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Organizational governance of inter-firm resource combinations: The impact of structural embeddedness and vertical resource relatedness

SUNGHO KIM* AND KYUHO JIN**

Abstract

Firms not only combine resources within firm boundaries but tap into, acquire, or consolidate resources outside firm boundaries. Alliances and mergers and acquisitions (M&A) are distinct vehicles for governing inter-firm resource combinations. Prior studies on the governance choice between them have relied on firm- or dyad-level attributes to explicate the choice firms make about the governance. However, any firm or dyad is a micro-structure embedded in networks that shape the flow of information and resources to the focal firm or dyad. In addition, although alliances and mergers and acquisitions involve either horizontal or vertical resource combinations, the vertical dimension of resource relatedness has been largely neglected in prior research. This study examines the impact of structural embeddedness and vertical resource relatedness on governance choice. We find that structural embeddedness is an important driver of governance choice and that a significant portion of resource combinations occurs along the vertical dimension of relatedness.

Keywords: organizational governance, resource combination, structural embeddedness, network cluster, vertical relatedness

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INTRODUCTION

The governance of inter-firm resource combinations is a fundamental issue in management. In order to gain and sustain competitive advantage and growth, firms not only leverage their own resources. They may ally with partner firms to pool and combine resources or engage in mergers and acquisitions (M&A) to consolidate their resource bases and exercise hierarchical control over an integrated entity. Alliance and M&A are two alternative and distinct vehicles for governing inter-firm resource combinations (Wang & Zajac, 2007; Wiklund & Shepherd, 2009; Argyres & Zenger, 2012).

While prior research on governance choice has taken a firm-level perspective (e.g., Villalonga & McGahan, 2005), governance choice is a bilateral decision involving joint value creation and value appropriation (Zajac & Olsen, 1993). Given this notion, recent studies have taken the dyad as the primary unit of analysis and provided further insights into the governance choice for inter-firm resource combinations (Wang & Zajac, 2007; Yang, Lin, & Lin, 2010). For example, it has been shown that dyad-specific knowledge and the resource similarity and complementarity between the firms in a dyad can determine their governance choices (Reuer & Ragozzino, 2011; Yang, Lin, & Peng, 2011; McCann, Reuer, & Lahiri, 2015).

* School of Business, Southern Illinois University, 2128 Founders Hall, Campus Box 1100, Edwardsville, IL 62025, USA
** College of Business Administration, Seoul National University, Daehak-dong, Gwanak-gu, Seoul 151-916, South Korea
Corresponding author: hypergeometric@mensakorea.org

However, any dyad is a micro-structure that is embedded within networks (Granovetter 1973, 1985; Gulati & Gargiulo, 1999). Networks shape the flow of information on the resources, capabilities, and behavior of prospective alliance partners (Gulati, 1999; Baum, Calabrese, & Silverman, 2000; Zaheer & Bell, 2005). Studies have shown that the resources and capabilities that are brought to an alliance are determined by the structure of networks of focal firms involved in the alliance (Zaheer & Venkatraman, 1995; Jones, Hesterly, & Borgatti, 1997; Gnyawali & Madhavan, 2001). Studies also have shown that networks influence alliance formation (Gulati, 1995; Uzzi 1996, 1997) and M&A (Haunschild, 1993; Beckman & Haunschild, 2002). In this regard, dyad attributes that can affect governance choices are shaped, in part, by networks.

Furthermore, dyadic and structural levels are inter-related in terms of the governance mechanisms of value creation and value appropriation in inter-firm resource combinations. For instance, a presence of strong structural embeddedness decreases the need for dyad-level governance (Rowley, Behrens, & Krackhardt, 2000). Besides, networks help to shape dyad-level resource attributes; this is because whole networks in which focal dyads are embedded are conduits of resource flow. In this sense, network embeddedness beyond dyad-level – structural embeddedness – shapes governance choices for inter-firm resource combinations. Thus, a more complete understanding of the governance of inter-firm resource combinations requires a simultaneous consideration of factors at the dyad- and structural-embeddedness levels. An important limitation of previous studies taking the dyad-level approach (e.g., Wang & Zajac, 2007) is their failure to consider such impacts of networks on the dyad, a problem referred to as 'dyadic atomization' (Granovetter, 1992: 33).

In parallel, in explaining the association between dyadic attributes and governance choices, prior studies have primarily considered the horizontal dimension of resource combinations, such as resource similarity, complementarity, and technology distance. What they have neglected, however, is that a non-negligible portion of resource combinations achieved by alliances and M&A are, in part, vertical (Ravenscraft & Long, 2000; Mesquita, Anand, & Brush, 2008). This neglect is understandable in view of the fact that the widely used standard industry classification system is not satisfactory for classifying vertically related businesses (Fan & Lang, 2000). Nonetheless, a significant portion of firm boundary decisions may involve the vertical dimension (Rothaermel, Hitt, & Jobe, 2006). Thus, any explanation of governance choice in relation to dyadic resource attributes would be incomplete without considering the vertical dimension.

The purpose of this study is to examine the impact of structural embeddedness and vertical relatedness on inter-firm resource combinations and the associated governance choice. In so doing, we further our understanding of governance choice by using a new operationalization of structural embeddedness called 'network cluster co-location' based on the Markov clustering algorithm (van Dongen, 2000, 2008). We also introduce a new dimension along which a dyadic resource configuration can be conceptualized: vertical relatedness (Fan & Lang, 2000).

The remainder of this paper proceeds as follows. We discuss theoretical background on the governance choice between alliances and M&A and on the relationship between governance choices and networks. Theories and hypotheses are then developed regarding the impact of vertical relatedness and structural embeddedness on governance choice. We outline how to test the developed hypotheses using data on strategic alliances and M&A from the computer industry. The methodologies and data set that were used for empirical analysis are explained. Finally, the implications of this study for the organizational governance literature are discussed.

