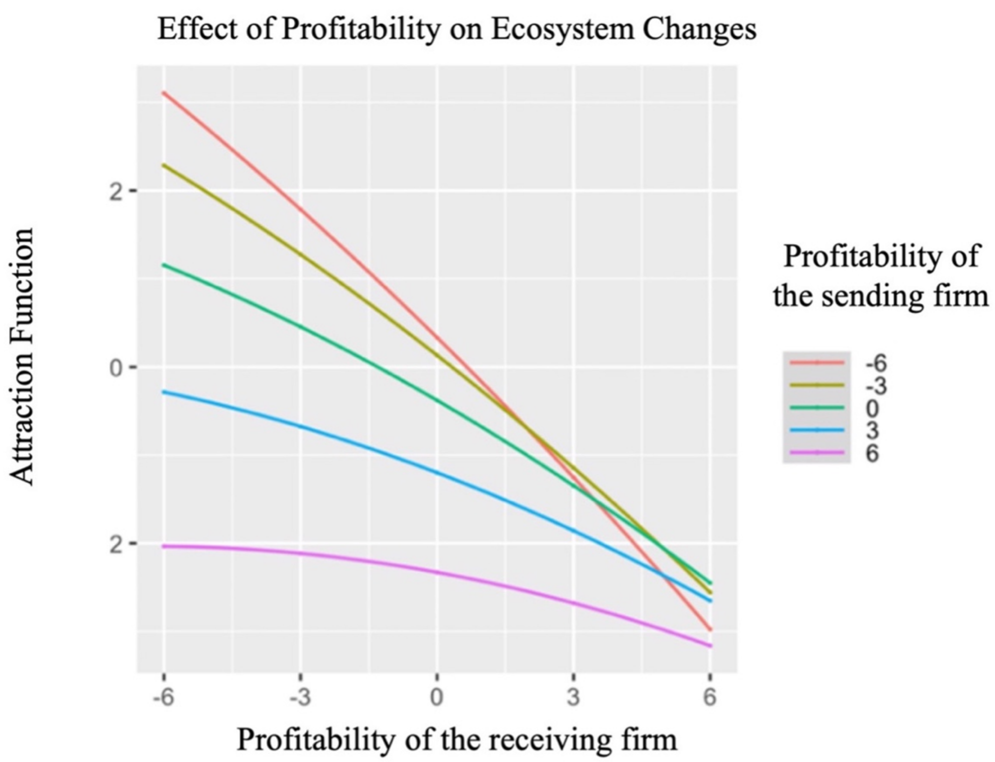
Figure 2.3: Attraction function visualizing the effect of firm size on partner selection



Examining this graph makes it apparent that firms show an *aspirational* tendency when considering *size*. These preferences decline with the company size of the selecting firm. To be precise, we see that the largest firms in our sample (represented by the purple line) show almost equal preference (as indicated by the Y-axis) for companies of all sizes (as indicated by the X-axis). The smaller the selecting firm, the stronger the preference for partnerships with larger companies compared to other small firms. Similar to what is the case with Figure 2.2, we can observe that, for smaller firms, only potential partners being considerably larger increases the likelihood of creating a new partnership, while other small firms are unlikely to be considered as a partner or, if they are already partners, these partnerships are likely to be dissolved. In sum, we can confirm H2.

The third attribute we included in our analysis is *profitability*. Here, too, the multi-parametric test yielded a significant result, which was significant at $p = 0.013$. We also observe a significant result for the effect of *Receiver* ($\theta = -0.22$, $p < 0.01$). Visualizing the attraction function provides us with Figure 2.4:

Figure 2.4: Attraction function visualizing the effect of profitability on partner selection



The attraction function does not reflect one of the selection mechanisms presented in this paper. Instead, we see that selecting firms will, on average, be more inclined to partner with firms that have low profitability. The more unprofitable a firm is, the more likely it is to partner with other unprofitable firms. Additionally, and similar to the attraction function of *size*, we see that this preference is less pronounced in firms that have higher *profitability* themselves. In other words: The more profitable a firm is, the less its partner selection diverges based on the receiving firm's value. As we do not observe a conformity pattern, we must reject H3. Moreover, the pattern in Figure 2.4 does not indicate homophily or aspiration either. It could perhaps best be described as *dominance* or *avoidance*.

2.4.3 Goodness of fit and standard error accuracy

We performed Goodness of Fit-tests for the out- and in-degree distribution as well as the Geodesic Distribution and Triad and Clique Census. These are based on calculating the Mahalanobis-distance and, importantly, should result in a p-value that is *not* 0. The conventional threshold of $\alpha = 0.05$ "is here even more arbitrary than in other cases" (Lospinoso and Snijders, 2019: 13). Our GoF tests for Outdegree Distribution ($p = 0.394$), Indegree distribution ($p = 0.003$), Geodesic Distribution ($p = 0.045$), Triad Census ($p = 0.022$) and Clique Census ($p = 0.914$) were all sufficient. The goodness of fit of the Indegree Distribution ($p = 0.003$) warranted further investigation, so we conducted period-wise tests. The p-values were *not* 0 for all periods and above $p = 0.05$ for all but the first period. Given that all other GoF-tests yielded satisfactory p-values and that we observe a network that is, due to its very nature, skewed regarding its in-degree distribution, the results are satisfactory. We also checked for a large enough number of simulations to produce accurate standard errors and, consequently, accurate significance levels, using the proposed R script on the RSiena web page[8]. We used 10000 simulations, while standard errors for our model become accurate at 6000-8000

[8] As this is not yet implemented in the RSiena-package and not citeable by the time of writing, we thank Nynke Niezink for providing said script.

simulations. Missing network data was rare, with a total number of 12 ties, corresponding to 0.001% of all ties. SAOMs handle this by carrying information forward (i.e., if there was a tie between two companies and 2016 and the data for 2017 is missing, it will be set to 1). If there is no information available, the value is set to 0, as the non-existence of a tie is more likely (Huisman and Steglich, 2008).

2.5 Discussion

Business ecosystems represent a specific way for firms to organize interdependencies and have become an increasingly important topic in management research (Shipilov and Gawer, 2020). Yet, while ecosystems have been recognized as dynamic forms of interorganizational relations, management literature systematically dealing with these dynamics is relatively sparse. Instead, research has focused on theory building (Jacobides *et al.*, 2018; Kapoor, 2018), ecosystem emergence (Thomas *et al.*, 2022; Thomas and Ritala, 2021) as well as empirical studies that deal with their outcomes (Adner and Kapoor, 2016; Toh and Miller, 2017). Our study set out to analyze the dynamics of the business ecosystems of four major US-based pharmaceutical firms: Pfizer, Merck & Co, Bristol Myers-Squibb and Johnson & Johnson. We constructed their business ecosystems based on their respective value chains and the value chain connections of their ecosystem incumbents among each other. To explain how partner firms are chosen in the sampled business ecosystems, we investigate the role of three partner selection mechanisms (homophily, aspiration, and conformity) and analyze how they correspond to three crucial resources (inventiveness, size, and profitability).

2.5.1 Theoretical implications

Our study results in three major contributions to the literature. First, we advance the conversation between business ecosystem research and network theory. The conversation between these fields is particularly fruitful because the still-emerging research field of ecosystems benefits greatly from the field of network research, which offers mature methodological approaches and rich knowledge regarding interorganizational dynamics and structures. Business ecosystems are well-suited to be analyzed from a network lens, but existing work treats them as static. We examine four business ecosystems over a period of four years and make use of recent advances in the modeling of network dynamics to accurately depict these business ecosystems as a changing network. Doing so, we address multiple core issues: For one, we highlight the role of three important firm attributes: inventiveness, size, and profitability. At the same time, we shine a light on the structural effects that drive business ecosystem dynamics. Our results show that the creation of connections and rate of change across all four business ecosystems is heavily influenced by the firms at their center, which are characterized by a high number of incoming ties. This result suggests that the hub firms coordinate how their business ecosystems are structured over time. However, in line with ecosystem theory (Jacobides *et al.*, 2018), we find no evidence of a hierarchical structure. What's more, we observe a negative tendency for *transitive closure* across the combination of all four business ecosystems. This would suggest that the number of triadic structures, in which three firms work together, reduces over time. The result would be a number of dyadic partnerships that are relatively independent from each other. Such a configuration would not be in line with ecosystem theory, in which interdependencies across multiple actors play an important role (Adner, 2017; Jacobides *et al.*, 2018; Kapoor, 2018). When estimating the tendency for transitive closure *within* business ecosystems, the results paint a more nuanced picture. For all but one business ecosystem, we find significant positive effects for *within ecosystem-transitivity*. This indicates that the negative tendency for transitive closure overall is mediated by belonging to the respective hub firm's business ecosystems. These results suggest that the hub firms in our sample may try to obtain exclusive partnerships and form triadic cooperation within their ecosystems. Thus, firms that are linked to more than one business ecosystem sever their connection to one of them over time and more fully integrate into the other. Considering that non-generic complementarities would become less valuable the more other competitors have access to them, this would speak to a successful business ecosystem orchestration. Our study not only benefits business ecosystem research by applying the mature methodology available in network research but in turn, directly benefits network research itself. Business ecosystems share the concept of a hub firm with other forms of organizational networks (Provan *et al.*, 2007). When modeling such highly centralized networks, the different importance of the network for each firm needs to be accounted for. We provide an effect that represents this importance regarding incoming connections – as is the case with business ecosystems but may also be important when analyzing centralized supply chain networks or alliance portfolios. This effect is published in the stochastic actor-oriented modeling package RSiena and can be used to improve model quality of SAOMs when analyzing the dynamics of interorganizational networks.

Second, we contribute to business ecosystem research by introducing homophily, aspiration and conformity as possible and competing mechanisms that explain partner selection and deselection (Baum *et al.*, 2005; Durand and Kremp, 2016; Voelker *et al.*, 2013). We relate these partner selection mechanisms to three attributes common in research on interorganizational relations: Inventiveness, firm size and profitability (Lee, Park, and Yoon, 2016; Withers *et al.*, 2020; Zhu and Westphal, 2021). We find that firms in business ecosystems look for potential partners in a business ecosystem that show similar inventiveness. We argue that, in the highly innovative context of the pharmaceutical industry, this represents strategic alignment and hence one of the key characteristics of how firms design their business ecosystems (Jacobides *et al.*, 2018). Our results suggest that, while similar inventiveness will increase the tendency of partnership formation, differences lead to the opposite. The stronger the difference in inventiveness, the more likely it is for firms to *not* seek others as a partner or even *end* an existing partnership. When analyzing the role of firm size, we observe a clear aspiration tendency in partner selection. This tendency, however, decreases, the larger the selecting firm is itself. This extends to a point where our results suggest that the largest firms in our sample are indifferent to the size of their potential partners. Conversely, smaller firms' interest in partnerships increases, the larger the potential partners are. Partnerships with other small firms remain unattractive and are not sought out or ended in favor of larger partners. This suggests that hub firms in business ecosystems, while not organizing their ecosystem hierarchically, may exercise power through a monopoly of strategic resources that come with size, such as production capabilities or market access. As such, they can freely set the standards for the smaller ecosystem incumbents, which are dependent on their access to said resources. To these smaller incumbents, however, these resources are non-generic complementarities and thus an essential motivation to join and align with a business ecosystem (Kapoor, 2018; Kapoor and Lee, 2013). Lastly, we theorized that conformity would be the dominant selection mechanism for firms when regarding profitability as an attribute of interest. Interestingly, we observe neither conformity, nor homophily or aspiration, but something that might be best described as *dominance* or *avoidance*. In other words, firms in our analysis are most inclined to engage in partnerships with others who are not profitable. Here, too, the tendency decreases the higher the profitability of the selecting firm. A possible explanation would be that firms will not want to enter a partnership where they are less powerful. Strong discrepancies in profitability may indicate that the terms of the partnership are dictated by the more profitable partner. Thus, it may be more attractive to partner with those firms whose profitability is very low. The idea that firms will not want to partner with others who are among the least profitable in the group of available partners, however, must be dismissed and our hypothesis rejected.

Third, our paper contributes to the literature on interorganizational dynamics. We systematically introduce aspiration and conformity as partner selection mechanisms relevant to interorganizational relations. While both aspiration and conformity are relevant concepts in management research, their application in the research of interorganizational relations has been sparse. Our research design allows different partner selection mechanisms to compete with each other and gives a nuanced depiction of the roles of the attributes of both firms in a potential partnership. This vastly improves the common representation of partner selection through either homophily or non-homophily in a single parameter. We can illustrate this by examining the attribute size. From our results, we can gather how smaller firms in business ecosystems may have something invaluable to offer, like knowledge of mRNA-technologies to develop vaccines against a novel disease but will need larger partners that offer them access to production capabilities, distribution centers, or international markets. We can also see that this tendency for attraction to larger firms while being present for every sampled firm, decreases the larger a selecting firm is. In a more traditional representation of homophily, this finding would likely be interpreted as *negative homophily*, or, expressed in a more proverbial manner, opposites attract. This explanation would, however, fall short of the occurring partner selection process. Instead, our findings suggest that, when researching interorganizational relations, scholars should take both, the attribute value of a selecting firm and the potential partner's attribute, into account and examine different combinations of exhibited attributes (i.e., large firms partnering with large firms, large firms partnering with small firms and small firms partnering with large firms). Taking this interplay into account offers more depth and insight into the complex relations between organizations. Our findings suggest that shifting the focus away from the firms at the core of business ecosystems, which is often a focal point in extant literature (Ansari *et al.*, 2016; Li, 2009), and taking the role of more peripheral actors into account, may yield novel and important insights.

2.5.2 Limitations and future research

We only observe firms' positions in a value chain but do not measure the strength of said ties. In consequence, a licensing agreement over $1 billion has the same meaning as a licensing agreement over $1. Although such high differences are hypothetical, we do not capture how valuable firms perceive their partners – and restricting this to the money involved in the partnership will likely not do the question of "how valuable is a partnership" justice, given how soft factors such as trust play a role and how the worth of single technological components may not accurately reflect their importance for the focal firm's final consumer-oriented product. Our study is also limited in the sense that we only observe publicly listed equities and no private companies (of which there were only very few in the initial sample), a limitation that has been primarily motivated by data constraints (i.e., the non-existence of attributes such as profitability). A third limitation is the time frame: For major pharmaceutical companies, four years are not a long time. Unfortunately, gathering objective data about past value chain connections has proven increasingly tedious and unreliable the further one looks to the past. For instance, the database we used, albeit of high quality, only shows information about the last time a value chain connection was mentioned publicly, be it in an annual report or a joint press statement. While all public statements that fell into a relevant time frame have been manually coded regarding content, start and end date, data became increasingly unreliable after four years. This may be due to survivor bias, i.e., no available information about firms that went bankrupt during recent years or have been acquired. We do not expect this limitation to strongly distort our estimations. An extension of the time period, however, would be welcomed to improve statistical power and show possible effects of external shocks, such as economic turmoil.

When thinking about interorganizational relations, there is a growing concern about the role of multiplexity (Novoselova, 2021; Shipilov *et al.*, 2014; Voelker *et al.*, 2013). It is entirely possible to assume that focal firms who choose partners which offer non-generic complementarities for their business ecosystem are not only influenced by salient attributes, but also by to other connections already established with these potential partners. These may range from equity stakes to board interlocks and as such will be subject to many different partner selection logics: while owning equity stakes might lead to more favorable terms of trade, board interlocks might mean firms have already established trust. Future researchers may deal with these issues both from a qualitative and a quantitative perspective. It also should be mentioned that the attributes we analyzed in our model serve as a sort of baseline for our understanding of business ecosystem dynamics, and there are other attributes that warrant further investigation, such as alignment with the technological trajectory of a firm. From a more generalized perspective on the dynamics of interorganizational relations, we strongly encourage researchers to model partner selection mechanisms more nuanced than is often the case. Specifically, we encourage management scholars to ask the question if what we know about the role of attributes important for partner selection in interorganizational relations, such as firm size, is sufficient or if the advent of novel modeling possibilities warrants further investigation. Allowing partner selection mechanisms to compete, for instance, may lead to far more detailed and perhaps surprising outcomes that will deepen our knowledge of interorganizational relations, no matter if they are business ecosystems or other forms.

Chapter 3
Modeling Core-Periphery Structures in Management Research

Abstract

Even though research on network dynamics in management research has steadily increased in popularity during the past decades, scholars have so far failed to account for the often-prevalent core-periphery structure in organizational networks. This essay presents four effects that have been developed for stochastic actor-oriented models. These effects can capture non-linear rate dependencies, thus allowing scholars to model the different importance of actors at the core or periphery of a network when these differences are thought to be theoretically meaningful. The mathematical formulation of the effects and potential use cases are discussed briefly before giving an example of how to apply them and showing how their inclusion may change results obtained from a model.

3.1 Introduction

Research on the dynamics of organizational networks has seen a steady increase in interest from management scholars (Chen *et al.*, 2022; Jacobsen *et al.*, 2022), with scholars relying on increasingly complex social network models to analyze their data. Perhaps the most popular method to analyze network dynamics in management studies (and the social sciences in general) are stochastic actor-oriented models (short: SAOMs; Kalish, 2020; Snijders *et al.*, 2010), as is evident by the large number of studies published in high-ranking management journals. These models are actor-oriented in the sense that nodes (for example, firms in an interorganizational network) decide whom to send ties to (for example, which firms they engage with in strategic alliances). To that end, the field of management studies greatly benefits from recent advances in SAOMs: The possibility to control for time heterogeneity and subsequently deal with it (Lospinoso *et al.*, 2011) allows for the compensation of external shocks when analyzing organizational networks for a long time or to specifically hypothesize how different time periods lead to differences in network dynamics (Sgourev and Operti, 2019). Options to analyze multiplex networks (Snijders *et al.*, 2013) allow researchers to analyze how advice ties and friendship ties differ in their influence on thoughts of quitting a job (Tröster *et al.*, 2019). Further additions, such as the possibility of modeling competing partner selection mechanisms (Snijders and Lomi, 2019) or making use of continuous variables instead of discrete categories (Niezink *et al.*, 2019), offer promising avenues for many future research ideas and potentially allow scholars to conduct studies on long-standing ideas that methodological restrictions have so far constrained. While all these extensions are invaluable, SAOMs so far only partly offered the possibility to account for the structural particularities that tend to make up interorganizational networks: a strong core-periphery structure. For instance, if one wants to analyze the evolution of alliance portfolios (Castro, Casanueva, and Galán, 2014) or business networks (Kaartemo *et al.*, 2020) from a network perspective, it seems clear that the core firms' decisions to create, maintain or dissolve ties have a much higher impact on the whole network than if a peripheral firm would decide to leave the network. Such network structures echo the typology of network governance proposed by Provan, Fish, and Sydow (2007), in which they make out three types of network governance: *Shared Governance*, in which organizations who are members of a network have a roughly equal say in governance decisions, the creation of *Network Governance Organizations*, in which an autonomous entity is created that takes governance decisions and takes care of network coordination and lastly a *Lead Firm*, where one central organization governs the network. Thus, a potential core-periphery structure should be considered when analyzing how interorganizational networks are governed and how they evolve. The only option to respect such a structure in the specification of stochastic actor-oriented models, however, was so far to condition the rate of changes per period on the number of linear or non-linear outgoing connections, linear incoming connections, or linear reciprocal connections of an actor. In practice, this means that when analyzing the dynamics of an interorganizational network, for example, in which a few core firms patent information from multiple other peripheral firms (e.g., large firms in the biopharmaceutical industry), the skewed indegree distribution of the network would likely lead to (1) problems in model convergence and/or (2) inaccurate estimation of the resulting parameters.