THEORY AND HYPOTHESES

Organizational governance and inter-firm networks

One of the key concerns of organizational governance is discriminating alignment, that is, aligning exchange conditions with governance alternatives (Williamson, 1979, 1991; Barney, 1999; Leiblein, 2003;

Nickerson, Yen, & Mahoney, 2012). From an efficiency perspective of organizational governance, a transaction should be organized by a governance form that economizes on transaction costs (Mahoney, 1992; Nickerson & Silverman, 2003). The choice of governance also affects the value created and appropriated from focal transactions and the locus of resource accumulation (Barney, 1999; Argyres & Zenger, 2012). The discriminating alignment perspective posits that optimal governance form varies according to exchange conditions and is affected by firm- and dyad-level factors like asset specificity, resources, and capabilities (Klein, Crawford, & Alchian, 1978; Barney & Ouchi, 1986; Miller & Leiblein, 2003). Governance choice has been examined in the contexts of the choices between make and buy (Walker & Weber, 1984; Masten, Meehan, & Snyder, 1991; Leiblein, Reuer, & Dalsace, 2002), between vertical integration and vertical contracting[1] (Villalonga & McGahan, 2005), between alliances and M&A (Hennart & Reddy, 1997; Dyer, Kale, & Singh, 2003; Wang & Zajac, 2007), and within the continuous spectrum of hierarchical control (Villalonga & McGahan, 2005).

Among the governance alternatives, alliances and M&A in particular, involve inter-firm resource combinations. Alliance and M&A are two alternative and distinct modes of governing inter-firm resource combinations (Dyer, Kale, & Singh, 2003; Wang & Zajac, 2007; Argyres & Zenger, 2012). Through strategic alliance, a focal firm may tap into its partner firms' resources and capabilities (Stuart, Hoang, & Hybels, 1999). Strategic alliances allow firms to augment and recombine internal and external resources and capabilities (Carayannopoulos & Auster, 2010; Rice, Liao, Martin, & Galvin, 2012). Furthermore, through alliances, firms may pool resources together, develop relation-specific capabilities (Dyer & Singh, 1998; Mesquita, Anand, & Brush, 2008), learn from each other (Hamel, 1991; Mowery, Oxley, & Silverman, 1996), or assimilate technological resources and implement breakthrough innovation (Srivastava & Gnyawali, 2011). Through M&A, an acquiring firm or a party with a control right can exercise hierarchical control over the resources of a combined entity. Post-merger integration involves consolidation, divestiture, or redeployment of the resources of acquiring and target firms (Anand & Singh, 1997; Capron & Hulland, 1999; Capron, Mitchell, & Swaminathan, 2001).

The choice between the two alternatives has been examined from multiple theoretical perspectives as well. Prior studies suggest that the two governance forms have different abilities to mitigate opportunism (Williamson, 1991) and to manage market or technological uncertainties (Folta & Miller, 2002; Nickerson & Silverman, 2003). They have different potentials for realizing synergies through redundancy elimination and the exploitation of complementary resources and capabilities (Jensen & Ruback, 1983; Dutz, 1989; Seth, 1990; Hoskisson, Johnson, & Moesel, 1994; Wiklund & Shepherd, 2009). Alliances and M&A present differential constraints and opportunities for future corporate growth (Lockett, Wiklund, Davidsson, & Girma, 2011).

Whereas the governance choice between alliances and M&A has been examined primarily at the firm- or dyad- level (Zajac & Olsen, 1993; Villalonga & McGahan, 2005; Wang & Zajac, 2007), any firm or dyad is a micro-structure that is embedded within networks (Granovetter, 1973; Gulati & Gargiulo, 1999). In addition, studies taking the dyad as a unit of analysis are often exposed to the problem of 'dyadic atomization' (Granovetter, 1992: 33). An economic sociology perspective of networks suggests that networks affect the governance of inter-firm resource combinations, that is, the choice between alliances and M&A. Inter-firm networks are conduits of information and resources among firms (Baker, 1990; Burt, 1992). From the networks, firms seek and acquire information on the capabilities and behavior of their current and prospective partners in exchanges (Granovetter, 1985; Coleman, 1988; Zaheer & Venkatraman, 1995; Gulati, 1999; Baum, Calabrese, & Silverman, 2000; Zaheer & Bell, 2005). Networks shape the behavior of the firms that are embedded in them

[1] Vertical contracting refers to a contractual relationship or other types of non-equity strategic alliances along value chains, as opposed to hierarchical control through vertical integration or vertical financial ownership (Mahoney, 1992).

(Gulati, 1998), including influencing alliance partner selection (Gulati, 1995; Uzzi, 1996, 1997) and the selection of target firms (Haunschild, 1993; Beckman & Haunschild, 2002).

To the extent that the governance of value creation and value appropriation within inter-firm resource combinations is concerned, the dyadic and structural network levels are interrelated. For instance, the presence of structural embeddedness decreases the need for dyad-level governance (Rowley, Behrens, & Krackhardt, 2000). When two unconnected firms share a common third party, the third party may relay information on the capabilities and behavior of one firm to the other, which can reduce information asymmetry and behavioral uncertainty in partner selection (Granovetter, 1992; Jones, Hesterly, & Borgatti, 1997; Gulati & Gargiulo, 1999; Baum, Shipilov, & Rowley, 2003; Burt, 2005). Such structural-level governance, in turn, leads to less need for relational governance like trust and reciprocity norms. In addition to shared third parties as a form of structural level governance, other structural embeddedness, such as network clustering and dense networks, can substitute, to some degree, for relational embeddedness (Rowley, Behrens, & Krackhardt, 2000). In addition, dyad-level resource attributes such as resource similarity can be affected by networks precisely because the whole network to which each firm in a focal dyad is embedded are conduits of resource flow. For example, studies have shown that networks affect the resources and capabilities that partners bring to an alliance (Zaheer & Venkatraman, 1995; Jones, Hesterly, & Borgatti, 1997; Gnyawali & Madhavan, 2001; Martin-Rios, 2014). It is likely that the resource similarity of a dyad increases if its firms take adjacent positions in a whole network. This is because the firms in a dyad are likely to have access to similar network resources.

In all, structural network embeddedness substitutes or complements the dyad-level mechanisms of governance. Thus, a better understanding of the governance of inter-firm resource combinations necessitates a consideration of the dyad-level drivers of governance in conjunction with those at the structural-embeddedness level. Whereas some organizational governance literature has recently been developed on the choice between alliances and M&A, the impact of networks on governance choice has been largely ignored, with a few exceptions[2]. In particular, among three kinds of network embeddedness (Gulati & Gargiulo, 1999) that have distinct mechanisms for affecting governance choice – relational, structural, and positional embeddedness – structural embeddedness has been largely neglected.

Resource similarity and governance choice

Resource-based view suggests that the resource similarity between firms is a determinant of organizational governance choice. Prior literature has suggested that resource similarity between potential partners increases the likelihood of M&A being chosen over alliances (Tanriverdi & Venkatraman, 2005; Wang & Zajac, 2007); this occurs for the following reasons. First, the magnitude of synergy in resource combinations is a function of the resource similarity between firms. The extent of redundancies is proportional to the degree of similarity between the resource stocks to be combined (Wernerfelt, 1984; Dussauge, Garrette, & Mitchell, 2000). By pooling similar resources, redundancy can be eliminated, leading to efficiency enhancement (e.g., Jensen & Ruback, 1983; Dutz 1989; Seth, 1990; Hoskisson, Johnson, & Moesel, 1994; Anand & Singh, 1997). While both alliances and M&A provide the opportunity for firms to eliminate this redundancy by pooling similar resources, they do differ in their ability to allow this to occur. Alliances provide the involved parties with access to the pooled resource stocks without full ownership. In contrast, M&A offer the acquiring firm not only access to, but also controlling rights over combined resource stocks. Since M&A are better than alliances at reducing resource redundancy, M&A will be favored over alliances as a means of improving efficiency through resource rationalization.

[2] Exceptions are Lin, Peng, Yang, and Sun (2009) and Yang, Lin, and Lin (2010). These studies are discussed in relation to our findings in the discussion section.

Second, when firms are more similar in their resources, markets, or distribution channels, the extent of competition between them increases (Hannan & Freeman, 1977). Thus, an alliance between similar firms is expected to escalate competition rather than promote cooperation between them. In contrast, M&A eliminate this potential competitive tension since the acquiring firm secures the control rights over the acquired or combined entity. Third, resource similarity between the potential partners alleviates the information asymmetry problem; both firms are able to accurately evaluate their partners' resources and capabilities (e.g., Gadde, Hjelmgren, & Skarp, 2012). Information asymmetry poses a greater risk to M&A because M&A involve irreversible commitments and are thus less flexible. In this vein, alliances are regarded as a real option or an intermediate stepping stone toward M&A for the purpose of reducing uncertainty about potential partners and maintaining a necessary level of strategic flexibility (Kogut, 1991). Thus, resource similarity may increase the likelihood of M&A being selected to a larger extent.

Taking all of this into consideration, we hypothesize that:

Hypothesis 1: The higher the degree of resource similarity between two focal firms, the more likely it is that M&A governance will be chosen over alliance governance.

Vertical relatedness and governance choice

It is worthwhile to note that, conceptually, resource similarity does not allow for the vertical dimension of resource combination. Thus, any consideration of resource combination is incomplete without considering this vertical dimension. A non-negligible portion of the resource combinations that are achieved by alliances and acquisitions are vertical or span vertical chains (Ravenscraft & Long, 2000; Rothaermel, Hitt, & Jobe, 2006; Mesquita, Anand, & Brush, 2008). In order to factor this vertical dimension into the argument, we introduce *vertical relatedness* between the potential partners as a determinant of their governance choice. Vertical relatedness indicates the extent to which 'one can employ the other's products or services as input for its own production or supply output as the other's input' (Fan & Lang, 2000: 630). If potential partners are vertically related, they can easily extend their activities backward or forward along the value chain, typically via vertical integration.

We maintain that vertical relatedness between potential partners increases the chance of M&A being selected over alliance for two reasons. First, in alignment with the foregoing logic concerning resource similarity, if the potential partners are less vertically related, they are less familiar with each other's business. The resulting information asymmetry may interfere with successful integration, once again rendering strategic alliances the more attractive mode of collaboration. Second, while vertically adjacent and interdependent activities offer an appealing venue for capability development (Rothaermel, Hitt, & Jobe, 2006), this necessitates strong, hierarchical organizational controls to manage the interdependence between vertically related activities (Gulati & Singh, 1998) and to mitigate the opportunistic behavior of the parties in an exchange (Teece, 1986). A good example of this is systemic innovation, an increasingly important mode of innovation within the computer industry, which is our empirical setting. Systemic innovation is known to generate novel capabilities and economic values by integrating vertically contiguous, interconnected activities through extensive collaboration and coordination efforts (Kapoor, 2013). Furthermore, innovations that are made through the collaboration of vertically adjacent firms usually require an investment in co-specialized assets (e.g., Buvik & Reve, 2001). Whereas such co-specialization runs the risk of the hold-up problem (Williamson, 1979; Teece, 1986), vertical integration effectively mitigates this through hierarchy (Rothaermel, Hitt, & Jobe, 2006; Kapoor, 2013). It should be noted that only potential partners that are vertically-related can consider integrating vertically adjacent activities as a feasible option. Accordingly, vertically-related

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partners would choose M&A rather than a strategic alliance to realize this opportunity of capability development. Taking this into account, we hypothesize that:

Hypothesis 2: The higher the degree of vertical relatedness between two focal firms, the more likely it is that they will choose M&A governance over alliance governance.