3.2 Approaching the Issue

3.2.1 Underlying functions in SAOMs

To understand how this problem can be solved for SAOMs, it is helpful to look at the underlying estimation process of these models. In general, stochastic actor-oriented models consist of two functions: the objective function and the rate function. The former reflects the decision of actor i to "change one network tie, or to keep the network as it is" (Ripley *et al.*, 2022: 42) and, in its most general state, can be expressed as follows (Snijders *et al.*, 2010: 47):

$$f_i(\beta, x) = \sum_k \beta_k s_{ki}(x)$$

The left side of the equation describes what value actor *i* awards to change, given the network state *x*. On the right side of the equations, we see the effects $s_{ki}(x)$ included in the model, while β_k represent the weights given by the statistical parameters. If these weights are 0, the effect plays no role in changes in the network, with positive values indicating a "higher probability of moving into directions where the corresponding effect is higher" (Snijders *et al.*, 2010: 47) and vice versa for negative values. In layman's terms, the objective function represents *what* an actor decides to do and with *whom*. This estimation process can be further complicated by splitting the evaluation function, which is included here and reflects general changes to the network, into a creation and endowment function, which would separate the values an actor ascribes to the creation and dissolution ties. For the purpose of this essay, the outline of the general formulation above is sufficient[9]. The other function relevant to estimating parameters in stochastic actor-oriented models is the *rate* function. This function produces rate parameters, which represent "the expected frequencies, between successive waves, with which actors get the opportunity to change a network tie" (Snijders *et al.*, 2010: 51)[10]. The rate function can be expressed as follows (Ripley *et al.*, 2022: 173):

$$\lambda_i^{net}(p, \alpha, x, m) = \lambda_{i1}^{net} \lambda_{i2}^{net} \lambda_{i3}^{net}$$

As can be seen, the rate function is a product of three terms: λ_{i1}^{net}, which accounts for differences between periods and is always included, λ_{i2}^{net}, which accounts for the role of actor covariates (e.g., the role of firm size in the decision to make changes to the network) and λ_{i3}^{net}, which accounts for the network position of the actor. The latter, λ_{i3}^{net}, is especially important when modeling network structures where "the network has a clear core-periphery structure" (Ripley *et al.*, 2022: 38) or when degree distributions are very skewed for other reasons.

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[9] Far more detailed explanations, including the information about the used algorithms, can be found in the extensive Siena Manual (Ripley *et al.*, 2022).

[10] The significance of rate parameters is not tested, as there would be no change in the network if these are 0. Given that a certain amount of change is a requirement for SAOMs and is typically tested by Jaccard Index values, testing for the significance of rate parameters is meaningless (Snijders *et al.*, 2010).

3.2.2 Incorporating non-linear dependencies.

In the aforementioned cases of core-periphery structures and skewed degree distributions, specifying non-linear dependencies, such as the logarithm of actors' outdegrees, often works best in terms of model fit and model convergence, which is a crucial prerequisite to interpret estimation results (Ripley *et al.*, 2022). While the effects included in the corresponding R-package have so far been able to account for skewed out-degree distributions and linear dependencies on in-degree and reciprocated degrees, researchers have been unable to model non-linear dependencies that depend on in-degree values or reciprocated degrees. However, these are highly relevant as the non-linear dependency reflects the assumption of differences in tie distribution being theoretically meaningful. This is the case for various network types relevant to management scholars. To illustrate this, I offer two hypothetical examples: In supply chain networks, large manufacturers may have many suppliers of single parts but do not send parts back. A strongly skewed indegree distribution would reflect such a constellation. Scholars might be interested in how information flows in an engineering department and thus analyze it as an advice network. The network might then be characterized by a few central senior engineers, who not only receive a lot of information due to occupying a central position but also are valuable sources of advice for their colleagues. Conversely, engineers at the periphery of this network may not reciprocate their advice ties to the same degree. This would then be reflected by a strongly skewed distribution of reciprocated degrees that is theoretically important since its interpretation would be that the central senior engineers do not hoard knowledge but rather share it with other members of the department who are in touch with them. The solution to accurately capture these network properties in SAOMs is to condition the rate effects on non-linear dependencies of in- and reciprocated degrees. To this end, I wrote four effects that reflect both the logarithmic and inverse effects of the number of actors' in-degrees and reciprocated degrees[11]. The logarithmic effects reflect the idea that the higher an actor's degree, the more theoretically relevant and impactful for the dynamics of the whole network are this actor's actions. Conversely, the inverse effects suggest that the lower an actor's degree, the more theoretically relevant and impactful this actor's actions are. As an example, when actors with low in-degrees join a network and there is a theoretical reason to believe that these actors will be very active in changing the network structure, one would want to incorporate an inversed degree effect. These effects can be expressed as follows:

(1) Logarithmic in-degree effect:

$$\exp\left(\ln\left(\alpha_h(x_{+i} + 1)\right)\right)$$

(2) Inverse in-degree effect:

$$\exp\left(\alpha_h/(x_{+i} + 1)\right)$$

(3) Logarithmic reciprocal degree effect:

$$\exp\left(\ln\left(\alpha_h\left(x_{i(r)} + 1\right)\right)\right)$$

(4) Inverse reciprocal degree effect:

$$\exp\left(\ln\left(\alpha_h\left(x_{i(r)} + 1\right)\right)\right)$$

For each of these four effects, α_h denotes the associated rate parameter, while x_{+i} and $x_{i(r)}$ reflect the respective in-degree and reciprocal degrees of each actor. To avoid problems that occur when taking the logarithm of 0 or dividing by 0, a degree of 1 is added to each actor's values, synonymous with the already existing logarithmic and inverse outdegree rate effects.

3.3 Application

To illustrate the use of the effects discussed in this essay, Table 3.1 shows an application to the value chains of a large pharmaceutical firm and the respective ties between the firms

[11] The effects have been coded in the programming language C++ and are based on the rate effects that already existed, specifically *outRateLog* and *outRateInv*. I am grateful towards Tom Snijders for implementing the effects mentioned in this paper into the RSiena-package for wider use.

belonging to that value chain, thus constituting a small network[12]. This network has a highly skewed indegree distribution, with the indegree of the core firm ranging from 6 to 11 between periods, while the majority of other firms either have an indegree of 0 or 1, with a few exceptions where firms have an indegree of up to 4. As is evident by the results in Table 3.1, the rate parameters also fluctuate quite strongly. This suggests that there are actors in the network whose actions have more influence on the network than others, thus influencing the estimated parameters.

Table 3.1: SAOM results on network change illustrating the application of rate effects

Effect name	M1	M2	M3	M4	M5
Rate period 1	0.26	0.13	1.12	0.13	4.67
Rate period 2	0.41	0.20	1.85	0.23	8.01
Rate period 3	0.29	0.14	1.19	0.14	5.01
Rate period 4	0.25	0.12	1.03	0.13	4.25
Log. Indegree effect on Rate	-	1.04***	-	-	-
Inv. Indegree effect on Rate	-	-	-2.12***	-	-
Log. Rec. degree effect on Rate	-	-	-	2.33***	-
Inv. Rec. degree effect on Rate	-	-	-	-	-3.53**
Density	-5.25***	-4.23***	-4.31***	-4.38***	-4.44***
Reciprocity	1.72	1.19	1.35	1.96	2.07
Trans. Triplets	0.99	-0.07	0.17	-0.39	-0.37
Indegree Popularity	-0.49	-1.80	-1.08	-1.70	-1.47
Outdegree Popularity	2.20**	3.99	2.88*	3.91*	3.59*
Overall maximum convergence ratio	0.14	0.10	0.12	0.18	0.12
Goodness of Fit for In-degree Distribution	0.33	0.33	0.41	0.36	0.39

As this only serves as an illustration, the model specification is very parsimonious and does not incorporate firm attributes. I have included the *density* effect (which serves as an intercept) and controlled for the tendency to *reciprocate* ties, the tendency to form *transitive triplets*, actor's tendencies to receive ties (*Indegree Popularity*) and actor's tendencies to send

[12] This data is a subset of the paper *Partner Selection in Business Ecosystems* in this dissertation and extended by one time period to illustrate better the effects discussed here.

ties (*Out-degree Popularity*). It is important to note that, for the network analyzed here, the *logarithmic in-degree* effect makes the most theoretical sense: The firm at the network's core plays a more important role in this network's coordination than the more peripheral firms. We can observe that both logarithmic effects (see columns M2 and M4 in Table 3.1) do a good job of smoothing the rate function, resulting in parameters close to the originally observed values but with less pronounced inter-period differences. The results also show that convergence was improved most by the *logarithmic in-degree* effect on rate, while the *logarithmic reciprocal degree* effect on rate increased the overall maximum convergence ratio. Most importantly, controlling for the prominent role of the core firm by including the logarithmic in-degree effect on rate decreased the significance of out-degree popularity, which is not significant in M2 in comparison to the other models. As can be expected for a network with a *Lead Firm*, the inverse effects on rate lead to a significant negative parameter, suggesting that the actions of firms with a lower in-degree have less impact on the network than their more central counterparts. Controlling for this also increases the rate parameters. This is, however, no cause for concern as it reflects how the inverse degree effects flip the role of the degree distributions on their heads. The goodness of fit for the base models in-degree distribution was already sufficient, so the impact of the included effects should not be discussed as meaningful changes. This is based on the fact that the goodness of fit-values should first and foremost *not* be 0, with the threshold of $p < 0.05$ being relatively arbitrary, but commonly used. Importantly, an increase in the *p*-values does *not* automatically translate to a better fit, so improving fit only becomes relevant when the *p*-values are low enough to warrant concern (Lospinoso and Snijders, 2019).

3.4 Conclusion

The effects discussed in this paper are highly relevant to various types of networks that are of potential interest to management scholars. Their inclusion in SAOMs allows to account for the theoretically relevant role of core-periphery structures in observed networks and potentially leads to a number of benefits, such as improving convergence or aiding with the goodness of fit when either model property turns out to be problematic. They also lead to a more accurate estimation of parameters, both in parameter size as well as significance. Most importantly, though, they allow scholars to statistically show that core (or peripheral) actors in a network have more influence on the dynamics of an observed network than their respective counterparts. Which of these benefits apply naturally depends on the researched network, and only in rare cases will all of them occur simultaneously. Rather, as in the results provided in this essay as an example, they will be beneficial for certain aspects of the estimated models. The reasons for including these effects may either be statistical issues when estimating SAOMs, such as problems with convergence or because there is an underlying theory about central or peripheral actors' roles in a network. In any case, *which* effects are included should be guided by theory and the research interest at hand. The rate effects presented here allow for more accurate models of network dynamics and, in cases where convergence was not achievable so far due to highly skewed degree distributions, for the analysis of networks that management scholars have so far been unable to analyze with SAOMs.

Chapter 4
The Coevolution of Board Interlock Networks and Corporate Strategic Actions

Abstract

Studies on board interlocks are divided into two streams, one examining their dynamics; the other, their consequences. Our paper proposes that both phenomena – board interlock dynamics and board interlock consequences – are interdependent. Adopting a structuration theoretical perspective, we theorize and empirically demonstrate how firm's corporate strategic actions (specifically, acquisitions and divestitures) influence their board interlock networks and how these networks, in turn, influence the firm's corporate strategic actions, revealing their recursive nature. Integrating these heretofore disjunct research streams, we complement the corporate governance literature by providing evidence that corporate strategic actions and board interlock networks coevolve. We contribute to theory on strategic networks by applying a structuration theory lens. Lastly, we illustrate methodological advances by using stochastic actor-oriented models to analyze coevolution processes.

4.1 Introduction

Board interlocks play an important role in corporate governance and have far-reaching implications for a variety of topics, ranging from the performance of firms to strategic decisions and the demographic structure of corporate elites (Gupta, Wowak, and Boeker, 2022; Howard, Withers, Carnes, and Hillman, 2016; Martin *et al.*, 2015; Westphal and Zhu, 2019). There are two major research streams on board interlocks, which, although clearly related, have developed mostly independently of each other. The first of them deals with the dynamics of board interlock networks (Howard *et al.*, 2017; Mizruchi and Stearns, 1988; Withers *et al.*, 2020). Studies in this domain have shown, among other things, how an organization's status influences the likelihood that new board interlocks will be created (Chandler, Haunschild, Rhee, and Beckman, 2013), how the desire to reduce patent litigation between partners facilitates the creation of board interlocks (Howard *et al.*, 2017), and how fads and fashions in an industry influence the formation and persistence of board interlock ties (Yue, 2012). The second research stream addresses the question of how board interlocks influence firms and their strategic decisions (Gupta *et al.*, 2022; Peng, Mutlu, Sauerwald, Au, and Wang, 2015; Tuschke, Sanders, and Hernandez, 2014). Studies in this stream have shown, for example, that board interlocks influence the adoption of internal governance codes (Okhmatovskiy and David, 2012), the decision to expand into new markets (Connelly *et al.*, 2011), and the adoption of new business practices such as stock option pay (Yoshikawa *et al.*, 2020).

Even though both streams have attracted considerable attention for decades, the dynamics of board interlocks and the consequences thereof have rarely been analyzed in conjunction. Instead, researchers tend to neglect possible interdependencies between the consequences of board interlocks and the networks from which they result (Okhmatovskiy and David, 2012; Sanders and Tuschke, 2007; Yoshikawa *et al.*, 2020). In this study, we argue that the dynamics and consequences of board interlock networks are interdependent and should be understood as a recursive process which means that the consequences turn into antecedents and vice versa. To theorize this phenomenon, we use structuration theory (Giddens, 1984), a theoretical perspective that "implies that action can and should only be analyzed with reference to structure; and structure only with reference to agency" (Sydow and Windeler, 1998: 266). At its core, the notion of structuration suggests that actors (in our case, firms) knowingly or unknowingly change the structures (here, board interlock networks) in which they operate through their actions (specifically, acquisitions and divestitures). At the same time, those overarching structures influence actors' actions (for the purposes of this study, corporate strategic actions). Giddens (1984) calls this recursiveness the *duality of structure*. Acknowledging this duality implies that corporate strategic actions and board interlock networks should be theorized as interlinked phenomena that *require* a coevolution perspective in order to be adequately understood.

Pursuing our considerations rooted in structuration theory, we derive hypotheses about the interdependencies between board interlocks and two corporate strategic actions: acquisitions and divestitures. These two major strategic actions have been the subject of inquiry in the research streams on the dynamics and the consequences of board interlock networks alike (Beckman and Haunschild, 2002; Haunschild, 1993; Hernandez and Menon, 2018). If acquisitions and divestitures influence how board interlock networks change (Hernandez and Menon, 2018, 2019) and are simultaneously consequences of those networks (Ahn and Walker, 2007; Connelly *et al.*, 2011; Haunschild, 1993), they cannot be seen as exogenous to them but need to be incorporated also as antecedents of changes in board interlock networks. To test our hypotheses empirically, we apply stochastic actor-oriented models, or SAOMs (Snijders *et al.*, 2010), to capture the coevolution of board interlock networks between a large sample of German firms from 2013 to 2018 and their corporate strategic actions—specifically, the acquisition and divestiture activities—in those years. We find support for our assumption that firms' corporate strategic actions lead to changes in network structure while being influenced by that structure. In other words, our results show that board interlock networks and acquisition and divestiture activities do indeed coevolve.

Our study makes three contributions to the literature. First, we complement research on corporate governance by providing evidence that corporate strategic actions and board interlock networks coevolve. We thereby integrate two previously largely disjunct streams of research and show that, figuratively speaking, firms are prisoners not only of their past actions but also of their present circumstances and the future circumstances that their actions will shape. The literature ignoring this recursiveness accordingly risks to overestimate firms' internal considerations that lead to corporate strategic actions, for it insufficiently considers the role of external circumstances, specifically network dynamics. Second, we contribute to theory on strategic networks by applying structuration theory (Giddens, 1984) to study board interlock networks and corporate strategic actions. We show how structuration theory provides a fruitful lens for theorizing the complex, recursive nature of strategic decisions and how it enables researchers to move beyond the views of strategy leading to structure and vice versa as one-way streets. Third, our study illustrates the usefulness of contemporary methodological advances in management research by applying SAOMs to answer questions about coevolutionary processes (Snijders *et al.*, 2010) of interest to strategic management scholars. SAOMs provide management scholars with the means to understand how firms actively shape their environment while controlling for effects endogenous to the broader social context and permitting causal interpretations.

4.2 Theoretical Background and Hypotheses

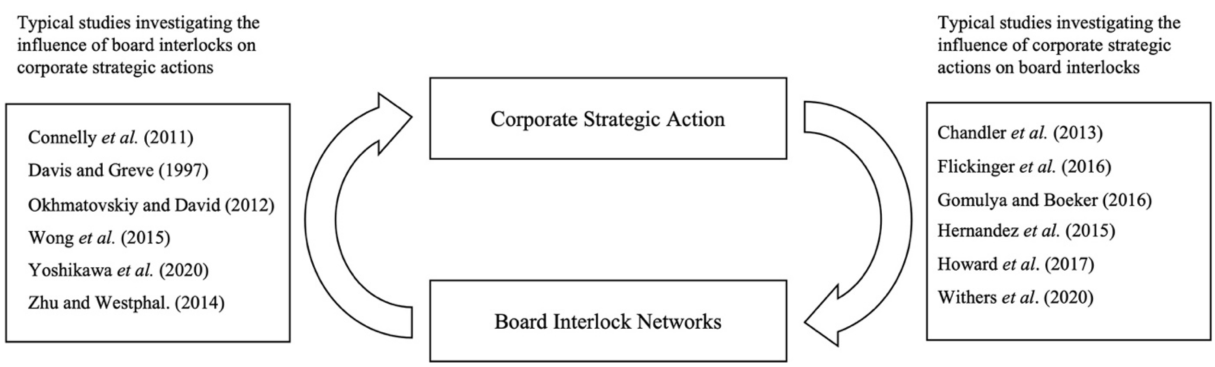
4.2.1 Dynamics and consequences of board interlock networks

Board interlocks exist when “a person affiliated with one organization sits on the board of directors of another organization” (Mizruchi, 1996: 271). This type of interorganizational relationship has played an important role in research on network dynamics and corporate governance for decades, resulting in an abundance of studies (Chen *et al.*, 2022; Lamb and Roundy, 2016). For example, studies show that firms create board interlocks to contend with resource dependencies (Martin *et al.*, 2015; Mizruchi and Stearns, 1994; Ong, Wan, and Ong, 2003). Scholars also show that board interlock networks change as the result of financial misconduct (Arthaud-Day, Certo, Dalton, and Dalton, 2006; Gomulya and Boeker, 2016; Withers *et al.*, 2020), underlining that a firm’s financial trustworthiness strongly influences board compositions and, hence, the dynamics of board interlock. Furthermore, research has examined the role of status in board interlocks at both the directorial (Flickinger, Wrage, Tuschke, and Bresser, 2016) and organizational level (Chandler *et al.*, 2013; Ebbers and Wijnberg, 2010). These studies indicate that the social status of directors as well as the status of the organization facilitate changes in a firm’s board interlock network. Other studies show how an external director’s alignment with the global trajectory of a focal firm increases the likelihood of interlock formation (Howard *et al.*, 2017) and that firms seek to design their board interlock network in a way that avoids knowledge spillover (Hernandez *et al.*, 2015).