Structural embeddedness, network clusters and governance choice

As discussed in the foregoing sections, both alliances and M&A involve a non-trivial amount of risks and uncertainties regarding potential partners, albeit to a different degree. Thus, reducing partnering hazards of this kind is an imperative rather than an option. We also argue that resource similarity and vertical relatedness act to alleviate such hazards, increasing the relative attractiveness of M&A. In connection to this, we turn our attention from dyadic resource conditions to the networks in which the dyads are embedded and the structural embeddedness derived therein.

The literature classifies network embeddedness into three conceptually distinct categories (Gulati & Gargiulo, 1999). One is relational embeddedness, which centers on dyadic cohesiveness. Cohesive ties and the attendant repeated interactions serve as an information conduit 'through which each partner can learn about the competencies and the reliabilities of the other' (Gulati & Gargiulo, 1999: 1446). Among others, such dyadic cohesiveness cultivates mutual trust and alleviates the behavioral uncertainties of the partners (Uzzi, 1997), thereby reducing the need for formal governance devices (Jones, Hesterly, & Borgatti, 1997; Rowley, Behrens, & Krackhardt, 2000). Another category is positional embeddedness, which concerns positions in the global network and relates to centrality and status. Actors occupying central positions in the global network are highly visible (Wasserman & Faust, 1994) and given prestige or status through social construction processes (Podolny, 1993); central positions send a signal about their quality as a potential partner to market participants (Gould, 2002; Podolny, 1993). From this viewpoint, positional embeddedness also serves as a mechanism for mitigating partnering hazards, especially under conditions of market uncertainty (Podolny, 1993).

Between these two categories of network embeddedness lies structural embeddedness, which is our central focus. Here, the frame of reference shifts from dyads and global networks to subgroups or clusters, the region in which connections among actors are denser than in other regions of networks (Wasserman & Faust, 1994)[3]. Similar to the other two types of embeddedness, structural embeddedness alleviates partnering hazards. Yet, it does so in a conceptually different manner. First, it delimits the boundaries of information flow (Baum, Shipilov, & Rowley, 2003; Burt, 2005; Rowley et al., 2005). Just as information on promising investment opportunities circulates within industry and geographical clusters, information on the partners is relayed, shared, and communicated only within the subgroups or network clusters; in effect, information in the network clusters is sealed off so that actors outside of the cluster are less able to get access to it. Second, the information shared among members within the subgroups or clusters serves as a platform for social control or network governance through reputational mechanisms (Jones, Hesterly, & Borgatti, 1997; Burt, 2005). Any assessment of a certain actor's behavior spreads quickly within the region, and any misbehavior is easily detected and sanctioned (Jones, Hesterly, & Borgatti, 1997; Burt, 2005). Arguably, then, the partnering risk will decrease when potential partners are structurally embedded or located in the same network cluster; this is because information on potential partners' capabilities and reliability is readily available *ex ante*, while collective sanctions are applicable *ex post*.

[3] In this regard, network-clusters are a kind of meso-level construct that links dyads with global networks (Rowley, Greve, Rao, Baum, & Shipilov, 2005).

The above discussion suggests the possibility that structural embeddedness impinges on governance choice. Given that M&A are economically less reversible than alliances, they normally incur greater costs than alliances when an exchange partner turns out to be opportunistic or has no sought-after resources and competencies (Folta, 1998; Leiblein & Miller, 2003; Villalonga & McGahan, 2005); M&A are generally less attractive than alliances when partnering hazards are substantial. However, structural embeddedness can reduce such hazards in the ways that have been discussed and thereby increase the relative attractiveness of M&A. Therefore, we hypothesize that:

Hypothesis 3: Structural embeddedness increases the probability that M&A governance is chosen over alliance governance.

METHODS

Sample

Two sets of archival databases were used in this study. The SDC Platinum database was used to construct inter-firm networks. Both alliances and M&A databases were included in samples used for constructing inter-firm networks and for statistical analysis. Well-known for its comprehensiveness, the SDC database of alliances and M&A incorporates information from a wide range of sources: many domestic and global news sources; SEC filings and their international counterparts; and the trade publications, wires, and proprietary surveys of investment banks, law firms, and other advisors. The widespread use of the SDC database in studies on M&A across disciplines suggests that its scheme for sampling M&A transactions is appropriate for statistical inference of population properties (e.g., Hayward & Hambrick, 1997; Reuer & Ragozzino, 2011; Erel, Liao, & Weisbach, 2012; Haleblian, McNamara, Kolev, & Dykes, 2012). Moreover, it has been verified that the alliance sample from the SDC database represents its population well, without introducing systematic bias, even if it does not cover all alliance transactions (see Schilling, 2009). For accounting and financial data, the COMPUSTAT database was used.

Both hardware and software firms in the computer industry were selected for this study[4]. The industry is ideal for testing our theory for two reasons. First, its firms must collaborate with others to combine resources in a synergistic manner in constantly and rapidly changing environment marked by strong pressure to continuously innovate (Rosenkopf & Schilling, 2007). Unsurprisingly, they routinely use alliances and M&A to accomplish this aim, thereby presenting a fertile field in which to test the resource combination argument (e.g., Yang, Lin, & Lin, 2010; Yang, Lin, & Peng, 2011). Such extensive use of alliances and M&A results in well-connected industry networks, enabling testing of theories that draw on social networks (e.g., Fleming & Marx, 2006; Schilling & Phelps, 2007; Yang, Lin, & Lin, 2010).

This study considers data on governance choices and financial information for each year between 1990 and 2010 and between 1989 and 2009, respectively. Two different time periods were chosen because 1-year lagged values were used for financial control variables. This 1-year lag takes into account the recording interval of financial statements (Zaheer, Albert, & Zaheer, 1999), that is, the fact that accounting data is updated on a fiscal-year basis and takes up to 1 year to be generated.

The sample selection process was as follows. To ensure a complete availability of financial information on the sample firms[5], the selection of sample entries began with the COMPUSTAT database. Only the records that included complete information on control variables and belonged to public firms in the United States were selected. As a result, the panel of COMPUSTAT entries in the given industry consisted of a total of 21,055 firm-year observations and 2,318 firm entries over the specified period. Next, consistently with other studies involving inter-firm networks (e.g., Gulati, 1995; Rowley,

[4] SIC codes: 3571, 3572, 3573, 3577, 7371, 7372, 7373, 7374, and 7375 (Yang, Lin, & Lin 2010).

[5] This relates to the rank condition required for the estimation of regression models.

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Behrens, & Krackhardt, 2000; Stuart, 2000), the transactions were selected according to the criteria that both parties to a transaction be members of the computer industry and have had at least one strategic alliance or M&A transaction with another industry member. In addition, for M&A transactions, only the transactions that entailed changes in control right were included in our sample. The change in control right was operationalized by two criteria: that the firm had a <50% ownership stake before M&A transaction, but majority ownership after the transaction. Selected M&A transactions were then matched with the COMPUSTAT entries in the same industry.

This sampling procedure resulted in 654 transactions in total (473 for alliances and 181 for M&A, respectively). Given that 21 dyads appeared more than once (i.e., 633 dyads of 654 transactions were unique), we reported robust standard errors to address potential inefficiency stemming from the correlated errors[6].

Measurements

Dependent variable

Governance choice. Given that the governance decision between alliances and M&A is this study's central concern, we operationalized the dependent variable as a binary variable (0 = alliance, 1 = M&A).

Independent variables

Resource similarity. Prior studies have measured resource similarity on the basis of Standard Industrial Classification (SIC) codes (e.g., Wang & Zajac, 2007)[7]. Specifically, they have assigned resource similarity values to two focal firms, reaching a value of 1 when the first four digits of the two focal firms' SIC codes were equal, 0.75 when the first three digits of the two focal firms' SIC codes were equal, 0.5 when the first two digits of the two focal firms' SIC codes were equal, 0.25 when the first digit of the two focal firms' SIC codes was equal, and 0 when the first digit of the two focal firms' SIC codes was not equal. This operationalization[8], however, suffers from the drawback of being grounded in a strong, arbitrary assumption that two, three, and four SIC digit levels of classification can be used as *invariable* reference points on an underlying scale of resource similarity[9] (Robins & Wiersema, 1995).

To relax this strong assumption, we used an advanced measure of resource similarity proposed by Fan and Lang (2000) and Robins and Wiersema (1995). We first collected the 2007 data of the US industry input-output matrix at the four SIC digit level from the Bureau of Economic Analysis[10]. Then, we calculated the matrix of structural equivalence (White, Boorman, & Breiger 1976; Faust, 1988) through the algorithm CONCOR[11] (Borgatti, Everett, & Freeman, 2002). Wasserman and Faust (1994) and others define each element of this as

$$r_{ij}=\frac{\sum(x_{ki}-\bar{x}_{\bullet i})(x_{kj}-\bar{x}_{\bullet j})+\sum(x_{ik}-\bar{x}_{i\bullet})(x_{jk}-\bar{x}_{j\bullet})}{\sqrt{\sum(x_{ki}-\bar{x}_{\bullet i})^2+\sum(x_{ik}-\bar{x}_{i\bullet})^2}\sqrt{\sum(x_{kj}-\bar{x}_{\bullet j})^2+\sum(x_{jk}-\bar{x}_{j\bullet})^2}}$$

where all the sums are over k.

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6 For this, we used the sandwich estimator. We also tried the cluster robust estimator and found the similar pattern.

7 Wang and Zajac (2007) employ the North American Industrial Classification System instead of SIC codes.

8 In this connection, this operationalization shares much with the concentric index (Robins & Wiersema, 1995).

9 This is often called an equidistance assumption.

10 http://www.bea.gov/industry/index.htm

11 Thus, the relatedness matrix is a symmetric correlation matrix, each element of which is bounded between −1 and 1, inclusive.

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Clearly, then, each element of this matrix reflects correlations between the two industries in terms of their input and output relations or exchange patterns and is bounded between −1 and 1. Arguably, this relational similarity is closely connected to resource similarity, in that the economic activities that underlie transactions typically involve the accumulation and transfer of resources. For instance, if two industries have similar input/output relational profiles, then their inputs can be jointly procured, and the marketing and distribution channels for their outputs can be shared (Fan & Lang, 2000).

Vertical relatedness. We used Fan and Lang's (2000) measure of vertical relatedness, which is also based on the industry input-output matrix. We first calculated a matrix of inter-industry vertical relatedness at the four SIC digit level[12]. Each element of this matrix was operationalized as

$$V_{ij}=\frac{v_{ij}+v_{ji}}{2}$$

where the dollar value of industry *i*'s output required to produce industry *j*'s total output is divided by the dollar value of industry *j*'s total output.

Stated differently, this implies 'the dollar value of industry *i*'s output required to produce 1 dollar's worth of industry *j*'s output' (Fan & Lang, 2000: 633). Intuitively, this measure can be interpreted as the possibility of two industries being vertically integrated. The value of a dyad's vertical relatedness is chosen from this matrix on the basis of the two focal firms' industries.