Perhaps even more prominent than research on the dynamics of board interlocks is research on their consequences. For instance, studies show how board interlocks improve the performance of firms by providing critical resources such as information, social capital, or outside perspectives that can improve decision-making (Carpenter, Westphal, and McDonald, 2010; Horton, Millo, and Serafeim, 2012; Peng *et al.*, 2015; Yeo, 2003). This performance increase owes partly to the fact that the private information received through board interlocks has more depth and contextual relevance than information that would be available to the public

(Beckman and Haunschild, 2002; Haunschild and Beckman, 1998). Research also shows that the reputation of the firm sending a director to another firm's board is likely to spill over, influencing how the receiving firm is perceived by the public. For example, Kang (2008) finds that the reputational loss inflicted by financial misconduct spills over to associated firms. Other studies show that board interlocks become particularly valuable in situations of high uncertainty and that firms in such situations fare better the more board interlocks they have (Boyd, 1990; Hillman, Zardkoohi, and Bierman, 1999). The most researched area regarding the consequences of board interlock networks is the one on the adoption and diffusion of corporate strategies. Indeed, "[m]ost studies show that when two firms are interlocked with one another, it is more likely that a strategic action will diffuse from the interlocked firm to the focal firm" (Lamb and Roundy, 2016: 1523) Such strategic actions span a wide range: Board interlocks influence firms in their decisions to expand to foreign markets (Connelly *et al.*, 2011), set corporate governance codes in response to institutional pressure transmitted through board interlocks (Okhmatovskiy and David, 2012), and tend to adopt poison-pill responses if that practice is common in their board interlock network (Davis and Greve, 1997) or executive compensation schemes (Wong, Gygax, and Wang, 2015; Yoshikawa *et al.*, 2020; Zhu and Westphal, 2014). Our review of the literature clearly suggests that both research streams—the one on board interlock dynamics and that on consequences of board interlock networks—revolve around similar, if not identical, phenomena, yet they are commonly treated as disjunct (see Figure 4.1).

Figure 4.1: The current disjunction of research on the interaction of board interlocks and corporate strategic actions



4.2.2 Structuration theory

Most studies on board interlocks apply theoretical perspectives that commonly assume that *either* board interlocks lead to corporate strategic actions *or* that these actions lead to change in board interlock networks. Examples are institutional theory (Okhmatovskiy and David, 2012), agency theory (Zahra and Pearce, 1989) and resource dependence theory (Howard *et al.*, 2017). Although all these theoretical approaches have merit and their use has yielded important insights, they do not represent viable choices for theorizing, understanding, and explaining whether and how corporate strategic actions and board interlock networks coevolve. Application of Giddens's (1984) structuration theory to board interlock research allows us to theorize that corporate strategic action not only influences board interlock networks but that this action is influenced by these networks at the same time.

At the heart of structuration theory lies the notion that actors are embedded in a structural context, which is reinforced or changed by the actions of these actors. The term *actors* may refer to individuals within organizations or to collective actors, such as entire organizations (Sydow and Windeler, 1998). Following common practice in strategic management research, we assume that directors being engaged in board interlocks act on their company's behalf (Boyd, 1990; Martin *et al.*, 2015; Tuschke *et al.*, 2014). We therefore treat firms, represented by their directors, as actors. According to Giddens (1984), actors have agency, meaning that they decide which actions to pursue. These actions are enabled and constrained by the surrounding structure, which forms an "*action realm*, in which individuals realize institutional orders within their day-to-day actions" (Jarzabkowski, 2008: 622, italicized in the original). This structure, in turn, exists only because of the activities of actors (Pozzebon, 2004: 253). In our case, *structure* refers to the board interlock network. Although competent actors may anticipate their actions' effects on the structure they are embedded in, changes in structure typically "result from intended as much as from unintended consequences of actions" (Sydow and Windeler, 1998: 279). In other words, when one is theorizing coevolutionary processes, observed structural changes might reflect unintended consequences of past actions, and actors may not always perform actions with the aim of changing an overarching structure. In summary, the structural context in which actors are embedded defines the range of possible actions and makes certain actions more or less likely, but said structure is often not apparent to actors. It does not determine action but rather influences it through enablement or constraint (Giddens, 1984).

Structuration theory further assumes that actors assess their actions in a process of reflexive monitoring, where they use their implicit rather than explicit knowledge. They base their decisions on routines and experiences, and they expect others to act according to similar principles (Zimmer and Ortmann, 1996). Whereas Giddens describes the relationship between action and structure as simultaneous, previous applications of structuration theory in management research have typically followed a sequential logic, where actions at one point in time influence structure at the next point and vice versa (Barley and Tolbert, 1997; DeSanctis and Poole, 1994; Jarzabkowski, 2008; Orlikowski, 1996). Such sequential logic allows an empirical assessment of structuration processes. Commonly adopted in management research, this approach to structuration theory figures in our study as well. We derive our hypotheses on the interdependencies between board interlock networks and corporate strategic actions accordingly. When talking about firms and board interlock networks, we henceforth use those two terms as equivalent to *actors* and *structure*, respectively, in structuration theory.

4.2.3 Hypotheses

Board interlock networks fit well into Giddens's structuration theory for multiple reasons. First, structuration theory accommodates equifinality in explanations of changes in structure (in our case, the formation and dissolution of board interlocks). In other words, there may be multiple simultaneous and distinct reasons for board interlock changes, including, as we argue, acquisitions and divestitures. Because organizations cannot decide which board interlocks other firms create or dissolve, the overarching *structure*—the board interlock network—is a result of the actions of each actor involved, irrespective of their reasons for performing these actions. Second, a firm's activities are influenced by what their top managers learn through membership in other firms' boards. In other words, the corporate strategic actions of a firm are enabled or constrained by its position in the board interlock network. Third, board interlocks are institutionalized through recurring board meetings and thus constitute structure. If board meetings were uncommon, board interlocks would still exist but would not constitute structure in the way Giddens proposes (Giddens, 1984; Sydow and Windeler, 1998).

Acquisitions and divestitures are corporate strategic actions that are particularly well suited for analysis from a structuration perspective, for both are relevant to board interlock dynamics and consequences alike. Regarding board interlock dynamics, we can assume that both types of "corporate action[s] can have a significant impact on the network that surrounds the actors involved in the transaction" (Hernandez and Menon, 2019: 81). More specifically, we theorize that acquisitions and divestitures influence the creation and dissolution of board interlocks and thus capture two key components necessary for understanding a network's dynamics. Regarding board interlock consequences, research finds that "imitation plays a powerful role in corporate acquisition activities" (Haunschild, 1993: 586). Although the influence of board interlock networks on divestiture activities has not yet been thoroughly investigated, the literature on the influence of board interlocks on corporate strategic actions permits us to integrate divestitures and acquisitions into our subsequent theorizing.

Creation of board interlocks. Although acquisitions and divestitures have their "own rationale, and considerations of external network structure may be secondary to the objectives of firms" (Hernandez and Menon, 2019: 83), both corporate strategic actions may significantly influence a firm's board interlock network. For instance, an acquisition may expose the acquirer to the network of its target, making many new potential partnerships, such as board interlocks, available. These board interlocks may be directly transferred by seating former managers of acquired firms on the acquirer's executive board, a frequently observed consequence of acquisitions (Campbell, Busenbark, Graffin, and Boivie, 2021; Li and Aguilera, 2008). Studies also show that a focal firm's acquisitions increase the propensity of this firm's directors to obtain board seats in other firms. For example, Avery, Chevalier, and Schaefer (1998) show that CEOs are more likely to obtain outside directorships after performing large acquisitions, indicating that prestige and career opportunities are external rewards for acquisitiveness. A study by Mira, Goergen, and O'Sullivan (2019) illustrates how acquisition performance influences the opportunities of nonexecutive directors to sit on the boards of other firms. Although one may assume that firms deliberately factor in the creation of new board interlocks after an acquisition, it does not necessarily occur. Instead, the creation of board interlocks may happen as an unintended, secondary consequence of acquisitions, an outcome consistent with one of structuration theory's essential assumption: that structure may change because of what an actor does even though the change was not the main purpose of that action (Giddens, 1984).

As with acquisitions, linking divestitures and a network perspective is likely to be fruitful (Brauer, 2006). Divestitures, too, may lead to the creation of board interlock ties. If a firm spins off part of its business but still wants to maintain influence over it or incorporate it into its network, that desire may lead to the creation of new board interlock ties. For instance, the German pharmaceutical firm Bayer divested its Material Sciences unit in 2015. The divested unit became the corporate spinoff Covestro, which immediately seated Bayer executives on its supervisory board. The divestiture thereby led to a new board interlock tie, giving Bayer unmediated access to the supervisory board meetings of Covestro and creating a relationship between the former parent and the divested unit. In summary, we expect acquisitions and divestitures alike to lead to the creation of new board interlock ties:

Hypothesis 1a (H1a): *A focal firm's acquisition activities positively influence the subsequent creation of new board interlock ties by that firm.*

Hypothesis 1b (H1b): *A focal firm's divestiture activities positively influence the subsequent creation of new board interlock ties by that firm.*

Dissolution of board interlocks. In addition to arguing that acquisitions and divestitures lead to the creation of new board interlock ties, we also propose that they lead to the dissolution of existing board interlock ties. Firms may pursue an acquisition to increase their capability of performing certain tasks in-house (Ahuja and Katila, 2001). Consequently, a board interlock with a firm that provided the services that are henceforth produced in-house might prove unnecessary and will be deleted in the course of the acquisition. Firms may also eliminate a board interlock by acquiring another firm with which the acquirer had an interlock prior to the acquisition (Hernandez and Menon, 2018, 2019). A divesting firm may sell part of its business, and the directors associated with that part might leave the core firm, taking their board interlocks with them. Simultaneously, divesting part of a firm may lower the need for existing ties that provide control or information. One of the reasons for this reduced need could be that these connections were relevant to the sold entity but not to the selling corporation. Given the evidence for the notion that serving on too many boards may negatively affect a director's performance (Connelly and Slyke, 2012; Lipton and Lorsch, 1992), a focal firm may decide that the benefit of having a board interlock no longer outweighs the cost of maintaining it (e.g., invested time and effort). There are also signs that directors of entities that are taken over are unlikely to retain their board seats, especially if the entity performed poorly before the takeover (Harford, 2003). In summary, we suggest that both acquisitions and divestitures will lead to the dissolution of existing board interlock ties:

Hypothesis 2a (H2a): *A focal firm's acquisition activities positively influence the subsequent dissolution of new board interlock ties by that firm.*

Hypothesis 2b (H2b): *A focal firm's divestiture activities positively influence the subsequent dissolution of new board interlock ties by that firm.*

Consequences of board interlocks. The idea of structuration necessarily entails not only that actors reproduce or change structure through their actions but also that this structure is shaped by said actions. Notably, structural influences are not assumed to force actors to take certain actions, but rather to increase or decrease the likelihood of those actions. Translated to our specific phenomenon, connections that a focal firm has to other firms in the board interlock network are likely to influence this firm's corporate strategic actions. Research shows that corporate strategic actions often diffuse through board interlocks and that imitation occurs (Lamb and Roundy, 2016; Mizruchi, 1996). For instance, Haunschild (1993) provides empirical evidence that firms tend to be influenced by the acquisition activities of firms to which they send a board interlock. This effect strongly indicates that "acquisition-related information may be communicated through director ties" (Haunschild, 1993: 586). In addition, Beckman and Haunschild (2002) find that focal firms paid lower premiums for acquisitions when they had network partners of varying size as well as partners that had "experience with acquisitions of heterogeneous sizes" (Beckman and Haunschild, 2002: 116).

Whereas imitation effects through board interlocks are well documented for acquisitions, the effects of board interlock networks on divestitures are underresearched (with notable exceptions, such as Ahn and Walker, 2007). As Brauer (2006: 775) states, "divestiture research has largely failed to explain why firms facing very similar conditions (e.g., bad performance) make very different decisions on whether and when to divest." We assume that divestitures, as shown for other corporate strategies, are also influenced by the actions of firms to which a focal firm is connected through board interlocks. An important distinction between our study and prior work on the link between board interlock networks and acquisition activities is that we move beyond dyadic influences and analyze the diffusion of strategic actions at a network level. From our perspective of structuration theory, we thus do not assume that firms necessarily imitate the actions of discrete network partners but rather that firms operating in a network are "embedded in the social context of the interfirm network, the industry, and the society" (Sydow and Windeler, 1998: 267). In other words, firms' decisions to acquire or divest may be influenced by both specific individual relationships in addition to their entire board interlock network. Activities observed from other firms and information obtained in board meetings of different firms lead to aggregated influence on executives' decisions and cannot be attributed to any one firm to which a focal firm is tied. Although both acquisitions and divestitures regularly have a large strategic and financial impact on the focal firm and have far-reaching implications, executives are likely to adapt their assessment of the strategic value of such major actions according to novel information they receive via board interlocks. Regarding the influence of board interlocks on corporate strategic actions, we thus propose:

> **Hypothesis 3a (H3a):** *A focal firm's acquisition activities eventually become more similar to the acquisition activities of those firms to which it has board interlock ties.*

> **Hypothesis 3b (H3b):** *A focal firm's divestiture activities eventually become more similar to the divestiture activities of those firms to which it has board interlock ties.*

A coevolutionary perspective. Next, we bring the pieces of the puzzle together by applying structuration theory to board interlock networks. This lens helps us theorize and explain how action and structure coevolve (Sydow and Windeler, 1998) and to assess the "temporal sequencing of causal mechanisms behind the emergence, evolution, and outcomes of networks" (Ahuja *et al.*, 2012: 446). To be precise, we assume that a firm's acquisition and divestiture activities are influenced by the board interlock network. Similarly, the board interlock network changes through the strategic actions of firms. These actions directly influence the structure that enabled or constrained the factors leading to these actions (Hernandez *et al.*, 2015; Martin *et al.*, 2015; Withers *et al.*, 2020). As we have reasoned above, acquisitions and divestitures potentially lead to immediate alterations in board interlock networks. In the case of board interlocks, such an immediate change may occur through having an executive of the acquired firm take a seat on the acquirer's executive board—a clear link between action and structure. Recursive coevolution unfolds as a process, with a firm's specific board interlock network providing a structure that influences the likelihood that this firm will carry out acquisitions and divestitures. These actions then change the existing board interlock network, which, in turn, influences the firm's corporate strategic actions. The change in structure, however, means that the action realm in which the firm operates also changes, potentially leading to changes in the firm's acquisition and divestiture activities. Consequently, we hypothesize that actions (acquisitions and divestitures) and structure (board interlock networks) evolve interdependently. We therefore propose:

> **Hypothesis 4 (H4):** *The acquisition and divestiture activities of a focal firm coevolve with its board interlock ties.*

4.3 Data and Method

4.3.1 Institutional setting

For the empirical analysis we investigated board interlocks in Germany as done in previous studies (Hernandez *et al.*, 2015; Sanders and Tuschke, 2007; Tuschke *et al.*, 2014). Germany has a two-tier board system, in which boards are separated into executive and supervisory boards. Executive boards consist of managers who lead the firm; supervisory boards, of managers from other firms, firm employees, and various shareholders, sometimes represented by government officials. The composition of supervisory boards depends on many factors such as the size of the firm and is clearly defined by German law (*Aktiengesetz*). The task of supervisory boards is to supervise and advise the executive board for which they have "to be involved in decisions of fundamental importance to the enterprise" (DCGK, 2019: 4).

The ability to distinguish between executive and supervisory boards allows for a unique perspective on corporate strategic actions. Whereas supervisory boards can veto strategic decisions such as acquisitions, they do not design corporate strategies. Instead, the executive board decides the strategic direction a firm takes. The German Corporate Governance Code states the function of the executive board as "managing the enterprise in its own best interests" and to "develop[s] the enterprise strategy, coordinate[s] it with the Supervisory Board and ensure[s] its implementation" (2019: 4). While leading their focal firm, executives holding a seat on the supervisory board of another firm are in the unique position of being transparently informed about that firm's strategic endeavors. This access to idiosyncratic knowledge makes it possible for the executive to learn about risk and opportunity assessments of the firms in which he or she sits on the supervisory board whenever a major corporate strategic action is considered.

Because of the German two-tier board system, it is possible to differentiate between board interlock ties from the executive to the supervisory board and ties between supervisory boards. To make this differentiation clear, we adopt the terms "primary" and "secondary" board interlocks as used in past research (Windolf and Beyer, 1996). Primary board interlocks consist of executives sent to supervisory boards of other firms and are directed network connections. Secondary board interlocks consist of undirected connections, in which firms are connected by the same person sitting on different supervisory boards. Distinguishing between these two types of board interlocks is not only semantically but also theoretically relevant, for primary interlocks are strategically important, whereas secondary interlocks serve the purpose of control or advice (Sanders and Tuschke, 2007; Tuschke *et al.*, 2014; Windolf, 1994). We note that it is not allowed in Germany for firms to reciprocate primary board interlocks. That is, if one firm sends an executive to the supervisory board of another, the receiving firm will not be able to send an executive back. As explained in the following sections, the focus in our study is on primary board interlocks.

4.3.2 Sample

Our sample encompassed all firms listed in the German Prime Standard indices between 2013 and 2018. For each year, there were 30 firms listed in the German stock market index (Deutscher Aktien-Index, DAX),[13] 60 in the MDAX, 70 in the SDAX, and 30 in the tecDAX. Firms in the tecDAX, an index specifically designed to take account of equities that focus on technology and R&D, may be listed in one of the other three indices as well. Our study's sample consisted of 211 firms, of which 104 were present across all waves. The remaining 107 firms

[13] The Mid-Cap-Dax (MDAX), Small-Cap Dax (SDAX) are composed of firms which have a lower market value than those included in the DAX. The tecDAX includes technology shares. In September 20121, the number of firms in the indices mentioned changed. For example, the number of firms in the DAX increased to 40. This alteration, however, has no bearing our analysis.

were absent from some of the waves because they were either not members of the indices listed above or did not exist at the time. Every wave consisted of at least 160 firms but no more than 190. We hand-collected data on board interlocks between the firms in our sample by analyzing the annual reports of every listed firm.

We chose to examine the years 2013 to 2018 because they reflected a relatively stable market after the economic turbulence that followed the financial crisis around 2008 and the Euro crisis around 2010. Our observation period ended before the COVID-19 crisis hit economies worldwide in early 2020. Possible time heterogeneity in our models should therefore not stem from disruptive momentum not captured in our data. The same is true for control attributes and the acquisition and divestiture activities of firms, all of which were recorded on each year's final day.

4.3.3 Measures

Our study posits the core assumption that networks of primary board interlocks and corporate strategic actions coevolve and that both sets of variables—board interlock networks and acquisitions and divestitures—are dependent and independent variables simultaneously.

Board interlocks. We examined the formation and dissolution of primary board interlock ties for all firms in our sample. These ties represent our first variable of interest. We observed the network yearly at the end of December. Thus, a tie lasting from November 2014 to June 2015, for example, appears in 2014, not 2015. The average number of outgoing primary board interlocks was low, ranging between 0.20 and 0.26. Cases in which a firm sent two executives to the same other firm's board were extremely rare, so we just looked at the presence or absence of board interlocks between two firms. There was no missing data regarding board interlocks Table 4.1 shows details on the observed yearly networks.

Table 4.1: Network descriptives

	2013	2014	2015	2016	2017	2018
			Primary			
Average outdegree[a]	0.26	0.24	0.21	0.20	0.22	0.22
Average indegree[a]	0.28	0.27	0.24	0.23	0.24	0.23
Number of ties	54	51	44	43	47	46
			Secondary			
Average degree[a]	1.54	1.49	1.50	1.68	1.48	1.33
Number of ties	162	157	158	177	156	140

[a]Average degrees refer to the average number of board interlock ties across all actors. Outdegree refers to directors sent to other firms; indegree, to directors received by other firms.