Structural embeddedness. There are several ways to operationalize structural embeddedness. These include measuring ego-network density (Rowley, Behrens, & Krackhardt, 2000), the number of common third parties (Gulati & Gargiulo, 1999), joint-brokerage position (Yang, Lin, & Peng, 2011), and cliques (Rowley, Baum, Shipilov, Greve, & Rao, 2004). However, ego-network density, the number of common third parties, and joint-brokerage position are highly egocentric and consider only up to triads, making them less reflective of networks that extend beyond two-step distant ties. On the other hand, cliques are too restrictive and too sensitive to changes in node degrees to be an accurate measure of structural embeddedness (Wasserman & Faust, 1994). While some studies use *n*-Clan (e.g., Rowley, Greve, Rao, Baum, & Shipilov 2005), the choice of *n* is unavoidably arbitrary. To address these issues, we chose to use the identification method of the Markov Clustering Algorithm (van Dongen, 2000, 2008), which identifies non-overlapping network clusters by taking account of global networks. By using the Markov chain of transition matrix that is derived from the adjacency matrix, and by employing the iterative procedures of matrix expansion and inflation, this algorithm identifies clusters within which information is likely to stay and between which it is unlikely to travel[13,14]. Specifically, we first identified network clusters in our adjacency matrices on the basis of Markov Clustering Algorithm. For this, we used UCINET 6.359 (Borgatti, Everett, & Freeman, 2002). According to the results, there were 53 non-overlapping clusters during our sample period. We then created a dummy variable that is set to 1 when the two firms in a dyad are located in the same network cluster and is otherwise set to 0.

Control variables

Following prior literature on dyadic analysis, we inserted control variables to exclude possible alternative explanations. We controlled for relative size, given that it influences the choice between alliances and M&A (Gulati, 1995; Seth, Song, & Pettit, 2000; Wang & Zajac, 2007). The literature suggests that size differences increase the probability of M&A being selected over alliance (Hennart & Reddy, 1997; Hennart & Reddy, 2000). We operationalized relative size as the total assets of the larger firm

[12] Given that our sample consists of nine different industries at the SIC four-digit level and that this matrix is symmetric, it suffices to calculate only $36({}_9C_2)$ elements of the matrix.

[13] This algorithm was devised to partition a graph (van Dongen, 2000, 2008).

[14] The optimal number of network clusters is determined by the graph's topological properties.

divided by those of the smaller firm in a dyad (Gulati & Gargiulo, 1999). We also controlled for relative slack because firms with slack resources may prefer M&A (Tan & Peng, 2003; Lin et al., 2009). We also controlled for relative firm performance, since it may affect the governance of inter-firm interdependence and cooperation (Gulati, 1995). We operationalized relative firm performance using the measure of return on asset (ROA). Since ROA could take negative values, we used the exponential ROA values to calculate the absolute value of the difference between the two firms' transformed ROAs as a proportion of the sum of the two firms' transformed ROAs (Wang & Zajac, 2007). Because *relative solvency* can affect the degree of complementarity between two focal firms' businesses, we also controlled for this variable (Gulati & Gargiulo, 1999). We operationalized relative solvency as the absolute value of the difference between two firms' ratios of long-term debt to total assets. For these financial control variables, 1-year lagged values were used to allow for the recording interval of financial statements that can get as long as 1 year (Zaheer, Albert, & Zaheer, 1999)[15].

We also controlled for the prior alliance experience of firms in a dyad (Gulati & Gargiulo, 1999). We counted the number of alliances that each firm in a given dyad had entered in the previous 5 years and summed the numbers for that dyad. We likewise controlled for the prior M&A experience of firms in a dyad in order to account for the organization-specific learning effects of M&A experiences. We counted the number of M&A that each firm in a dyad had been involved with during the previous 5 years and summed those numbers. We also controlled for alliance history to account for dyad-specific effects associated with trust, information asymmetry, and relational routines (Gulati, 1995a, 1995b; Gulati & Singh, 1998). We operationalized this variable as the total number of alliances that the firms in a dyad had forged in the previous 5 years. Finally, to control for the unobserved yearly effects on governance choice of macroeconomic shocks and environmental changes, we included year dummies.

Estimation technique

Given that our dependent variable is binary, we chose to use the probit model. This model addresses the shortcomings of the linear probability model by using the standard normal distribution function to ensure that the dependent variable is bounded between 0 and 1 (Greene, 2012):

$$Pr(y_i = 1) = \Phi(x_i b)$$

here $\Phi()$ is the cumulative distribution function of a standard normal random variable, while x_i is a vector of covariates and b is the vector of their parameters.

One drawback of this model, however, is that parameter estimates could be less efficient, inasmuch as the variance of the probability distribution is assumed to be fixed at 1 irrespective of the heterogeneity of the observations (Williams, 2010; Greene, 2012). For the sake of robustness and to address the potential efficiency loss, we additionally ran the heteroscedastic probit regression, a generalization of the probit model in which the variance of the error term is modeled as a multiplicative function of appropriately chosen variables:

$$Pr(y_i = 1) = \Phi\left\{\frac{x_i b}{exp(z_i \gamma)}\right\}$$

here $\Phi()$ is the cumulative distribution function of a standard normal random variable, while x_i is a vector of covariates, b is a vector of their parameters, and z_i and γ are vectors of the chosen variables and their parameters, respectively. To control for heteroscedasticity, we have reported robust standard errors. For estimation, we used the *probit* and *hetprob* command in STATA 11 (StataCorp, 2009).

[15] In this sense, accounting data is backward-looking (Demsetz & Villalonga, 2001).

In addition, given that our sample consists only of dyads in which both firms possess all necessary financial information, concern about sample selection bias naturally arises[16]. We addressed it by using the two-step econometric treatment recommended by Heckman (1979). In the first-stage probit model, we estimated the probability that at least one firm in a dyad has at least one missing value as a function of the sales difference between the two firms in the dyad and year dummies[17]. The reason for choosing these variables is that the probability increases when a firm makes too few sales and confronts unfavorable macroeconomic conditions. After confirming that each first-stage model achieved a sufficient model fit, we computed the inverse Mills ratio from the results. Because this ratio is generally correlated with the unobserved portion from sample selection bias in the residual in the second-stage model, we re-estimated each of our models after inserting the inverse Mills ratio as a control variable.

RESULTS

Table 1 presents the descriptive statistics and correlations for all variables used in the analysis. Although every correlation appears modest, we calculated and examined variance inflation factors (VIFs) and condition numbers for all of the models. The VIF tests (mean VIF = 1.94, maximum VIF = 5.30) confirmed that collinearity was not an issue.

Table 2 presents the results for probit and heteroscedastic probit estimates for governance choice. Models 1 to 4 report probit estimates, and models 5–8 report heteroscedastic probit estimates. Notably, the χ^2 tests in models 5–8 strongly reject the null hypothesis that the probability distribution had a fixed variance of 1 at $p < .01$. This suggests that the traditional probit estimates are likely less efficient. Models 1 and 5 present a baseline model that includes only control variables. Consistent with our expectations, prior alliance experience increased the chance of alliance being selected, whereas prior M&A experience increased the chance of M&A being selected. Interestingly, the effect of alliance history was positive, though not significant.

This implies that acquirers choose an alliance with the target firm as a prelude to possible acquisition in order to reduce the information uncertainty about the firm. It is noteworthy that the inverse Mills ratio is consistently significant at $p < .05$ in all models except model 5, implying the existence of sample selection bias. The negative coefficients suggest that the observations omitted from our sample because of the missing values tend, ceteris paribus, to choose alliance over M&A.

Hypothesis 1 states that resource similarity increases the probability that M&A will be selected over alliance. Since the coefficients were positive and significant in model 6 ($p < .01$), the results provide partial support for this hypothesis. As detailed in the methods section, the fact that the coefficient was not significant in model 2 but significant in model 6 implies that probit estimates can be less efficient. Remarkably, in the rest of the models in which vertical relatedness was also inserted, the effect sizes of the coefficients non-negligibly decreased. Hypothesis 2 argues that vertical relatedness increases the probability of M&A being selected over alliance. The results show that these coefficients are positive and highly significant in models 3 and 7 ($p < .01$); therefore, we find strong support for this hypothesis. Of particular note here is the fact that, set alongside the results of resource similarity above, these results suggest that a non-trivial portion of variance in resource similarity comes from vertical relatedness.

Hypothesis 3 maintains that structural embeddedness measured as network cluster co-location increases the probability of M&A being chosen over alliance. Structural embeddedness is insignificant in model 4, but significant in model 8 ($p < .10$), providing partial support for this hypothesis. Again, though, this is no surprise in view of the fact that the probit estimates suffer from inefficiency in our

[16] We thank an anonymous referee for pointing this out.

[17] All the observations in the initial sample have sales data, whereas most missing values are found in ROA.

Table 1. Descriptive statistics and correlation matrix[a]

	Mean	*SD*	*Min*	*Max*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1. Governance choice	0.28	0.45	0	1										
2. Relative size	0.24	0.27	0	1	−0.01									
3. Relative ROA	0.12	0.14	0	0.97	−0.09	−0.12								
4. Relative slack	2.09	2.75	0	27.82	−0.06	0.01	0.02							
5. Relative solvency	0.17	0.41	0	5.88	0.06	0.01	0.04	−0.04						
6. Prior alliance experience (combined)	6.42	8.12	0	50	−0.24	−0.26	−0.04	−0.07	−0.04					
7. Prior M&A experience (combined)	0.69	1.26	0	9	0.08	−0.16	−0.12	−0.13	0.00	0.31				
8. Alliance history	0.05	0.3	0	4	−0.04	−0.03	−0.04	−0.05	0.00	0.29	0.03			
9. Resource similarity	0.83	0.24	0	1	0.10	0.18	−0.01	−0.01	0.00	−0.25	−0.19	−0.12		
10. Vertical relatedness	0.04	0.16	0	0.87	0.17	−0.04	−0.10	−0.02	0.03	−0.07	0.06	−0.02	0.16	
11. Structural embeddedness	0.04	0.2	0	1	0.00	0.11	−0.05	−0.08	0.01	0.20	0.06	0.27	0.03	−0.05

Notes. M&A = mergers and acquisitions; ROA = return on asset.

[a]Correlations of |0.077| or greater significant at $p < .05$ and correlations of |0.100| or greater are significant at $p < .01$.

Table 2. Probit and heteroscedastic probit estimates[a,b]

	Probit estimates				*Heteroscedastic probit estimates*			
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Relative size	−0.839 (0.278)**	−0.828 (0.276)**	−0.834 (0.275)**	−0.867 (0.276)**	−0.569 (0.267)*	−0.662 (0.270)*	−0.593 (0.272)*	−0.665 (0.275)*
Relative ROA	−0.931 (0.518) +	−0.889 (0.520) +	−0.755 (0.514)	−0.744 (0.514)	−1.288 (0.611)*	−1.285 (0.611)*	−1.109 (0.605) +	−1.140 (0.607) +
Relative slack	−0.040 (0.025)	−0.036 (0.025)	−0.034 (0.024)	−0.032 (0.024)	−0.030 (0.027)	−0.025 (0.029)	−0.021 (0.028)	−0.016 (0.028)
Relative solvency	0.075 (0.142)	0.079 (0.136)	0.062 (0.137)	0.060 (0.138)	0.084 (0.143)	0.088 (0.138)	0.069 (0.138)	0.070 (0.138)
Prior alliance experience (combined)	−0.063 (0.014)***	−0.063 (0.015)***	−0.058 (0.015)***	−0.059 (0.015)***	−0.195 (0.054)***	−0.193 (0.055)***	−0.192 (0.057)***	−0.210 (0.058)***
Prior M&A experience (combined)	0.158 (0.050)**	0.171 (0.050)***	0.166 (0.051)**	0.165 (0.051)**	0.275 (0.086)**	0.310 (0.088)***	0.301 (0.091)***	0.320 (0.093)***
Alliance history	0.310 (0.193)	0.348 (0.197) +	0.322 (0.194) +	0.237 (0.201)	0.818 (0.467) +	0.911 (0.493) +	0.900 (0.495) +	0.632 (0.487)
Inverse Mills ratio	−4.461 (1.704)**	−3.877 (1.748)*	−4.776 (1.720)**	−4.726 (1.716)**	−0.307 (0.280)	−0.780 (0.354)*	−0.781 (0.354)*	−0.737 (0.359)*
Resource similarity		0.413 (0.286)	0.269 (0.288)	0.260 (0.289)		0.656 (0.326)*	0.540 (0.329)	0.533 (0.332)
Vertical relatedness			1.041 (0.343)**	1.063 (0.344)**			1.075 (0.392)**	1.126 (0.398)**
Structural embeddedness (network cluster co-location)				0.362 (0.282)				0.842 (0.465) +
Observations	654	654	654	654	654	654	654	654
χ^2 statistic	93.09***	94.34***	107.5***	108.3***	89.41***	88.77***	92.70***	92.59***
χ^2 statistic for heteroscedasticity					8.957**	8.827**	8.498**	10.43**