Corporate strategic actions. Information about acquisition and divestiture activities was drawn from the Thomson Reuters Refinitiv database with less than 3.5% missing observations for both categories of strategic action. The number of all acquisitions and divestitures was aggregated yearly to resemble the number of acquisitions and divestitures performed by focal firms each year. Both strategic actions showed a highly skewed distribution. In each year, most firms in our sample performed no acquisitions or divestitures, followed by a quickly declining distribution with a long tail (e.g., extremely few firms performing more than five instances of either action). To smooth this distribution, we recoded acquisitions as well as divestitures in a manner that accurately represented the shapes of the original distributions. This procedure resulted in four categories: 0 (*zero actions performed; "no activities"*), 1 (*one to two actions performed; "low level of activity"*), 2 (*three to five actions performed; "moderate level of activity"*), 3 (*six or more actions performed; "high level of activity"*). Table 4.2 contains the distribution cumulated over the entire observation period. Table 4.3 provides descriptive statistics.

Table 4.2: Distribution of corporate strategic actions

Level of activity	Acquisition	Divestiture
None	739	896
Low	310	214
Moderate	111	75
High	64	45

Table 4.3: Descriptive statistics for firm attributes over six waves of observation

Variable	Aggregated mean	*SD*	Number of performed acquisitions	Number of performed divestitures	Size of firm (log. total assets, centered)
Number of performed acquisitions	0.59	0.70	-	-	-
Number of performed divestitures	0.41	0.63	.77***	-	-
Firm size (log. total assets, centered)	-1.85	2.13	.11	.17*	-
Profitability (log. return on assets, centered)	-0.03	0.80	-.07	-.22**	-.43***

Values from column 3 onwards represent Pearson correlations; n = 211

Control variables. We relied on various attributes as control variables. In SAOMs such attributes may refer to the actor (i.e., the individual firm) or to the dyad (i.e., a pair of firms). Actor attributes that we included were firm size (measured by total assets) and profitability (measured by return on assets) (see Table 4.3). Both are commonplace in network and strategy research (e.g., Kim *et al.*, 2016). This data, too, was drawn from the Thomson Reuters database. In both cases we divided the individual values by the mean values of the respective firm's sector in our sample, a procedure similar to that used by Haunschild (1993). Firm size and profitability were log-transformed. We also used three dyadic attributes. First, our hypotheses related to primary interlocks only, but the latter are embedded in a network of secondary interlocks. This network represented important restrictions on the formation of new primary interlocks, as discussed above. We therefore controlled for secondary board interlocks between firms. Descriptive information about the secondary board network appears in Table 4.1. Second, we controlled for firm similarity in location (categorized by federal state). Third, we controlled for similarity in industrial sector (coded into nine sectors as classified by the German Stock Exchange (Deutsche Boerse AG). For these latter two variables, firms sharing the same category were set to 1; others, to 0.

4.3.4 Model specification

We used SAOMs which are specifically designed for the analysis of network dynamics and the assessment of coevolutionary processes (Snijders *et al.*, 2010). The value of these models is increasingly gaining recognition in management research (Kalish, 2020; Parker *et al.*, 2022; Tröster *et al.*, 2019) because they allow researchers to explore network dynamics by incorporating network structural variables (e.g., tendencies towards closure[14]), dyadic attributes (e.g., location in the same state), actor attributes (e.g., a firm's size), and the effects of network structure on actor outcomes (in our case, acquisition and divestiture activities). SAOMs have strong data requirements and make a few critical assumptions about the data (Snijders *et al.*, 2010). First, time is assumed to be continuous, but network observation only occurs at discrete time points. Our estimation of the network was based on the data available on 31 December of each year covered by the study. Second, actors control their out-going ties and choose the recipient of a connection, so the agency lies with the firm that sends the primary board interlock. For secondary interlocks, agency is assumed to lie with both firms, for the ties are undirected. A third assumption holds that firms have full knowledge of the network. Because data about executive and supervisory boards of all firms in our sample was public, this assumption is considered fulfilled.

SAOMs use a rate function and an objective function as part of the estimation process. The rate function estimates the frequency at which firms have the opportunity to change network ties; the objective function "expresses how likely it is for the actor to change her/his

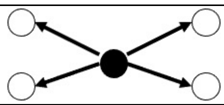
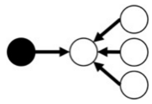
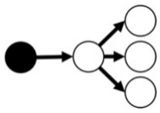
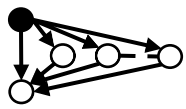
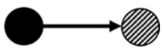
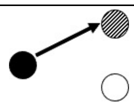
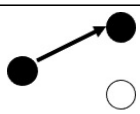
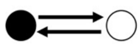
[14] A tendency for network closure refers to the commonly observed social process illustrated by the proverb "a friend of a friend is a friend." In the context of this study, it refers to the likelihood of firm A to establish a board interlock tie with firm C if both A and C already have an interlock tie with firm B, i.e., if they have a common third party.

network in a particular way" (Snijders *et al.*, 2010: 47). For coevolution studies SAOMs are split into two parts: one estimating network changes (selection), and the other one estimating changes in activities that are due to a focal firm's network position (influence). Just as the network-dynamics part of the model has rate and objective function, so does each activity outcome. The two parts of the model are estimated at the same time. A more mathematical explanation, along with an extensive list of available effects, can be found in the RSiena manual (Ripley *et al.*, 2022). Jaccard indices, which represent change between subsequent waves, are used to test whether the data is suitable to be used with SOAMs. For our data, they showed adequate values well over the recommended threshold of .3 for using SAOMs (Ripley *et al.*, 2022). More specifically, values ranged from .48 to .74. Standard errors were calculated over 10,000 iterations. The overall maximum convergence ratio across all our models was 0.14 and thus less than the recommended ratio of 0.25, indicating good model convergence (Ripley *et al.*, 2022). Missing attribute data in SAOMs are handled through built-in imputation. The imputed values are omitted in the calculation of the target statistics, which produce parameter estimates and standard errors used, among others, to test our hypotheses (Huisman and Steglich, 2008).

Hypothesized effects. For H1a, H1b, H2a, and 2b we modeled changes in the network of board interlocks. We included *sender* effects, which represent how acquisition and divestiture activities of a focal firm influence the likelihood of that firm (the "sender" of a tie) to make changes to its outgoing, primary board interlocks. Our hypotheses required us to distinguish between the likelihood of creating and dissolving board interlock ties. SAOMs enable researchers to specify this distinction in terms of different types of effects, called *creation* and *maintenance sender* effects. A positive creation effect indicates an increased likelihood of creating new board interlock ties, and a negative maintenance effect indicates an increased likelihood of dissolving existing board interlocks. For H3a and H3b we were interested in how a focal firm's network influences these focal firms' acquisition and divestiture activities. This dynamic is captured in our model by the *average similarity* effect, which expresses the likelihood that a focal firm will change its activities (in our case, acquisition or divestiture activities) to resemble those of the firms with which it has network ties.

Structural effects and control attributes. SAOMs allow researchers to account for network-endogenous, structural effects that influence network change (Kalish, 2020; Kim *et al.*, 2016). The most fundamental effect is the *outdegree* (*density*) effect, which acts as an intercept akin to those in classical regression models. We included several other structural effects. First was the *outdegree activity* effect, representing a focal firm's tendency to establish board interlocks with other firms based on the number of board interlocks already established by the focal firm. Second was the *indegree popularity* effect, which represents the tendency of a focal firm to establish board interlocks with alter firms based on the number of primary interlocks that the alters receive. Third was the *outdegree popularity* effect, which represents the tendency of a focal firm to establish board interlocks with another firm based on the number of board interlocks that this other firm has established with yet other firms. Outdegree activity, indegree popularity and outdegree popularity were expressed through a square-root term, which often leads to an improved fit and is recommended by Ripley et al. (2022). We included the *geometrically weighted edgewise shared partners effect* (GWESP), capturing network closure. Lastly, we controlled for *GWESP based on secondary interlocks* (the effect of network closure mediated through secondary board interlocks) and for *popularity in secondary interlock network and activity in secondary interlock network* (the effects that a firm's popularity and activity in the network of the secondary board interlocks have on the primary board interlocks). Typically, SAOMs include a *reciprocity* effect, which captures the likelihood of reciprocating ties. In our case, however, reciprocity is impossible because it is legally forbidden for an executive of firm A to sit on the supervisory board of firm B if firm B is already sending an executive to sit on the supervisory board of firm A. To abide by this proscription in our models, we fixed the *reciprocity* effect and set the parameter at a very low value in our directed network, all but precluding reciprocal ties. Because network effects are often best explained by graphical representation, we summarize them in Table 4.4.

Table 4.4: Visual representation of structural effects included in the SAOM

Effect name	Visual representation	Interpretation
Outdegree (density)		Overall tendency to send executives to supervisory boards; akin to intercepts in regular regressions.
Outdegree activity		The tendency of firms to send primary interlocks because they already tend to do so.
Indegree popularity		Tendency of a firm to establish interlocks with alter firms based on the number of primary interlocks that the alters receive.
Outdegree popularity		Tendency of a firm to establish interlocks with alter firms based on the number of primary interlocks that the alters establish.
Network closure (geometrically weighted edgewise shared partners)		Tendency for network closure of board interlocks.
Sender		Effect that the sending firm's attribute value has on changes in board interlocks.
Receiver		Effect that the receiving firm's attribute value has on changes in board interlocks.
Similarity		Effect on changes in board interlocks when the attribute values of the sending and receiving firms are similar (for continuous attributes).
Sameness		Effect on changes in board interlocks when the sending firm and receiving firm are in the same category (for categorical and binary attributes).
Reciprocity		Tendency to reciprocate board interlocks (forbidden in Germany and therefore fixed in our models).

Black circles indicate the sending firm, white circles the receiving/other firms, dashed circles the relevant attribute and checkered circles existing interlocks between supervisory boards (if applicable).

As for attributes of firms, we included size and profitability in our model as *sender* and *receiver* effects, where the corresponding covariate value of either the focal firm (sender) or the tied firm (receiver) influences changes in board interlocks, and as a *similarity* effect, where the influence on network changes is based on how similar the focal and tied firms' values are. Both the sector and the location of the headquarters were included as *sameness* effects, which measure whether belonging to the same category influences tie changes. Because we controlled for the structure of the secondary board interlock network and its effect on the primary board interlock network, it, too, needs to be modeled as a network. Given that it serves as a control variable, we modeled it as parsimoniously as possible. To that end we included the *degree activity plus popularity* effect in its square-root version, the GWESP effect mentioned above, and sameness effects regarding headquarters locations and the sectors of the firms.

For the influence part of the model, we included the linear and squared intercept (strategic action activity and strategic action activity [squared]), that is, the effect of acquisition and divestiture activities on themselves. We also controlled for two network structural effects on acquisition and divestiture activities: *out*- and *indegree*, representing the number of primary board interlocks that a firm sends or receives. To explain changes in acquisition or divestiture activities, we also included size and profitability as control attributes.

4.4 Results

To improve readability, we present the results of our SAOMs as two separate tables, as done in past research (Parker *et al.*, 2022; Tröster *et al.*, 2019). It is important to note that these tables show estimates modeled simultaneously and that these estimates thus belong to the same model. Table 4.5 shows the part of our models that explains how acquisition and divestiture activities influence changes in the (primary) board interlock network. Table 4.6 shows those parts of the models that represent the influence that board interlocks of a firm have on its corporate strategic actions. Parameter estimates in this table indicate a focal firm's tendency to change its acquisition or divestiture activities. We estimated three models: a base model (Model 1), a model addressing acquisition activities (Model 2), and a model addressing divestiture activities (Model 3). We calculated significance levels by comparing *t* ratios to a standard normal distribution. We calculated these ratios by dividing the estimated parameter by its standard error.

Table 4.5: Results of SAOMs of change in primary board interlock ties

Parameter	Model 1: Base		Model 2: Acquisitions		Model 3: Divestitures	
	Estimate	SE	Estimate	SE	Estimate	SE
Structural Effects						
Outdegree (intercept)	-8.93***	(1.28)	-9.67***	(1.47)	-9.52***	(1.28)
Outdegree activity	1.58*	(0.76)	1.67	(1.03)	1.47	(0.84)
Indegree popularity	0.15	(0.76)	0.16	(0.73)	0.18	(0.70)
Outdegree popularity	0.60	(0.44)	0.61	(0.43)	0.51	(0.45)
GWESP[a]	2.30	(2.51)	2.56	(2.82)	2.54	(1.28)
Activity in secondary interlock network	0.53	(0.31)	0.42	(0.32)	0.30	(0.29)
Popularity in secondary interlock network	0.04	(0.24)	0.04	(0.23)	0.08	(0.22)
GWESP based on supervisory board ties	1.35*	(0.55)	1.40**	(0.54)	1.39**	(0.51)
Reciprocity	fixed	-	fixed	-	fixed	-
Control Attributes						
Profitability (sender)	-0.46	(0.32)	-0.43	(0.35)	-0.45	(0.35)
Profitability (receiver)	0.32	(0.24)	0.29	(0.21)	0.25	(0.19)
Profitability (similarity)	3.71	(3.37)	2.72	(2.80)	2.77	(2.72)
Size (sender)	-0.21	(0.11)	-0.26	(0.17)	-0.28	(0.18)
Size (receiver)	0.08	(0.08)	0.07	(0.08)	0.08	(0.07)
Size (similarity)	0.03	(1.29)	-0.39	(1.22)	-0.07	(1.17)
Sector (same)	0.75*	(0.37)	0.66	(0.36)	0.58	(0.35)
State (same)	1.07**	(0.37)	0.92*	(0.37)	0.88*	(0.36)
Corporate Strategic Actions						
H1a: Acquisitions: Interlock creation[b] (sender)	-	-	1.50*	(0.68)	-	-
H1b: Divestitures: Interlock creation[b] (sender)	-	-	-	-	2.08	(1.26)
H2a: Acquisitions: Interlock mainintenance[c] (sender)	-	-	-10.53**	(3.88)	-	-
H2b: Divestitures: Interlock maintenance[c] (sender)	-	-	-	-	-	(4.11)
Rate Function						
Period 1 (T1–T2)	0.35		0.44		0.46	
Period 2 (T2–T3)	0.53		0.62		0.67	
Period 3 (T3–T4)	0.66		0.76		0.86	
Period 4 (T4–T5)	0.29		0.35		0.37	
Period 5 (T5-T6)	0.45		0.52		0.56	

Significance levels are two-tailed. Standard errors in parentheses. *$p < .05$. **$p < .01$. ***$p < .001$. $n = 211$.
[a]Geometrically weighted edgewise shared partners effect.
[b]Positive interlock creation effects mean that the likelihood of creating an interlock is greater than not creating it.
[c]Negative interlock maintenance effects mean that the likelihood of dissolving an interlock is greater than maintaining it.

4.4.1 Board interlock dynamics

When estimating the influence of corporate strategic actions on the creation of board interlocks, we found a positive coefficient for the *acquisitions: interlock creation* effect ($\theta = 1.50$, $p < .05$). This finding indicates that acquisition activities increase the likelihood of primary board interlocks being created, supporting H1a. However, we observed a nonsignificant effect for *divestitures: interlock creation* ($\theta = 2.08$, $p > .05$). Thus, we reject H1b; there is no influence of a focal firm's divestiture activities on the subsequent creation of new board interlock ties by that firm. Regarding the dissolution of existing board interlocks, we found a significant negative *acquisitions: interlock maintenance* effect ($\theta = -10.53$, $p < .01$) as well as a significant negative *divestitures: interlock maintenance* effect ($\theta = -16.38$, $p < .001$). These results indicate that both acquisition and divestiture activities increase the likelihood of a focal firm dissolving board interlocks, supporting H2a and H2b.

As far as structural effects and control attributes go, our results suggest that structural network variables contribute little to explaining the dynamics of primary board interlock networks in Germany. Neither *GWESP* nor *popularity* or *activity* effects were significant. The GWESP based on secondary interlocks showed a significant positive effect across all our models, indicating that firms formed primary interlocks in a way that led to multiplex network closure (i.e., primary interlocks showed a tendency to close open triads in which two firms are connected to the same third firm via secondary board interlocks). Additionally, headquarters locations in the same federal state influenced interlock creation and dissolution across all our models. Belonging to the same sector showed a significant effect in the base model only. We did not find significant effects for size and profitability in Models 2 and 3.

Table 4.6: Results of SAOMs of the evolution of corporate strategic action activity

Parameter	Model 2: Acquisitions		Model 3: Divestitures	
	Estimate	SE	Estimate	SE
Intercept				
Strategic action activity	-0.48***	(0.07)	-0.98***	(0.10)
Strategic action activity (squared)	0.03	(0.04)	0.15**	(0.05)
Control Variables				
Profitability	-0.02	(0.04)	-0.07	(0.05)
Size	0.01	(0.02)	0.03	(0.03)
Main Variable				
Indegree	-0.04	(0.09)	0.17	(0.10)
Outdegree	0.36***	(0.10)	0.31***	(0.09)
H3a, 3b: average similarity	2.02*	(0.81)	2.48**	(0.88)
Rate Function				
Period 1 (T1–T2)	2.36		2.14	
Period 2 (T2–T3)	2.93		2.98	
Period 3 (T3–T4)	3.09		2.55	
Period 4 (T4–T5)	2.15		2.56	
Period 5 (T5–T6)	2.25		2.10	

Significance levels are two-tailed. The significance of rate functions is not tested in SAOMs. Standard errors in parentheses. *$p < .05$. **$p < .01$. ***$p < .001$. $n = 211$.

4.4.2 Board interlock consequences

Models 2 and 3 comprise the effects for corporate strategic actions. Both models showed significant positive *average similarity* effects. The estimated parameters for these effects (Model 2 for acquisitions: $\theta = 2.02$, $p < .05$; Model 3 for divestitures: $\theta = 2.48$, $p < .01$) indicated that a focal firm shows a tendency to decrease the distance between itself and its partners in terms of acquisition or divestiture activities and, thus, to become more similar to them. For example, if a focal firm's value for acquisition activities were 1, and the average value of its partners were 2, the focal firm will tend to increase its value. These results support H3a and H3b.

In terms of control effects, the linear effect for *strategic action activity* showed a tendency for actors to exhibit a low acquisition and divestiture activity, a result consistent with the distribution presented in Table 4.2. The significant *strategic action activity (squared)* effect in Model 3 indicated a slight tendency of firms to regress to the mean regarding their divestiture activities. Whereas the number of primary interlocks a firm receives (represented by the *indegree* effect) showed no significant results for either acquisitions or divestitures, the *outdegree* effect was significant in Models 2 and 3 alike. The positive *outdegree* effect indicated that the greater the number of primary board interlocks a firm sends to others, the higher the likelihood of an increase in that firm's acquisition activities or divestiture activities. We also controlled for the effects of size and profitability on both acquisition and divestiture activities but found none in either model.

4.4.3 Coevolution of board interlock networks and corporate strategic actions

For coevolution to be present, the analyzed actions (acquisition and divestiture activities) would have to influence the subsequent network structure (which we investigated as per H1a, H1b, H2a, and H2b). Simultaneously, the actions would have to be influenced by the structure in which an actor operates (which we investigated as per H3 and H3b). Our tests of H 1 through H3 showed that the prerequisites of coevolution exist. To statistically test whether processes of coevolution were present, we conducted a series of multiparametric Wald-tests for Model 2 and Model 3. These tests were based on the parameter estimates of our SAOMs and served the purpose of confirming that the influence of a combination of the parameters was not zero (Wald, 1943). We took three steps for both models. First, we tested the significance of the combined creation and maintenance effects that the respective corporate strategic action activities had on the primary board interlock network. Then we tested for the significance that the set of network-based explanations had on acquisitions and divestitures. These explanations included the indegree, outdegree, and average similarity effects. Lastly, we combined both effect sets—those influencing the board interlock network and those influencing corporate strategic actions—and tested for their joint significance. All Wald-tests were highly significant

($p < .001$). In conclusion, we find support for H4: a focal firm's board interlock network and its corporate strategic action coevolves.

4.4.4 Goodness of fit and robustness checks

We tested for goodness-of-fit using the method proposed and Lospinoso and Snijders (2019). For goodness of fit to be acceptable, the resulting *p*-values should not be zero and preferably be larger than .05. We analyzed goodness of fit for the outdegree distribution, the indegree distribution of the primary interlock network, and the distribution of acquisition and divestiture activities. All tests showed *p*-values higher than $p > .5$, indicating a good fit (Lospinoso and Snijders, 2019).

We performed sensitivity analyses for the recoded corporate strategic actions (acquisitions, and divestitures) to ensure that our categorizations were not arbitrary and did not lead to biased results. Changing the number of categories and their respective content led to significant effects in the same direction, even when a fine-grained approach with ten categories was brought to bear. The only exception was coding corporate strategic actions into dummy variables where 0 represented "no actions performed" and 1 "any number of actions performed." That coding precluded an essential prerequisite for SAOMs to work and be interpreted: model convergence. Our categorization best represents the original shape of the distribution when it represents a sharp decline and keeps appropriate ratios between the categories. To check for robustness, we also ran models controlling for several other attributes of firms, such as the number of employees, Tobin's Q, and market value. None yielded significant effects and have thus been excluded to avoid issues of overfitting.

4.5 Discussion

Although research on the dynamics and consequences of board interlock networks revolves around similar phenomena and has been a central topic in management research for decades (Chen *et al.*, 2022; Lamb and Roundy, 2016), extant literature has largely neglected the idea that the two research streams are connected. Drawing on structuration theory (Giddens, 1984), we have conceptualized how corporate strategic actions in the form of acquisitions and divestitures coevolve with board interlock networks. Our longitudinal study on these networks rests on a dataset of the largest German firms between 2013 and 2018 and has found empirical support for the interdependent nature of board interlocks and corporate strategic actions. Specifically, our models show that acquisitions increase the likelihood of board interlock creation and dissolution, whereas divestitures increase the likelihood of board interlock dissolution, but not their creation. Our models also show that a firm's acquisition and divestiture activities are influenced by the firm's board interlock network. Most important, we find direct evidence of a coevolutionary process.

4.5.1 Theoretical implications

This study makes three key contributions to the relevant literature. First, we complement research on corporate governance, specifically the role of board interlocks, in multiple ways. Showing that corporate strategic actions and board interlock networks coevolve, we address open questions of causality and interdependence between both phenomena (e.g., Ahuja et al., 2012), which have usually been treated as mostly disjunct.[15] Although research on board interlocks has largely neglected the possibility that board interlock dynamics and consequences constitute a recursive process, our findings suggest that such a process is indeed occurring. They further suggest that the dynamic nature of board interlock networks plays a much larger

[15] Of course, the results of our study should be interpreted as a form of Granger causality, meaning that the influence of X at $t(0)$ on Y at $t(1)$ strongly suggests a causal relationship as long as it is supported by theoretical reasoning (Granger, 1969).

role regarding board interlock network's influence on corporate strategic actions and vice versa than is assumed in the literature. Acknowledging the coevolutionary process at hand means that firms are, figuratively speaking, prisoners not only of their past to a greater extent than is commonly assumed, but also of their present and future. More specifically, based on our findings we propose both that firms learn from past successes and failures and that a firm's past activities shape the firms present surroundings, constraining and enabling further actions. Then, in such a continuous cycle, the activities of the present shape a firm's surrounding structure in a way that will likely influence its future activities. Put differently, failure to anticipate how the present's actions shape future structure leads to potentially unforeseen, perhaps even unwanted, constraints or to overlooked opportunities. In other words, our results suggest that, by neglecting the present recursiveness, literature in this field may overestimate the salience of internal considerations in decisions that firms make to change their acquisition and divestiture activities. Conversely, the literature may insufficiently consider the role of external circumstances, specifically network dynamics, which are directly influenced by a firm's actions.

Apart from substantiating a process of coevolution, our findings enrich two streams of board interlock research: one on dynamics, the other on consequences. We show that acquisitions and divestitures drive board interlock changes. This contribution is important in two ways. First, both corporate strategic actions directly alter the properties and structure of a firm. The idea that such alterations lead to changes in board interlock networks—and organizational networks in general—is "virtually missing from research on interfirm networks" (Hernandez and Menon, 2019: 80). Accounting for the alteration of the structure that surrounds firms offers a stark contrast to other studies that likewise investigate the dynamics of board interlocks but focus on activities that do not necessarily change the acting organization (Howard *et al.*, 2016, 2017; Zhu and Westphal, 2021). By empirically showing that firm alterations *need* to be taken into account, our study also adds to the discussion of what drives interorganizational connectedness (Novoselova, 2021).

We further complement research on corporate governance by separately testing for the effects of acquisitions and divestitures on both the creation and dissolution of board interlocks, a distinction seldom made in the literature. Indeed, only recently has tie dissolution attracted keen attention among management scholars (Clough and Piezunka, 2020; Ozcan, 2018; Tröster *et al.*, 2019). Our findings show that acquisitions lead to the creation and dissolution of board interlocks, whereas divestitures lead only to their dissolution. Hence, although there are real-world examples of divestitures leading to the creation of new board interlock ties, such as Bayer's spinoff of Covestro and the subsequent creation of a board interlock, our results suggest that they are exceptions and that firms will typically *not* see divestitures as a means of extending their board interlock network. Divestitures will likely lead to a more focused and less widely spread board interlock network, for existing ties are dissolved but no new ones are created. These findings support the argument made by Hernandez and Menon (2019) that divestitures indicate a firm is trying to increase its network closure. More generally, our findings support the idea that different forms of change in a board interlock network, specifically tie creation and dissolution, may result from the same corporate strategic action. This insight indicates that one cannot adequately understand the dynamics of board interlock networks and organizational networks in general by aggregating changes of focal firms to either more or fewer ties than before. Instead, tie creation and dissolution may coincide, and analyzing them separately may lead to rich insights.

In addition to complementing research on board interlock dynamics, our findings also add to research on board interlock consequences. They do so by leveraging state-of-the-art network methodology to analyze the diffusion of corporate strategic actions through board interlock networks. We show that firms tend to adjust their acquisition and divestiture activities in a way that makes them more closely resemble the corresponding average activities of the firms in their network of primary board interlocks. Although previous research has already presented profound results on the influence that board interlocks have on acquisition activities, our analysis offers a whole network perspective. Lastly, our study provides insights into the effect of board interlock networks on the sparsely researched occurrence of divestitures. We thus complement "dominant economic and institutional explanations for divestitures with behavioral (e.g., social-constructivist) explanations" and thereby do "greater justice to the complexity of divestitures, which often result from a complex interaction of factors rather than being the result of single factors" (Brauer, 2006: 776).

Second, we contribute to theory on strategic networks by taking on a structuration theoretical perspective to theoretically link how strategy influences networks and networks influence strategy. Specifically, we show that structuration theory (Giddens, 1984) provides a fruitful framework for conceptualizing coevolutionary processes and allows for the integration of literature streams that assess the same phenomenon from different causal perspectives. Such integration offers great potential for enriching our understanding of how firms' strategies are often based on recursive processes in which firms interact with their environment. Ignoring the interdependencies between action and structure restricts the extent to which scholars can effectively theorize about the impact that outside influences have on a firm's strategy. This point is relevant for a wide range of settings, from organizational networks to institutional settings, for these circumstances shape a focal firm's actions, which then recursively shape the surrounding circumstances. In addition, application of structuration theory allows for conceptualizing equifinality when it comes to structural changes (Giddens, 1984). As we have been able to demonstrate, two different actions or mechanisms, namely an acquisition or a divestiture, may lead to the same outcome, the creation or deletion of a board interlock tie and vice versa. Some of these creations or deletions of board interlock ties may be unintended. Whereas unintended consequences are commonplace and unavoidable in the complex undertakings of firms, our study illuminates how structuration theory makes it possible to capture these outcomes theoretically. Broader management literature already has applied Gidden's structuration theory (e.g., Barley, 1986; Feldman and Pentland, 2003; Jarzabkowski, 2008). By adding an empirical application of structuration theory specific to strategy research, our study illustrates that this theory is a viable alternative to more widely used contemporary perspectives used for strategy theorizing (such as agency or institutional theory), as it allows scholars to move beyond the views of strategy leading to structure and vice versa (Sydow and Windeler, 1998).

Third, our study illustrates the application of stochastic actor-oriented models as a way to answer questions about possible coevolution in strategy research (Snijders *et al.*, 2010). As with most current network models—Exponential Random Graph Models, for instance (Kim *et al.*, 2016)—SAOMs grant researchers opportunity to control for effects inherent in the structure under which actors operate. These effects may consist of things such as a tendency to reciprocate existing ties or the tendency toward closure, like partnering with a firm with which a partner already has a connection. SAOMs differ from other models in that they focus on actors' agency, such as the way(s) in which actors decide to change their own networks. Management scholars may thus apply SAOMs to answer questions about how firms operate under changing circumstances and interact with their environment. Because of their longitudinal nature, SAOMs also help management scholars infer causal interpretations, a feature which is amplified by the capability of SAOMs to model the coevolution of networks and action. Our study exemplifies how such coevolution models are suited not only for interpersonal networks, on which a growing body of studies is emerging in management research (Ebbers and Wijnberg, 2019; Parker *et al.*, 2022; Tröster *et al.*, 2019), but also for interfirm networks.

4.5.2 Limitations and future research

Like most research, our study comes with limitations. First, although our sample represents a large portion of the German economy and thus gives us confidence that our results shine a reliable light on the processes we investigate, they might be context-specific and other settings, such as the Fortune 500 in the United States, might produce different results. Whether this context specificity shows and which differences exist to what extent seems to be a fruitful avenue for future research. A second limitation regarding generalizability is that we take only a limited time span into account. One could assume that different years yield different results, for example the period before the financial crisis or the years leading up to the Dotcom crisis. In the US in particular, the Sarbanes-Oxley act, which increased board independence and director accountability, created a considerable disruption for firm's board interlock networks (Withers, Kim, and Howard, 2018). Combining external shocks, such as disruptive legislation, with a strategy perspective makes for a rich context to assess the role of time for decision making in strategy and network research.

Although the notion of unintended consequences is a cornerstone of structuration theory (Giddens, 1984), our research design does not equip us to differentiate between intended and unintended consequences of corporate strategic actions. We call for further research to examine the difference between intended and unintended consequences as drivers of change in board interlock networks or, more generally, in organizational networks. Recent debates in organizational network research on the role of actor agency could offer a starting point for such endeavors (Tasselli and Kilduff, 2021). Unintended consequences may lead to undesired outcomes or, conversely, give rise to unforeseen opportunities. Our results suggest that firms' corporate strategic actions are more dependent on the dynamic structures these firms act in than is commonly assumed. Thus, research specifically addressing the unintended consequences of internal strategic considerations of firms and how these consequences shape these firms' action realm may be another avenue of future research.

Yet another area that bears potential for future research is the integration of different levels of analysis. While we treat board interlocks as connections between firms, the process in which directors are appointed to boards is inherently two-sided and occurs on both the firm and the individual director level (Withers *et al.*, 2012). Incorporating director level attributes and the motivation of directors to serve on other boards – such as the desire to belong to the corporate elite – would allow for a more nuanced understanding of the dynamics and consequences of board interlocks. Finally, the idea of coevolution processes in strategy research is unlikely to be restricted to board interlock networks. Rather, structuration theory may help to introduce the idea of coevolution to other types of interorganizational relations, such as strategic alliance networks (Baum *et al.*, 2000; Gulati, 2017; Kumar and Zaheer, 2019).

4.6 Conclusion

Whereas earlier studies on board interlocks have examined both their dynamics and consequences, little, if any, research has acknowledged the issue of possible coevolution. Instead, most studies have treated the two phenomena as disjoint aspects. Our study addresses this gap by conceptualizing corporate strategic actions and board interlock networks as part of a recursive coevolutionary process, which our empirical results confirm. Based on our findings, future research on board interlocks, but also on strategic networks and corporate governance more generally, should consider whether the network dynamics and consequences they study are truly separate phenomena or, instead, mutually interdependent.

Chapter 5

Integrating Two Modes of Board Interlock Research

Abstract

Board interlock research typically focuses either on the firm or the director level. While many of the findings from both firm and director-level research align with each other, extant literature points to some contradictory results between these research streams. Using an exponential random graph model to analyze the board interlock network of the Fortune 500 in 2022, this study illustrates that a two-mode network approach can help to resolve these contradictions. The results suggest that effects on the firm level are spurious when introducing director attributes, while attributes on the director level are more robust. This paper contributes to the relevant literature in three ways: First, by empirically integrating findings from the firm and director level, thereby showing that social processes dominate the rational considerations that scholars typically attribute to director appointments and raising concerns about the validity of existing findings. Second, by approximating the prevalence of issues created by omitting either the firm or director level in board interlock research and illustrating the severity of biases introduced by said omissions. And third, by illuminating potential future applications of two-mode network analysis in prospective fields of management research.

5.1 Introduction

Whether from a firm-level (Howard *et al.*, 2017; Kim *et al.*, 2016; Martin *et al.*, 2015) or director-level perspective (Gulati and Westphal, 1999; McDonald and Westphal, 2013; Zhu and Westphal, 2014), the appointment of outside directors to corporate boards and the resulting board networks have been of interest to management scholars for more than a century (Lamb and Roundy, 2016). However, even though it is clear that "the director selection decision is inherently a two-sided process in which appointing firms and potential directors come together" (Withers *et al.*, 2012: 262), research rarely integrates both sides –firm, and director - of said process. Instead, scholars typically focus on either the firm or the director level, while the respective other level is omitted. At first glance, studies on both levels offer complementary results. A second look, however, reveals contradictory results. These contradictions may be rooted in the different theoretical premises behind both levels of analysis: Firm-level studies often argue from a resource dependency or agency perspective (Hillman and Dalziel, 2003; Hillman *et al.*, 2009; Jiang, Luo, Xia, Hitt, and Shen, 2022), while director-level studies often develop their arguments based on social capital or social cohesion theory (Chu and Davis, 2016; Johnson, Schnatterly, Bolton, and Tuggle, 2011). These theoretical perspectives lead to different research foci and vastly different assumptions about why board interlocks are formed. According to Ahuja, "an understanding of network outcomes is incomplete and potentially flawed without an appreciation of the genesis and evolution of the underlying network structures." (Ahuja *et al.*, 2012: 434) Thus, given that extant literature has found board interlocks to have a substantial influence and impact on the strategic actions firms enact – for instance in regard to internalization efforts, the adoption of stock option pay or acquisition activities (Connelly *et al.*, 2011; Haunschild, 1993; Heyden, Oehmichen, Nichting, and Volberda, 2015; Yildiz, Morgulis-Yakushev, Holm, and Eriksson, 2021) – it is essential for strategy scholars to better and more clearly understand what drives board interlock formation.

To that end, studies on the firm level find, for instance, that financial restatements lead to the exit of outside directors, but that the propensity of such exits is mitigated by the social status of a restating firm (Withers *et al.*, 2020). Other studies find that high tech start-ups whose teams exhibit a low level of diversification will aim to seat outside directors on their board who can take on a service role (Knockaert and Ucbasaran, 2011) or that occupying brokerage positions in a board interlock network increases corporate performance, since these positions allow the occupying firm to receive valuable and exclusive information (Wang, Lu, Kweh, Nourani, and Hong, 2021). On the director level, research finds that board networks exhibit small world properties, illustrating how these networks play an important role in the cohesion of the corporate and social elite (Davis, Yoo, and Baker, 2003; Mizruchi, 1996). Westphal and colleagues highlight different social aspects of the director selection process, among them how providing advice and information to CEOs increases the chances of board appointments or interpersonal influence towards those who control access to board positions offers an alternative pathway to directorships for those who do not belong to the corporate elite by virtue of their social and educational credentials (Westphal and Stern, 2006, 2007; Zhu and Westphal, 2014). While these findings offer invaluable insights into the formation process behind board networks, scholars researching board networks increasingly note that the firm- and director-level should not be treated separately (Lamb and Roundy, 2016; Valeeva *et al.*, 2020). Rather, “a clearer picture of governance lies in the integration of these two views” (Withers *et al.*, 2012: 244). Apart from providing a fuller understanding, integrating social and rational perspectives on board interlock formation is necessary, because, as mentioned above, some of the evidence found in board research offers contradictory insights: While companies in peril are more likely to attempt to seat prestigious outside directors on their boards (Hermalin and Weisbach, 1988; Weisbach, 1988), this contradicts the interest of potential candidates (Finkelstein, Hambrick, and Cannella, 2009). As another example, firms may be aware of the positive effects of diversity in the boardroom (Carter, Simkins, and Simpson, 2003), but social mechanisms such as homophily or reservations toward diversity may make it difficult to act on this (McDonald and Westphal, 2013). In consequence, it is unclear how the results of either stream of studies hold up when integrating the respective other – firm or director – perspective. In addition to contradicting findings between the firm and director level of board network research, scholars have been increasingly vocal about potential methodological issues (Hernandez *et al.*, 2015; Opsahl, 2013; Piepenbrink and Gaur, 2013) that occur when so-called two-mode networks – which refer to networks that typically consist of one actor- and one group- or event-level – are *projected* onto one mode. This technique has been a typical procedure in the analysis of board networks for decades (Davis and Greve, 1997; Mizruchi and Stearns, 1994; Stearns and Mizruchi, 1986) but may lead to biases in the resulting estimations. By omitting either the firm or director level from their analysis, researchers forgo the embeddedness of individuals into the overarching firm structures or, respectively, the role of individual attributes in the formation of ties between firms. In consequence, one-mode projections may lead to "biases in measures of closure" (Hernandez *et al.*, 2015: 1257) and thus potentially to the misinterpretation of a study's findings, as scholars recently began to address (Opsahl, 2013; Piepenbrink and Gaur, 2013). Considering the theoretical contradictions and methodological constraints in board network research laid out above, it stands to question to what extent the conclusions we draw from existing analyses are biased and reliable.

This paper consequently aims for two things: First, I aim to integrate the analysis of attributes on the firm- as well as the director-level, addressing the need for an integrative perspective on board networks to "resolve some seemingly contradictory evidence" (Withers *et al.*, 2012: 264). Second, given that "[t]here is little guidance on the prevalence of this [projection] problem" (Hernandez *et al.*, 2015: 1257), I aim to approximate said prevalence of the problems that occur when omitting the firm- or director-level. To realize these goals, I draw on the director selection framework laid out by Withers et al. (2012), which proposes that the director selection process is a result of the interaction of four factors: A firm's characteristics, the firm's environment, the potential director, and the characteristics of the board itself, for example the tendency to adhere to social elite cohesion mechanisms. In line with the aim and scope of this study, I focus on firm- and director-level attributes which are known from extant literature to be relevant for the appointment of *outside* directors. To empirically assess this, I use Exponential Random Graph Models (Robins *et al.*, 2007a; Wang *et al.*, 2009) to first model the Fortune 500 companies and directors serving on their boards in 2022 as two projected one-mode networks – once on the firm- and once on the director-level – and then as a two-mode network. In the latter approach, directors are connected with each other by being affiliated with the same firm, while firms are connected through directors being affiliated with the boards of multiple firms. The results show that projections introduce considerable bias into the analysis of board interlock networks, while the two-mode approach confirms most of the assumptions made by the framework of Withers et al. (2012). Moreover, I find that firm-level effects are relatively spurious when integrating director-level attributes including, but not limited to the reversal of parameter signs. Conversely, the integration of firm-level attributes does not change the estimated director-level effects in a substantial manner. Taken together, these results offer novel insights into the outside director selection process. In addition, I find that, while the overall model quality improves by integrating both firm- and director-level attributes, this improvement is not as substantial as one may expect. Since the goals of this study do not lend themselves to classical hypothesis testing[16], in which one would either confirm or reject assumptions by testing for significance, I develop propositions from my findings.

My study makes three contributions to management literature. First, I complement research on corporate governance. I do so by integrating firm-, and director-level attributes relevant to the selection of outside directors in a two-mode exponential random graph model

[16] To elaborate on this, there is no formal statistical test in contemporary network models that would allow to answer a question such as "The omission of firm-level attributes influences the estimated parameters on the director-level more strongly than vice versa.". Additionally, the framework which this study utilizes is already built on assumptions for which extant literature has found support.

estimating the network between the Fortune 500 companies. Thereby, I address questions about contradictory findings between board research on the firm- and director-level, which are rooted in different theoretical perspectives. I propose that the omission of director-level attributes from empirical analysis leads to a potential overestimation and misinterpretation of firm-level effects because the social phenomena driving network formation are already partly captured on the firm level. Based on these findings, I call for the development of theoretical perspectives that take the multisided reality of director selection into account instead of omitting one unit of analysis. Second, my study contributes to research on the formation of board interlock networks. I do so, by providing empirical evidence that projecting board interlock networks, which are naturally two-mode phenomena, onto one-mode networks introduces considerable biases in the estimated results. Taking a two-mode approach resolves this and does a far better job at reproducing assumptions made in extant literature and improves model quality, even when using a parsimonious set of attributes. To aid reflections on past studies and the design of future research, I provide guidance on when a two-mode approach is preferable or necessary. Grounding said guidance in my empirical findings and extant literature, I propose that the integration of two levels of analysis leads to a substantial improvement in theoretical insight when explanations on the firm and director-level are contradictory. Third, my study illustrates the application of novel methods in management research, namely the two-mode extension to exponential random graph models. I introduce modeling networks as two-mode phenomena as a way of resolving contradictory findings between two levels of analysis in management research. I provide examples of multiple potential applications, with which management scholars may advance their understanding of their prospective fields.

5.2 A Tale of Two Modes

Research on corporate boards has been a cornerstone of management research for decades, with a major stream of studies focusing on the appointment of outside directors. These outside directors are directors who are affiliated with more than one firm, thus constituting board interlocks (Mizruchi, 1996) – or board networks when analyzing multiple such interlocks. Studies on board networks trace back as far as the early 20th century, with scholars researching the relationship between banks and industry or links between the finance and railway industry (Dixon, 1914; Durand, 1914; Jeidels, 1905). Already in these early studies, board networks were often analyzed on only one level – either firm or director – using a technique that later became known as projection. From the firm perspective, a director sitting on the boards of multiple firms connects these firms with each other. The direct connection of said director with other directors and the role of attributes on the director level is thereby omitted. Conversely, the director perspective analyzes which attributes make it more likely for directors to be appointed to multiple boards, but the firm's role is neglected. In the past decades, board research on the firm and director level has further continued to develop relatively independently from each other. While many of the results in extant literature point towards a complementary nature of firm and director-level research, scholars increasingly note that some findings on the firm and director level contradict each other (Withers *et al.*, 2012).

5.2.1 Firm-level research

From a firm-level perspective, research finds that outside directors are appointed for many different reasons (Lamb and Roundy, 2016). These include the reduction of environmental uncertainty by securing scarce resources (Howard *et al.*, 2016, 2017; Martin *et al.*, 2015), the cooptation of financial institutions by inviting said institutions' representatives to sit on the home firm's board (Dooley, 1969; Ong *et al.*, 2003), the attempt to increase a firm's legitimacy and signal success by partnering with prestigious firms' or inviting high-status individuals (Galaskiewicz, Wasserman, Rauschenbach, Bielefeld, and Mullaney, 1985; Gulati and Higgins, 2003) or the ability to monitor other companies (Carpenter and Westphal, 2001; Gulati and Westphal, 1999; Hagendorff, Collins, and Keasey, 2010). One of the most prominent theoretical perspectives in board network research on the firm level is resource dependency theory (Pfeffer and Salancik, 1978), which became the dominant theory to understand board networks in the late 20th century (Caiazza and Simoni, 2019). While much of extant literature finds support for the assumptions of resource dependence theory (Howard *et al.*, 2017; Knockaert and Ucbasaran, 2011; Wang *et al.*, 2021), some studies challenge these results (Galaskiewicz *et al.*, 1985; Martin *et al.*, 2015). A second prominent theory that is often used to explain board interlock formation is agency theory. Scholars researching the appointment of outside directors from an agency lens find support for the appointment of directors from firms with similar boards (Zajac and Westphal, 1996) or focus on the role of director's independence (Carcello, Hermanson, and Ye, 2011; Cohen, Krishnamoorthy, and Wright, 2008).

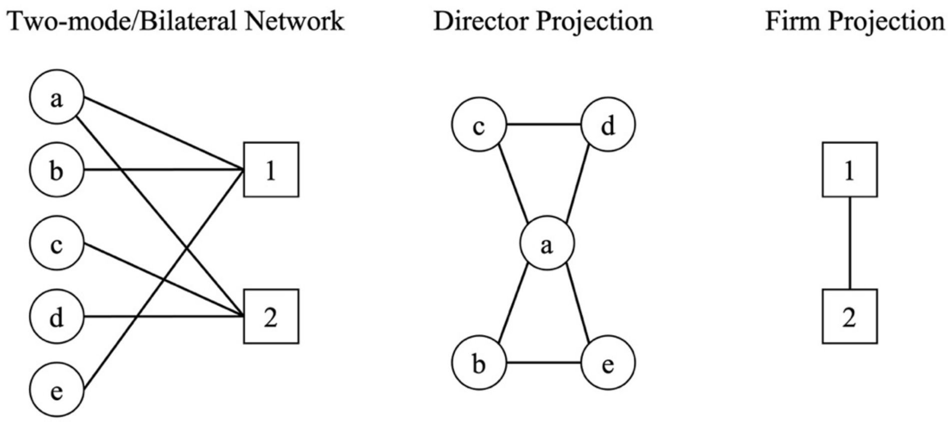
5.2.2 Director-level research

On the director level, the theoretical reasoning for the appointment of outside directors is vastly different from perspectives commonly applied to firm-level research. Whereas scholars often assume that director selection on the firm level is mostly driven by rational choices (Howard *et al.*, 2017; Okhmatovskiy and David, 2012; Zahra and Pearce, 1989), the individual perspective focuses far more on social processes (Withers *et al.*, 2012). Studies on the director level deal with questions of social cohesion, human and social capital or social influence behaviors, to name but a few categories (McDonald and Westphal, 2010, 2013; Zhu and Westphal, 2014). For instance, research finds that, when board members are appointed with the clear aim to monitor corporate governance, CEOs who exhibit signs of non-clinical paranoia tend to appoint executives similar to them, thus leading to a higher level of top management team homophily (Carpenter *et al.*, 2010). Park and Westphal (2013) show how CEOs who belong to a minority are more likely to receive blame in the event of a firm exhibiting low performance. Other phenomena that regularly come up in societal and political discourse, such as the under-representation of women and minorities in top management teams are also frequently analyzed. For instance, a US-based study finds that demographic diversity in the corporate elite is negatively influenced by a tendency of directors to provide lower mentoring to first-time directors who are women or belong to a minority, which in turn leads to fewer board appointments outside of the focal firm (McDonald and Westphal, 2013). Yet another study shows how ingratiation, which is “a fundamental means of building and maintaining one’s social capital” (Keeves, Westphal, and McDonald, 2017: 484) may lead to resentment from top managers towards the CEO and, in turn, leads to the undermining of outside communications. In sum, the evidence extant literature provides for the role of social elite cohesion (Chu and Davis, 2016; Davis *et al.*, 2003; Ward and Feldman, 2008), social and human capital (Johnson *et al.*, 2011; Johnson, Schnatterly, and Hill, 2013; Purkayastha, Karna, Sharma, and Bhadra, 2021) or demographic attributes (Farrell and Hersch, 2005; Kesner, 1988; McDonald and Westphal, 2013) makes it clear that individual-level characteristics play an important role for the appointment of outside directors.

5.2.3 Integrating two modes of board network research

Even though the importance of integrating the firm and director level perspectives of board network research is evident by reviewing the extant literature and recent studies call for more research on the issue (Lamb and Roundy, 2016; Withers *et al.*, 2012), a comprehensive empirical investigation of the phenomenon is so far missing. Notably, research in recent years has started to try and bridge these perspectives. For example, Gupta and colleagues link director’s political leanings – a very personal trait – with the adoption of a CEO-chair separation structure – a corporate governance choice on the firm level (Gupta *et al.*, 2022). Studies that treat board networks as actual two-mode networks, however, remain rare, with very few exceptions. For example, scholars find that, when analyzing the Danish board network using relational event models, the appointment of directors is indeed driven by the structural properties of both director- and firm level networks (Valeeva *et al.*, 2020) and that the Swedish board network is driven, in part, by peer referrals (Koskinen and Edling, 2012). These studies have, however, focused on showcasing modeling approaches such as relational event models or the extension of stochastic-actor oriented models by Bayesian inference schemes. In turn, they neglect the extant management literature and pay little attention to the question what consequences for management research follow from two-mode models of board networks. It remains unclear, however, to what extent results in management research are influenced by projecting onto the firm or director level (Hernandez *et al.*, 2015; Opsahl, 2013). Figure 5.1 visualizes the occurring information loss. Circles in this figure represent directors, and squares represent firms.

Figure 5.1: The effects of projection



It becomes clear that a lot of information originally present in the two-mode depiction of corporate boards is lost through projection onto either level. I argue that the inclusion of both modes of board research resolves the contradicting theoretical expectations that are ignored by the omission of one mode. For example, studies show that young firms which have only recently completed their IPO experience benefit from appointing directors with a high prestige, for instance in the form of increased valuation (Certo, Daily, and Dalton, 2001; Filatotchev, 2006). Findings on social elite cohesion, however, would suggest that prestigious directors are less inclined to serve on boards that are not well-established (Chu and Davis, 2016; Davis *et al.*, 2003). Thus, controlling for the cohesiveness of the director level network will likely reveal that, while firms that just made their IPO aim to seat prestigious directors on their boards, this firm level goal is constrained by underlying social mechanisms. Likewise, a higher diversity of board members – i.e., a higher representation of women - has been shown to improve firm performance (Carter *et al.*, 2003; Erhardt, Werbel, and Shrader, 2003; Farrell and Hersch, 2005), so firms would have a rational incentive to appoint more diverse outside directors. Robust social mechanisms such as homophily, which refers to "the tendency to associate with similar others" (Ertug *et al.*, 2022: 38), are likely to infer with these rational considerations. Given that "[w]omen and racial minorities have historically tended to be substantially underrepresented" (McDonald and Westphal, 2013: 1169) in boards of directors, it is clear that the broader social context plays an important role in the selection of directors. Research also suggests that poor performing firms may have an interest in appointing more outside directors to alleviate the spiral of organizational decline (Hermalin and Weisbach, 1988; Weisbach, 1988). However, other studies suggest that directors will be inclined to leave – or *not* join - firms that exhibit poor performance (Finkelstein *et al.*, 2009; Pearce and Zahra, 1992), leading to the issue that "firms performing poorly are more likely to seek out outsiders to join their board, but they may have difficulty keeping them" (Withers *et al.*, 2012). Given that prestigious directors are highly sought-after and have more options to choose the boards they serve on (Davis, 1993; Hillman and Dalziel, 2003), integrating the director level will likely constrain the positive effect of poor performance in comparison to just observing firm-level ties.

From a comprehensive perspective that takes the firm- and director-level into account, the director selection process – regardless of focus on inside or outside directors - "occurs within the context of the social dynamics of the board and the external environment" (Withers *et al.*, 2012: 263). According to a framework proposed by Withers et al. (2012), four major determinants explain how directors are appointed to boards: (1) the environment, which includes the competitive, institutional, and regulatory circumstances, (2) the characteristics of the appointing firm, which includes firm performance, firm strategy and firm life cycle stage,

(3) board characteristics, which includes CEO influence, the overall cohesion of the social elite and the characteristics of the board itself and lastly, (4) the characteristics of the director him/herself, which includes the human or social capital that is ascribed to the director in question. Going forward, I apply the framework presented here to the board network of the Fortune 500 and introduce attributes that relate to the selection of outside directors and represent relevant aspects of the framework.

5.3 Data and Method

5.3.1 Sample

I analyze the board interlocks between the Fortune 500 companies in 2022. While some studies use different samples to analyze board networks, such as sets of Danish or German firms (Hernandez *et al.*, 2015; Valeeva *et al.*, 2020), the Fortune 500 – or a subset thereof – has been the most frequent choice in the study of board networks (Daily, Certo, and Dalton, 1999; Withers *et al.*, 2020; Zhu and Westphal, 2014). Thus, the Fortune 500 offer an ideal context for this study. As commonly done (Withers *et al.*, 2020), only companies that were an independent operation at the time and for which complete board data has been available were included in the sample, leading to a total number of 489 companies. On average, firms have 19.6 directors on their boards with a standard deviation of 5.6. As for the 8606 unique directors in the sample, the overwhelming majority of directors (7755) is only affiliated with one firm, with 731 directors having two affiliations, 106 directors having three affiliations and 14 directors having four affiliations. This makes for a total of 851 connections between firms through interlocking directors.

5.3.2 Measures

Firm-level attributes. To integrate the current knowledge of what drives director selection into a comprehensive empirical analysis, I adhere closely to the framework proposed by Withers et al. (2012). For the characteristics of the appointing firm, this means that I include the firm performance and life cycle stage. Given that studies find that declining firm performance is positively related to the aim of appointing outside directors (Hermalin and Weisbach, 1988; Weisbach, 1988), I compared each firm's five-year average of Cash Flow/Sales to its current Cash Flow/Sales and used this as an indicator of an increasing or decreasing *performance*. It is also proposed that firms early in their life cycle stage are more prone to seat directors on their board that are already affiliated with other firms. Studies examining this commonly use the IPO date as an indicator of a firm's life cycle (Certo *et al.*, 2001; Certo, Holcomb, and Holmes, 2009). Thus, I include information about firms having their *IPO date 2017 or later*[17]. Regarding the firm's environments, I assume that the overall institutional environment is similar, given that all firms operate in the US economy. Competitiveness and regulatory circumstances, however, vary. To capture this, I allocated every firm according to the standard US classification of *Industrial*, *Utility*, *Transportation*, *Bank/Savings*, *Insurance* and *Other Financial*. I use the category *Bank/Savings* as the baseline in my analysis because (a) it is subject to heavy regulations (Booth, Cornett, and Tehranian, 2002; Hagendorff *et al.*, 2010) and (b) has been found to play a central role in board interlock networks (Mizruchi and Stearns, 1988, 1994). To control for the overall power and influence of the CEO (Howard *et al.*, 2017; Withers *et al.*, 2020), I include information about a *dual CEO-chair structure*, which refers to the CEO also occupying the position of executive chairman. Finally, I include firm size (logarithmized *Total Assets*) and rating (*Tobin's Q*) as control attributes, as is often done in board interlock research (Howard *et al.*, 2017; Withers *et al.*, 2020). Table 5.1 offers descriptive information about the presented firm-level attributes:

[17] The post-IPO phase usually refers to one to five years after the IPO (Certo *et al.*, 2009). I opted for five years, which is the upper bound but reflects a more substantial subset of the sample than a shorter time period would.

Table 5.1: Firm level attributes

	Mean	SD	Declining Firm Performance	CEO is Chairman of the Board	IPO 2017 or later	Tobin's Q
Declining Firm Performance (1=Yes)	0.29	0.46	-	-		
CEO is Chairman of the Board (1=Yes)	0.51	0.50	-.06	-		
IPO 2017 or later (1=Yes)	0.07	0.26	0.01	-0.04		
Tobin's Q			-0.20***	0.01	0.00	
Total Assets (log.)			0.04	0.03	-0.02	-0.11*

Aggregated means, standard deviations and Pearson correlations. Industry classification is excluded since it is a categorial attribute.
Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Director-level attributes. On the director level, I include the role of human capital by including information about the director holding a *C-level position*, thus bringing valuable expertise as well as for *age*, as a proxy for more general experience and career building opportunities (Kor and Sundaramurthy, 2009). I also include information about the *gender* of the directors, as it is one of, if not the most well documented outcome of social influence behaviors in boards, given the tendency for demographic similarity (McDonald and Westphal, 2013; O'Hagan, 2017). This also takes the composition of the *current board* into account. In the same vein, I include information about the director being the CEO of a firm, as this is seen as a prestigious position and is known to increase the likelihood of holding outside directorships (Fahlenbrach, Low, and Stulz, 2010). To control for *social elite cohesion*, I also control for CEOs serving on boards on which many other outside directors who are CEOs in their focal firm serve (Bellenzier and Grassi, 2014; Chu and Davis, 2016). *Social Capital*, which in this context refers to "prestige and connections with other firms" (Withers *et al.*, 2012: 249) is reflected by the network structure. Table 5.2 offers relevant descriptive information about the director level attributes:

Table 5.2: Director level attributes

	Mean	SD	Gender	Age	C-Level Position
Gender (1=Male)	0.65	0.48	-	-	-
Age	55.15	15.48	.22*	-	-
C-Level Position (1=Yes)	0.29	0.45	.01***	-.17***	-
CEO Position (1=Yes)	0.07	0.26	-.01***	-.08***	.05***

Means, standard deviations and Pearson correlations.
Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

5.3.3 Model

I apply exponential random graph models in my study. Compared to more traditional statistical approaches, network models – such as exponential random graph models (short: ERGMs) – assume that observations are not independent but depend on one another. Estimated parameters show the likelihood of an observed network pattern compared to a random network, with positive values indicating that a given pattern is observed more often than would have been expected randomly and negative values indicating that a given pattern is observed less often than would have been expected randomly. In their general form, ERGMs can be expressed as follows (Robins *et al.*, 2007a: 178):

$$\Pr(Y = y) = \left(\frac{1}{k}\right) \exp\{\sum_{A} \eta\, \mathrm{A} g \mathrm{A}(y)\}$$

where (i) A stands for the network configuration; (ii) the parameter ηA corresponds to the configuration A and (iii) $gA(y)$ is the network statistic that corresponds to configuration A. In the presented form, all ERGMs describe "a general probability distribution of graphs on *n* nodes" (Robins *et al.*, 2007a: 179), which is dependent on the statistics in network **y** and all non-zero parameters specified in ηA. For the two-mode networks, I apply the two-mode – or: multilevel – network extension of ERGMs (Wang *et al.*, 2009, 2013), in which the network "represents the association between two or more sets of nodes where each set is a different social entity" (Wang *et al.*, 2009: 12)[18]. To be specific, in two-mode networks of board interlocks, one mode represents the firms, the other mode represents the directors and connections are constituted through affiliations between directors and firms. Importantly, extending exponential random graph models to two mode-networks treats these networks as undirected. In other words, the network does not depict firms choosing directors or directors choosing firms, but the observed network is the result of a mixture of both. The two-mode specification allows for the inclusion of network properties that cannot be observed in one-mode networks, such as two-stars (i.e., two firms being connected through affiliations with one director). I model the board interlock networks by using a Monte-Carlo Maximum Likelihood-algorithm (Robins *et al.*, 2007b).

5.3.4 Model specification

Structural effects. The purpose of structural effects is to "capture the effects of endogenous local structures, and more generally, to understand the antecedents and mechanisms involved in network formation" (Kim *et al.*, 2016: 24). Since the framework by Withers et al. (2012) is relatively comprehensive in identifying what drives director selection, I opt for a very parsimonious specification and only include three structural effects. The included effects depict theoretically relevant aspects of the framework or are indispensable for model fit and convergence, which is an important prerequisite of ERGMs (Robins *et al.*, 2007a). First is the *edges*-effect, which captures the overall likelihood of observing ties and is akin to the intercept in ordinary regressions. It thus must be included for statistical reasons and is present in both the projected as well as the two-mode models. In the one-mode projections, the *geometrically weighted degree*-effect is included which captures tendencies of network closure and aids in preventing model degeneracy (Robins *et al.*, 2007b). For the two-mode networks, I

[18] For a thorough mathematical explanation and derivation of the extension, see the referred articles by Wang and colleagues in this section.

have included the *Firm level: 2-stars*-effect[19], which captures the likelihood of two firms being connected through individual directors and thus depicts the likelihood of firms to appoint outside directors to their board. Third and last is the *Director level: One Affiliation*-effect, which captures the likelihood of directors being affiliated with only one firm. As can be seen in Table 5.1, most directors in the sample only serve on one board of the Fortune 500-companies and do so by a large margin. Thus, the *Director level: One Affiliation*-effect helps to accurately depict the network structure on the individual level. Table 5.3 offers a short visualization and description of the effects I use to model the projected one-mode networks and two-mode networks, including attribute-based structural effects on the firm- or director level. The projections additionally include geometrically weighted structural effects, which are explained in detail in extant literature (Robins *et al.*, 2007b).

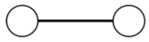
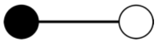
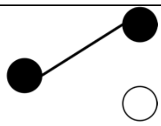
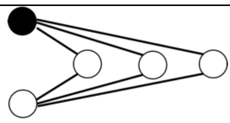
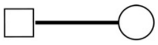
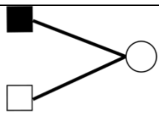
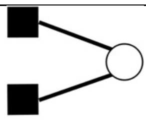
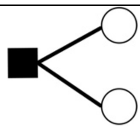
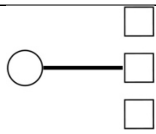
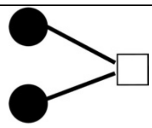
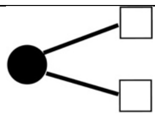
Firm-level effects. On the firm level, I include the *Homophily: Industry*-effect. This effect estimates the likelihood of firms being connected to others from the same industry. I also include an effect for *Attribute: Bank/Savings Industry*, which tests if there is an increased likelihood for firms in the banking industry to appoint more directors (in other words: have larger board sizes) compared to their counterparts, as high levels of regulation are often associated with board size (Booth *et al.*, 2002; Hagendorff *et al.*, 2010). I also include the *2-stars*-effect as well as three attribute-based *2-stars*-effects. *2-stars*-effects reflect the likelihood of a firm being connected to another firm through one director, where the attribute-based *2-stars*-effects reflect the likelihood of a firm being connected to another through one director if it exhibits a given attribute. *2-stars*-effects also help to capture the likelihood of network closure. First is the *2-stars: Poor Performance*-effect, which indicates the likelihood of firms having outside directors on their board if the firm's performance has decreased compared to its performance during the past five years. Second is the *2-stars: CEO is Chairman*-effect, which

[19] This effect would technically be called a *director-centered 2-star*, since two firms are connected through a director. Given that I only integrate 2-star effects on the firm level, the name *2-stars* combined with the placement in the firm segment of the results table is more intuitive.

indicates the likelihood of firms having outside directors on their board if the firm's CEO is also acting as the chairman of the board. And third, the *2-stars: IPO date 2017 or after*, indicating the likelihood of a firm being connected to other firms via board interlocks if its IPO happened 2017 or later. All firm level effects are included in *Model 1: Firm level (Projection)*, *Model 3: Firm level (Two-Mode)* as well as *Model 5: Full Model (Two-Mode)*.

Director-level effects. On the director level, I include various *Homophily*- and *Attribute*-based effects. First, I include two effects for the role of gender. These are *Homophily: Gender* and *Attribute: Male*. The former represents the likelihood of a director sitting on a board based on the number of other directors with the same gender, while the latter represents the likelihood of male directors holding multiple directorates compared to female directors. Similarly, *Attribute: Age* estimates the effect of a director's age on the likelihood of holding multiple directorships. The role of CEOs is represented by the *Homophily: CEO Position*- and *Attribute: CEO Position*-effects, where the former represents the likelihood of sitting on a board on which multiple other directors hold CEO positions in one company, while *Attribute: CEO Position* estimates the more general effect of being a CEO on holding multiple directorships. Finally, I control for the effect of holding a C-Level position, such as Chief Financial Officer, by including the *Attribute: C-Level Position*-effect. This effect captures if the likelihood of holding multiple directorships is influenced by a director holding a C-Level position in a company. All effects mentioned here, including the *One Affiliation*-effect explained above, are included in *Model 2: Director level (Projection)*, *Model 4: Director level (Two-Mode)* as well as *Model 5: Full Model (Two-Mode)*.

Table 5.3: Visual representation of included network effects

Effect	*Visual representation*	*Summary*
	One-Mode Effects	
Edges		Overall likelihood of observing affiliations between firms or directors
Attribute		Likelihood of a firm or director attribute influencing the number of ties the firm or director has
Attribute Homophily		Likelihood of a firm or director to be tied if they share an attribute
Geometrically weighted degree		Likelihood of observing network closure in firm or director networks
	Two-Mode Effects	
Edges		Overall likelihood of observing affiliations between firms and directors
Firm 2-stars		Likelihood of a firm seating outside directors (either general or dependent on attribute)
Firm Homophily		Likelihood of firms being connected through a director if the firms share an attribute
Firm Attribute		Likelihood of a firm attribute influencing the number of directors affiliated
One Affiliation		Likelihood of directors being affiliated with exactly one firm
Director Homophily		Likelihood of directors sitting on the same board if they share an attribute
Director Attribute		Likelihood of a director attribute influencing the number of firm affiliations

Note: For two-mode effects, circles represent directors, squares represent firms. This distinction does not apply to one-mode projections, where circles represent either firms or directors. Black symbols represent which nodes attributes are included, if applicable.

5.4 Results

5.4.1 ERGM results

Table 5.4 presents the results of the exponential random graph models estimating the drivers of board network formation. In general, “a positive coefficient suggests greater prevalence of a given configuration in the network than that which would be expected, conditional on the other effects” (Kim *et al.*, 2016: 36), while a negative coefficient suggests the opposite. The *Edges*-effects will not be interpreted, given that it is akin to “an intercept term or a grand mean in regression or ANOVA” (Kim *et al.*, 2016: 36) and thus serves as the model baseline. Going forward, I will first describe the results of the projected models that only include firm level connections and effects (*Model 1*), followed by the model that only includes director level connections and effects (*Model 2*) in Table 5.4. I then present information about three models estimated on the two-mode data set in Table 5.5: *Model 3*, which only includes firm level attributes, *Model 4*, which only includes director level attributes and *Model 5* – the *full model*, which includes all information used in prior models. I discuss notable differences between the projected networks and their two-mode counterparts. All networks are treated as undirected.

Table 5.4: ERGM results of one-mode projections of board interlock networks

Parameter	Model 1: Firm level Estimate	Model 1: Firm level SE	Model 2: Director level Estimate	Model 2: Director level SE
Intercept				
Edges	-9.03***	(0.72)	-6.23***	(0.04)
Firm-level Effects				
Geometrically weighted degree	-1.51***	(0.11)	-	-
Attribute: Poor Performance	0.06*	(0.03)	-	-
Attribute: CEO is Chairman	0.09**	(0.03)	-	-
Attribute: IPO after 2017	-0.05	(0.07)	-	-
Attribute: Rating (Tobin's Q)	0.01	(0.01)	-	-
Attribute: Firm Size (Total Assets)	0.31***	(0.04)	-	-
Homophily: Industry	0.14	(0.12)	-	-
Attribute: Industrial vs. Banking	0.11	(0.12)	-	-
Attribute: Utility vs. Banking	-0.02	(0.11)	-	-
Attribute: Transportation vs. Banking	0.25	(0.13)	-	-
Attribute: Insurance vs. Banking	-0.11	(0.10)	-	-
Attribute: Other Financial Services vs. Banking	-0.04	(0.11)	-	-
Director-level effects				
Geometrically weighted degree	-	-	1.60	(58.64)
Homophily: Gender	-	-	0.02**	(0.01)
Attribute: Male	-	-	-0.05***	(0.01)
Attribute: Age	-	-	0.01***	(0.00)
Homophily: CEO Position	-	-	-0.05*	(0.02)
Attribute: CEO Position	-	-	0.07**	(0.02)
Attribute: C-Level Position	-	-	-0.05***	(0.01)
Information Criterion				
Akaike Information Criterion (AIC)	11941		1345864	
Bayesian Information Criterion (BIC)	12076		1346003	

Note: Significance levels are two-tailed. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Model 1: Firm-level (Projection). For the projected board interlock network on the firm level, I estimated a significant negative parameter for *geometrically weighted degrees* (-1.51, $p < .001$), which suggests that we observe a lower tendency for network closure in the present network than we would expect in a random network. The results also showed that poor performing firms (0.06, $p < .05$) and firms in which the CEO also holds the position of chairman of the board (0.09, $p < .01$) tend to have more board interlocks than those firms which do not exhibit poor performance and, respectively, in which the CEO and chairman position are separated. I also found that firm size, as represented by *Total Assets*, had a positive influence on the number of board interlocks of a firm. The other estimated effects were not significant at $\alpha = .05$.

Model 2: Director-level (Projection). For the projected board interlock network on the director level, I found no significant parameter for *geometrically weighted degrees*, which offers a stark contrast to the projection in *Model 1* but is in line with prior results that projections of board networks onto the firm level lead to substantial overestimations of closure coefficients (Opsahl, 2013). The results also showed that directors tend to form gender-homophilic connections (0.01, $p < .01$) and that male directors, even though they are far more prevalent in the sample, tend to have less connections to other directors (-0.05, $p < .001$). My findings further showed that the likelihood of having connections to other directors increases with age (0.01, $p < .001$). They also suggested that CEOs tend to have more connections in general (0.07, $p = .01$) but that they are less likely to be connected to other CEOs than non-CEO directors (-0.05, $p < .05$). Finally, my results suggested that occupying a C-level position in general decreases the likelihood of having connections to other directors (-0.05, $p < .001$).

Table 5.5: ERGM results of two-mode board interlock networks

	Model 3: Firm level		Model 4: Director level		Model 5: Full model	
Parameter	Estimate	SE	Estimate	SE	Estimate	SE
Intercept						
Edges	-3.08***	(0.19)	-6.83***	(0.15)	-5.12***	(0.42)
Firm level Effects						
2-stars	-5.06***	(0.12)	-	-	-2.63***	(0.18)
2-stars: Poor Performance	-0.15*	(0.06)	-	-	-0.12*	(0.05)
2-stars: CEO is Chairman	-0.03	(0.07)	-	-	-0.03	(0.06)
2-stars: IPO after 2017	0.16*	(0.08)	-	-	0.10	(0.06)
Attribute: Rating (Tobin's Q)	-0.00	(0.01)	-	-	-0.00	(0.00)
Attribute: Firm Size (Total Assets)	0.12***	(0.02)	-	-	0.08***	(0.02)
Homophily: Industry	-0.17**	(0.07)	-	-	0.21**	(0.07)
Attribute: Industrial vs. Banking	-0.08	(0.06)	-	-	-0.09	(0.05)
Attribute: Utility vs. Banking	-0.16*	(0.07)	-	-	-0.10*	(0.05)
Attribute: Transportation vs. Banking	-0.08	(0.08)	-	-	-0.04	(0.07)
Attribute: Insurance vs. Banking	-0.22***	(0.06)	-	-	-0.14**	(0.05)
Attribute: Other Financial Services vs. Banking	-0.15*	(0.07)	-	-	-0.10	(0.06)
Director level effects						
One Affiliation	-	-	3.10***	(0.04)	3.53***	(0.17)
Homophily: Gender	-	-	0.01*	(0.00)	0.01*	(0.00)
Attribute: Male	-	-	-0.22***	(0.05)	-0.46***	(0.07)
Attribute: Age	-	-	0.02***	(0.00)	0.04***	(0.00)
Homophily: CEO Position	-	-	0.02***	(0.00)	0.01***	(0.00)
Attribute: CEO Position	-	-	0.68***	(0.10)	1.37***	(0.14)
Attribute: C-Level Position	-	-	-0.16**	(0.06)	-0.45***	(0.10)
Information Criterion						
Akaike Information Criterion (AIC)	125423		124454		123344	
Bayesian Information Criterion (BIC)	125595		124576		123609	

Note: Significance levels are two-tailed. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Model 3: Firm-level (Two-Mode). On the firm level, I estimated a significant negative parameter for the *2-stars*-effect (-5.06, $p < .001$), indicating that less firms are connected through directors than we would expect in a random network. This tendency is in line with the negative *geometrically weighted degree*-effect in *Model 1*. Next, the estimates showed a significant negative *2-stars: Poor Performance*-effect (-0.15, $p < .05$). This parameter indicates that firms which experience a decline in performance are less likely to have directors on their board that are also affiliated with other firms than firms whose performance does not decline. The *2-stars: IPO date 2017 or after*-effect showed a positive significant parameter (0.16, $p < .05$), indicating that firms which had their initial public offering in 2017 or later, are more likely to have directors on their boards that are also affiliated with other firms. *Firm Size* was also found to positively influence the number of appointed directors (0.12, $p < .001$). I also found a significant negative effect for industry homophily (-0.17, $p < .01$). This suggests that companies are more likely to be connected to companies that do *not* belong to the same industry. Next, I found significant estimates that suggest that firms in the industries *Utility* (-0.16, $p < .05$), *Insurance* (-0.22, $p < .001$), and *Other Financial Services* (-0.15, $p < .05$) overall appoint less directors than firms in *Banking*. The other estimated effects were not significant at $\alpha = .05$.

Model 4: Director-level (Two-Mode). On the director level, the *One Affiliation* effect showed a positive significant parameter (3.10, $p < .001$). This indicates that more directors are affiliated with exactly one firm than we would expect to find in a random network. Next, I found a positive effect for *Homophily: Gender* (0.01, $p < .05$), indicating a slightly increased likelihood for directors to sit on boards on which more directors share their gender. As for the *Attribute*-effect of being *male*, I found a significant negative effect (-0.22, $p < .001$). This indicates that, even though there is a high prevalence of male directors, their female counterparts are more likely to hold a higher number of board seats. As for the *Attribute: Age* effect, the model showed a significant positive effect (0.02, $p < .001$), which suggests that the older a director is, the likelier it is for him/her to hold multiple board seats. The positive *Homophily: CEO Position*-effect (0.02, $p < .001$) indicates a slight tendency for CEOs to serve on boards of firms on which other directors also hold a CEO position, suggesting a tendency for elite cohesion. As for the *Attribute: CEO Position*-effect, I found a significant positive effect (0.68, $p < .001$), which suggests that CEOs have a higher likelihood of occupying multiple directorates than their non-CEO peers. Finally, I found a negative parameter for the *Attribute: C-Level Position*-effect (-0.16, $p < .01$), which indicates that directors occupying a C-Level position in a firm are significantly less likely to occupy board seats in multiple firms than their counterparts who do not hold such a position. Overall, the results echo those of the one-mode projection in *Model 2*, with the substantial difference that CEOs seek to serve on boards on which other CEOs are also present. This gives more insight into the process of social elite cohesion than the projected network, which misestimated this effect.

Model 5: Full Model (Two-Mode). The full model integrates attributes on the firm and director level and thus allows for a more holistic perspective. Considering that the goal of this study is to not only integrate both levels of board research, but also approximate how consequential it is to omit one of these levels, the difference in parameter estimates between *Model 5* and the two former models is of major interest. For the firm level effects, these differences are substantial: While *Model 3* estimated a negative parameter for industry homophily, suggesting that firms will be more likely to be connected to firms from other industries, *Model 5* indicated the opposite. I found a significant positive *Homophily: Industry*-effect (0.21, $p < .01$), indicating that firms will be connected to other firms from the same industry via shared directors. The significance levels for industry *Attribute* -effects decreased for *Insurance vs. Banking* (-0.14, $p < .01$) as well as *Other Financial Services vs. Banking*, the latter of which is no longer significant at $\alpha = 0.05$. I also found that the *2-stars: IPO date 2017 or after*-effect is no longer significant at $\alpha = 0.05$ when controlling for director level attributes. The differences between the estimated models suggest that researchers may not only overestimate the role of some firm level effects when omitting information about the involved directors – as suggested by the loss of significance of the *2-stars: IPO date 2017 or after*-effect -, but that they also possibly misinterpret the direction in which the estimated effects point, as is evident by the *Homophily: Industry*-effect. Effects that captured director level attributes were not as strongly impacted by the integration of the firm level attributes as vice versa. I found that the significance levels and parameter signs for director level-effects remain unchanged compared to *Model 4*, but that some effect sizes increased, indicating that their relative explanatory power and thus importance in explaining the formation of the observed network increases when including information about firm level attributes.

5.4.2 Goodness of fit and robustness checks.

I discuss goodness of fit and robustness checks for the two-mode network models as they showed an improvement in results compared to the one-mode projections and will be the basis for discussion going forward. For goodness of fit assessment, ERGMs include a separate function (Hunter, Goodreau, and Handcock, 2008) that provides additional information to the AIC and BIC criteria reported in Table 5.5. Nevertheless, using AIC and BIC to aid model selection remains common practice in management and network research alike (Almquist and Butts, 2014; Kim *et al.*, 2016). Here, lower values are desirable. The AIC and BIC criteria values for *Model 5* were the lowest across all two-mode models, followed by *Model 4* and *Model 3* in that order. While it is difficult to say how substantial these differences are, they do reflect a notable reduction in statistical noise, suggesting that, out of the three models presented in Table 5.5, *Model 5* is the preferable choice. Regarding goodness of fit, all model statistics in *Model 5* exhibited *p*-values higher than 0.80, indicating a sufficient fit. This was further confirmed by a visual inspection of the GoF-plots. The Goodness of Fit statistics for all included model statistics in both *Model 3: Firm level* and *Model 4: Director level* are slightly inferior to those achieved for *Model 5: Full Model* but these differences are not drastic. For robustness checks, I included different measures for *poor performance* (such as Book Value or Return on Assets), which led to similar results. I also included an attribute indicating that the IPO date took place in 2012 or after instead of 2017 or after. This did not yield significant results in neither *Model 3* nor *Model 5*, suggesting that measuring up to five years after the IPO date – as is custom in the post-IPO literature - is a more reasonable cut-off. Finally, I estimated different model specifications which included all additional structural effects available for two-mode networks in the *statnet*-package[20], such as the *geometrically weighted dyadwise shared partners*- and the *geometrically degree distribution*-effects. The inclusions of these effects led

[20] For a full list, see the R vignettes of the statnet- and ergm-packages.

to drastic convergence issues, thus making the models non-interpretable. One specification converged model but yielded similar parameters at the same significance levels and the included *geometrically weighted degree distribution*-effect was not significant itself. Geometrically weighted effects serve to better capture aspects of the degree distribution and tie structure than reduced homogeneous Markov specifications (such as 2-stars) are capable of. In consequence, they often help in preventing model degeneracy (Robins *et al.*, 2007b). Since no model degeneracy occurs and considering the very peculiar degree distribution in which an overwhelming majority of directors has only affiliations with one firm, the underlying network structure is better captured through estimating the prevalence of having only one affiliation and parameters such as 2-stars. The inability to specify converging models using geometrically weighted effects further indicates overestimation of network closure in one-mode projections (Opsahl, 2013) is especially prevalent in board interlock networks. To further guard the models against degeneracy, the homophily-effects in all two-mode models were specified in a way that is similar to geometrically weighted effects in the sense that the contribution of actors to the target statistic decays with the number of actors.

5.5 Discussion

Board research commonly attempts to explain why firms select outside directors by focusing on attributes that are located either on the firm level (Martin *et al.*, 2015; Withers *et al.*, 2020) or the director level (McDonald and Westphal, 2013; Westphal and Stern, 2007). Yet research has long acknowledged that the director selection process is inherently a multi-level process and that the omission of one of these levels of analysis may have serious theoretical and methodological implications (Hernandez *et al.*, 2015; Opsahl, 2013; Withers *et al.*, 2012). My study set out to do two things: First, to integrate both levels of board interlock research and second, to illustrate how omitting one of these levels may result in misleading findings. Drawing on the director selection framework proposed by Withers et al. (2012), I include various attributes on the firm and director level that explain the appointment of outside directors. I use exponential random graph models to analyze the formation of the board interlock network between the Fortune 500 firms in 2022 based on these attributes. My empirical results illuminate biases introduced by one-mode projections and show what drives board network formation when integrating attributes on both the firm and director level. I find that the effects on the director level are more robust towards one-mode projections and the integration of firm level effects in two-mode analysis. Conversely, effects on the firm level appear to be more spurious.

5.5.1 Theoretical implications

My study makes three contributions to the literature. First, I complement research on corporate governance by integrating attributes on the firm- and director-level into the outside director selection process. I do so by applying the two-mode extension of exponential random graph models (Wang *et al.*, 2009) to a large board interlock network, integrating multiple attributes on both the firm and director level that have been found to drive board network formation in earlier studies. My empirical results show that the integration of both levels of board research leads to substantial changes in results when compared to estimations based on only the firm or director level. Thereby, I address open questions about contradictory empirical findings. These contradictions are rooted in different theoretical premises that shape both streams of research. While board research on the firm level commonly focuses on the selection of outside directors from a resource dependency or agency perspective (Hillman *et al.*, 2009) and thus treats director selection as a rational process, research on the director level typically draws on social cohesion or social capital theory (Kim and Cannella, 2008; McDonald and Westphal, 2013) and puts underlying social aspects into focus. Even though much of the research published in both domains has led to complementary results, some studies show contradictory evidence. My results suggest that social processes tend to dominate the director selection process over rational considerations. Specifically, the role of a firm's life cycle stage and industry homophily appear to be spurious when introducing attributes on the director level, while the director-level effects remain relatively unchanged when introducing firm-level attributes. A possible reason for this is that, while including only firm-level attributes allows for existing ties to be included in the analysis, there is no differentiation between the type of directors that form these ties. For example, the increased likelihood of CEOs holding multiple directorships plays an important role in understanding how social elite cohesion works. Information about the prestige that CEOs bring with them, however, is lost when only analyzing the firm level. Such information loss is not trivial: On the contrary, my results strongly suggest that such information is crucial to the accurate analysis of certain questions on the firm level, such as the question if firms in their early life cycle are successful in their attempt to "dramatically increase their hiring of prestigious directors and executives" (Withers *et al.*, 2012: 255).

The tendency for firm-level effects to be substantially influenced by the integration of director-level attributes can be further illustrated based on the reversal of the parameter sign of the industry homophily effect. As opposed to the effect in the model including only firm attributes, the results in the full model suggest that directors are more likely to join the boards of firms in the same industry branch. A potential reason for this might be that the human capital of the appointed director, which can be defined as "the set or bundle of skills, knowledge, and perspectives that outside directors collectively bring to the board" (Kor and Sundaramurthy, 2009: 984) among other aspects may be more applicable in the context of the same industry; a nuance, that is lost through the omission of the director level from the analysis. While estimates on the firm level change substantially when integrating director-level attributes, the director level estimates remain relatively consistent when introducing firm-level effects. If anything, their relative importance increases in a model that controls for both levels of analysis. A possible explanation for this is that the firm level network is a result of the decisions made by individual directors, who are themselves actors embedded into an economic context (Granovetter, 1985). Thus, the social processes underlying network formation, such as social cohesion of the corporate elite, are captured in part. In summary, this leads to my first proposition:

Proposition 1: *In board networks, social mechanisms tend to dominate the rational and strategic processes that are often attributed to board interlock formation.*

Second, I contribute to research on the formation of board interlock networks by approximating how impactful the omission of one level of the phenomenon is, adding to a longstanding theoretical and methodological debate (Hernandez *et al.*, 2015; Opsahl, 2013; Withers *et al.*, 2012). I do so by showing how the projection onto one-mode networks introduces considerable biases, most notably the overestimation of closure and misrepresentation of the role of industry homophily in firm-level projections. The biases introduced by one-mode projections are resolved by taking a two-mode approach. This approach then further benefits from not only accounting for the underlying two-mode structure but integrating attributes on both levels of analysis. While the results at first glance imply the conclusion that omitting the director level in two-mode analyses may lead to a misestimation of certain findings, this is unlikely to be true for all findings produced by research on boards in the past. My results illustrate this: For example, poor firm performance is found to reduce the likelihood of outside directors in a firm, regardless of the introduction of director attributes – likely because being affiliated with a firm that experiences performance decline is neither in the interest of other firms nor directors. Thus, the theoretical reasoning behind the firm- and director-level is aligned. This is only an example of the many ways in which theory on the firm and director level offers complementary interpretations. This implies that, while it is advisable to be cautious of the reliability of one-mode results, a two-mode analysis does not necessarily lead to substantial changes in the estimated parameters. For instance, Zajac and Westphal (1996) show that directors, whose reputation as board members is to be more active, have a higher likelihood of being appointed to boards, in which the board members have a relatively high power. On the contrary, board members with a reputation to be more passive, have a higher likelihood of being appointed to boards of firms, in which the CEO is more powerful. In both cases, these director-level findings are likely to align with the strategy and overall governance of the appointing firms. Thus, one would not expect the integration of a second mode to contradict the results, but rather add more substance to the findings.

The improved AIC/BIC values suggest that the inclusion of attributes on the firm and director level in the same model will lead to an overall higher model quality. However, the goodness of fit does not notably increase but is overall good. Rather, the added complexity leads to an incremental improvement, as some explanations behind the formation of board networks overlap on both levels. Given the increased complexity and data requirements of two-mode analysis, researchers studying board network formation may want to consider the following three questions when deciding if a two-mode approach is beneficial: First, can it be expected that the inclusion of a second mode provides relevant additional information to the analysis? This may be the case when the social or human capital of individuals plays a role in the benefits a firm wants to achieve through board interlocks, such as learning about other firms' strategies by appointing well-connected directors to the board. Second, does theory suggest that the expected outcomes on both levels are similar or do they contradict each other? A firm may want to appoint prestigious outside directors on its board to signal and complement ongoing success, which may be an attractive endeavor for said prestigious directors but also an attractive connection for the director's focal firm. In such a case, the director and firm interests align, suggesting that a two-mode analysis would not substantially improve the findings of a one-mode analysis. And third, in reference to specific attributes, does extant literature suggest that our knowledge about the role of these attributes is secure? For instance, it is common to control for attributes such as firm sector or performance. If extant literature shows that results for these attributes are similar in multiple different contexts and constellations, it may be assumed that it is more likely for them to show robust results when controlling for a second mode than it is for effects that show substantially different results across various studies. In sum, I propose that:

Proposition 2: *The integration of firm and director attributes in a two-mode analysis will lead to a substantial improvement in model quality and insight when theoretical assumptions on the director and firm level suggest different outcomes.*

Third, my study contributes to methods in management research by illustrating the empirical application of modeling networks as two-mode phenomena instead of omitting one mode through the technique of projection. The potential benefits of this method, such as a more nuanced and robust understanding of network formation become clear from the results. The analysis of two-mode networks is not restricted to the study of board networks or broader context of corporate governance. Rather, they are applicable to different fields of management studies that contain affiliation structures. For instance, the results of a study on the role of problem-solving and dissonant ties for engineers in the aerospace industry (Brennecke, 2020) may benefit from controlling for the additional information of which projects the engineers are affiliated with and thus jointly work on. Analysis of citation networks between studies (Zupic and Čater, 2015) may benefit from controlling which institutions authoring scholars are affiliated with. Apart from enriching fields of research that are already applying network methodology, it is possible to make use of affiliation structures in cases, where it is difficult to obtain more traditional network data. For example, researchers may want to include entrepreneur's affiliations with business incubators when studying entrepreneurial success, incorporate joint partaking in extracurricular work activities when studying well-being in an organizational department, or include the label affiliations of a musician's feature guests when studying the likelihood of expanding beyond the focal musician's typical genre.

5.5.2 Limitations and future research

As with most empirical work, this study is subject to several limitations. Most notably, not all aspects of the framework proposed by Withers et al. (2012) are included as attributes in the exponential random graph models. Specifically, *firm strategy, as well as the competitive and institutional environment,* are not explicitly part of the model. While it can be argued that the firms operate in a similar institutional context – the US economy – and operate in a competitive environment – the free market – it would be disingenuous to assume there will be no differences between firms in the sample. These differences are only approximated by including information about which industry sector firms belong to, but even then, it is unlikely that a firm's relation to its industry environment is captured in a binary attribute. *Strategy* is also not included as its own attribute in the model. While one may argue that appointing outside directors is reflective of overall strategy, as the propensity of outside directors may lead to benefits such as organizational learning (Tuschke *et al.*, 2014; Woelfle and Tuschke, 2017), this is unlikely to reflect the complex reality of strategy research. For example, firm strategy in director selection may refer to the director's alignment with the global trajectory of the appointing firm or the director's monitoring behavior before an acquisition (Howard *et al.*, 2017; Li and Aguilera, 2008). Both of these examples shine light on very different aspects of firm strategies, illustrating how strategy would be difficult to capture as a single attribute.

A second substantial limitation is that some attributes are related to multiple aspects of the framework. For instance, the role of *gender* in director selection can be attributed to *social influence* in the form of preferences for homophily, but how strong this preference is and if it manifests itself will likely depend on the composition of the *current board*. CEOs may be preferable as outside directors than regular directors, representing the desire to maintain *social elite cohesion*, but this also increases the CEO's *social capital*. Thus, while most of the aspects of the underlying framework are included, not every attribute is distinct enough to be pinpointed to a single aspect of the framework. Given the notions that "empirical testing is more often limited to one set of factors to the exclusion of the rest" and that "providing more integrative views of director selection is not an easy task" (Withers *et al.*, 2012: 263f), the aforementioned limitations should not diminish the value of the presented findings but be perceived as an initial step towards a deeper understanding of the outside director selection process and an incentive for further research. Considering the limitations of this study, one exciting avenue for further research might be the role of strategy and a firm's environment in the selection of outside directors while integrating the director perspective. Research in these areas will surely benefit from the application of two-mode network models and lead to new insights into these multi-dimensional, multi-faceted constructs. More generally, my findings call for theories on the director selection process that take its multi-level nature into account, especially for theory that provides a strong focus on social rationales when theorizing from the vantage point of the firm. A third opportunity for future research is to extend the application of two-mode networks in management research to dynamic settings. The application of dynamic models, such as temporal ERGMs (Leifeld *et al.*, 2018), stochastic actor-oriented models (Snijders *et al.*, 2013), or dynamic network actor models (Stadtfeld *et al.*, 2017) may help answer the call "to examine possible differences in network dynamics when the node is a person versus organization" (Chen *et al.*, 2022: 1638).

5.6 Conclusion

Research on the selection of outside directors has mostly analyzed either the role of attributes on either the firm- or the director-level. However, scholars have noted for a long time that this differentiation suffers from theoretical contradictions as well as possible methodological issues. My study addresses both aspects by empirically analyzing the selection of outside directors based on firm- and director-level attributes alike. Based on my findings, I argue that director-level attributes and thus social processes offer more robust explanations of board network formation than firm-level attributes do, which are often used to frame board interlocks as a result of rational considerations. I propose that studies run the risk of misestimating and misinterpreting effects when projecting two-mode networks onto one-mode networks but also when omitting director-level attributes in two-mode analyses. However, the prevalence of this risk is conditional on the quality of additional information, the theoretical alignment of both levels of analysis, and the robustness of prior findings in extant literature.

Chapter 6
Conclusion

Organizational networks are phenomena that many people come in touch with every day – from asking a colleague at work for advice, watching one's favorite TV series on the weekend or ordering a product, which has been the result of a joint effort of multiple companies (Brennecke, 2020; Powell *et al.*, 1996; Soda *et al.*, 2021). In this light, it is unsurprising, that research on organizational networks has seen a steady increase over the past couple of decades in management research (Borgatti and Foster, 2003; Chen *et al.*, 2022; Tasselli and Kilduff, 2021; Zaheer *et al.*, 2010). A specific type of organizational network, which this dissertation focuses on, is networks between organizations. While business scholars have made large strides in analyzing different types of interorganizational networks – such as strategic alliances or board interlocks (Gulati, 2017; Mizruchi, 1996) - and taken on different perspectives on interorganizational networks – such as researching their formation and dynamics versus their consequences (Howard *et al.*, 2016; Kim *et al.*, 2016; Ryan-Charleton *et al.*, 2022) -, extant literature often treats research streams that emerged over time as separate fields. Like the network paradigm helped to bridge atomistic and overly embedded explanations of the social reality of economic actors (Granovetter, 1985), in this dissertation, I attempt to bridge the gaps between some of these separate fields. Taken together, the empirical studies reported in this dissertation provide new and valuable insights on various aspects of interorganizational networks. These insights result in important contributions to management studies and vast possibilities for future research.

6.1 Main Contributions

While the empirical studies in this dissertation make several contributions each, three main contributions – one for each chapter representing an empirical study – can be identified that refer to the theme of this dissertation: bridging gaps in extant literature. First, the chapter *Partner Selection in Business Ecosystems – A Network Approach* attempts to bridge the business ecosystem and network research literature. While ecosystems have long been treated as a form of interorganizational relations that is distinct from organizational networks, scholars have repeatedly used network methodologies to depict business ecosystems (Best, 2015; Li, 2009). Answering recent calls to open a conversation between both fields (Shipilov and Gawer, 2020), the chapter in this dissertation applies modern network methodology to business ecosystems and, based on partner selection mechanisms from network research, gives a nuanced depiction of what drives partner selection in these ecosystems and which roles different resources play. On a more abstract level, the chapter demonstrates how contemporary network models may be useful to produce novel insights in fields, in which the application of said models is not immediately obvious. Second, the chapter *The Co-Evolution of Board Interlock Networks and Corporate Strategic Actions* theorizes and empirically demonstrates that a firm's board interlock networks and its acquisition and divestiture activities co-evolve. Typically, scholars have treated these processes – the influence of board interlock networks on corporate strategic actions (Haunschild, 1993; Haunschild and Beckman, 1998; Yoshikawa *et al.*, 2020) and vice versa (Howard *et al.*, 2017; Withers *et al.*, 2020) – as separate. Based on board interlocks between large German firms, the chapter demonstrates that network dynamics and consequences are not necessarily separate phenomena, even though they represent different research foci in organizational network research. The study uses structuration theory (Giddens, 1984) to develop hypotheses and thereby illustrates an underutilized theory that allows management researchers to conceptualize co-evolution processes in networks. Third and last, the chapter *Integrating Two Modes of Board Interlock Research* takes a novel perspective on board interlocks by integrating research on the firm and director level, which has led to contradictory results in the past. Based on an empirical analysis of the board interlock network between the Fortune 500, my study finds that social processes, which are typically attributed to the director level (McDonald and Westphal, 2013; Westphal and Khanna, 2003; Westphal and Stern, 2007), tend to dominate the rational considerations scholars often attribute to decisions made on the firm level (Hernandez *et al.*, 2015; Howard *et al.*, 2016; Yue, 2012). Adding to both theoretical and methodological debates, the results of the study suggest that there is much value to be gained for management researchers by accurately capturing multimodal network structures instead of analyzing them as one-mode networks. In sum, the findings presented in this dissertation imply that, while research on organizational networks itself emphasizes connectedness, the different research streams that encompass organizational network research are much more connected than extant literature would suggest, even though they have emerged in a (more or less) separate fashion. The chapters of this dissertation illustrate different ways to bridge these gaps that, when taking a closer look, are much narrower than first meets the eye.

6.2 Future Research

In the same way that each empirical study in this dissertation discusses contributions that directly refer to the respective content of the study in more detail than provided in this conclusion, each chapter discusses avenues for future research that directly refer to the study's findings and limitations. However, some additional avenues for future research can be identified, which directly relate to the dissertation's overarching theme of *bridging gaps* and to some of the concepts introduced in the first chapter. First is the need for existing management theories to further adapt in a way that captures the complexity, and often recursive nature, of organizational networks. While some existing theories, such as structuration theory (Giddens, 1984), allow scholars to put the recursive nature of network dynamics and consequences at the core of their theorizing, this is not the case for the most prevalent theoretical perspectives. Going off the example of board interlock networks, resource dependence theory and agency theory are the most prominent theoretical perspectives that scholars use to theorize and explain both the dynamics and consequences of board interlock networks (Hillman and Dalziel, 2003; Howard *et al.*, 2017; Pugliese, Minichilli, and Zattoni, 2014). Both theoretical lenses, however, typically lead to the development of one-directional arguments, such as *knowledge dependence leading to the formation of board interlocks* or *board interlock ties leading to similarities in executive compensation*, thus neglecting potential interdependences. In the same vein, the findings in this dissertation strongly suggest that management theories need to advance in a way that allows processes in networks spanning multiple levels to be theorized accordingly. This sentiment echoes the assessment that "[a] richer understanding of the specific resources individual directors bring to a board" (Hillman *et al.*, 2009: 1411) is needed to complement the strategic considerations on the firm level that resource dependence theory focuses on; as well as the call "for theory and research to examine possible differences in network dynamics when the node is a person versus an organization" (Chen *et al.*, 2022: 1638). A second avenue for future research is to make use of the largely untapped potential offered by the compendium of available network models. While SAOMs and ERGMs have seen many applications in the field of management research already, their contemporaries that were presented earlier, REMs, DyNAMs, and ALAAMs, have been used to a far lesser extent. Of these three, DyNAMs appear to be the most potent, given that they can bridge relational states and relational events and thus are able to capture the "ongoing interplay of relational states and relational events that we must more fully understand" (Chen *et al.*, 2022: 1638) to advance our knowledge of how networks evolve over time. Third and last, all empirical studies must subject themselves to the question if their findings can be generalized and, at best, are representative of a larger population than depicted in the sample. Generalizability is an issue that is especially prevalent in network research, as every actor is dependent on all other actors in the network. To complicate things further, the actor compositions in networks regularly change over time, and actors react differently to changes in their surroundings. No matter if these changes are institutional or environmental, how each actor reacts to them potentially influences how other network actors react and vice versa. Some of the findings in this dissertation lead to claims that challenge existing research, such as the claims that research on the dynamics and consequences of networks can often not be treated as separated if one wants to understand the full picture or the claim that neglecting one mode of analysis in two-mode phenomena leads to flawed contributions. They thus offer interesting and important opportunities for replication studies, that take place in other settings and time periods.

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