Notes. M&A = mergers and acquisitions; ROA = return on asset.
[a]Standard errors in parentheses.
[b]Year dummies included but not reported.
****p* < .001; ***p* < .01; **p* < .05; + *p* < .1.

sample (as statistically confirmed above). In other words, the insignificant findings in model 4 may have come about due to the low statistical power of the traditional probit model.

Prior studies call for caution when interpreting the coefficient estimates of non-linear models (Hoetker, 2007; Wooldridge, 2010; Greene, 2012). While we are generally interested in the marginal effects of the focal variables, the coefficient estimates do not necessarily represent marginal effects; more precisely, the marginal effects are determined not only by the estimated coefficients, but also by the covariates (Greene, 2012: 736–739). The best practice is to additionally report the average partial effects calculated by aggregating all of the individual marginal effects (Hoetker, 2007; Wooldridge, 2010; Greene, 2012). The average partial effects in this data set are presented in Table 3. The overall pattern remains similar. In conclusion, a non-trivial portion of resource similarity variance comes from vertical relatedness, therefore adding precision to our understanding of how the resource profiles of two focal firms can shape their governance choice.

DISCUSSION

This research was motivated by an observation that the intersection of network literature in management and organizational governance literature is remarkably underexplored. Although many studies have shed light on the impact of inter-firm networks on alliance formation, extant literature does not provide answers to the association between network embeddedness and heterogeneity in governance or the choice that firms make between alliances and M&A to govern resource combinations across firm boundaries. This study uses a structural embeddedness perspective to disentangle the heterogeneity in governance choices.

In particular, this study advances our understanding of governance choice by shedding light on how it is affected by network embeddedness and, specifically structural embeddedness. Prior literature on governance choice has revolved around dyadic conditions, paying little attention to the networks within which the dyads were embedded (e.g., Wang & Zajac, 2007). From a network embeddedness standpoint, the literature's attention has been limited to relational embeddedness at best. Two other types of embeddedness have been largely neglected: structural and positional embeddedness (Gulati & Gargiulo, 1999). In other words, there has been a concern about dyadic atomization (Granovetter, 1992), that is, neglect of the implications of the fact that any dyad is a micro structure embedded in a network. Recently, Yang, Lin, and Lin (2010) attempted to examine how governance choice is shaped by status, one measure of positional embeddedness, and its differential between two focal firms. However, no research that we are aware of has systematically considered how structural embeddedness regulates governance choice.

This study fills the void by drawing attention to the fact that structural embeddedness delimits the boundary of information circulation within subgroups or network clusters, also showing that it serves as a foundation for social control or network governance through reputational sanction (Jones, Hesterly, & Borgatti, 1997; Burt, 2005). This means that structural embeddedness decreases partnering risks and renders M&A relatively more attractive. In so doing, we also newly introduced an advanced measure of structural embeddedness, network cluster co-location based on the Markov clustering algorithm (van Dongen, 2000, 2008). This measure is arguably superior to the other measures of structural embeddedness like ego network density (Rowley, Behrens, & Krackhardt, 2000), the number of common third parties (Gulati & Gargiulo, 1999), and cliques (Rowley et al., 2004; Rowley et al., 2005) because it takes into account a global network beyond local networks as well as being more robust and less restrictive and arbitrary.

One recent study investigates geographical cluster co-location as a determinant of the governance choice (McCann, Reuer, & Lahiri, 2015). It is akin to our approach in the sense that its central tenet revolves around mitigating information hazards between exchange partners through shared clusters.

Table 3. Average partial effects of probit and heteroscedastic probit estimates[a,b]

	Probit estimates				*Heteroscedastic probit estimates*			
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Relative size	−0.236 (0.077)**	−0.232 (0.077)**	−0.230 (0.075)**	−0.238 (0.075)**	−0.133 (0.061)*	−0.153 (0.061)*	−0.135 (0.060)*	−0.148 (0.060)*
Relative ROA	−0.261 (0.144) +	−0.249 (0.144) +	−0.208 (0.140)	−0.204 (0.140)	−0.300 (0.136)*	−0.297 (0.134)*	−0.252 (0.132) +	−0.254 (0.130) +
Relative slack	−0.011 (0.007)	−0.010 (0.007)	−0.009 (0.007)	−0.009 (0.006)	−0.007 (0.006)	−0.006 (0.007)	−0.005 (0.006)	−0.003 (0.006)
Relative solvency	0.021 (0.040)	0.022 (0.038)	0.017 (0.038)	0.017 (0.038)	0.019 (0.033)	0.020 (0.032)	0.016 (0.031)	0.016 (0.031)
Prior alliance experience (combined)	−0.018 (0.004)***	−0.018 (0.004)***	−0.016 (0.004)***	−0.016 (0.004)***	−0.039 (0.008)***	−0.038 (0.008)***	−0.037 (0.008)***	−0.039 (0.008)***
Prior M&A experience (combined)	0.044 (0.014)**	0.048 (0.014)***	0.046 (0.014)***	0.045 (0.014)***	0.064 (0.017)***	0.071 (0.017)***	0.069 (0.018)***	0.071 (0.018)***
Alliance history	0.087 (0.054)	0.097 (0.055) +	0.089 (0.053) +	0.065 (0.055)	0.191 (0.103) +	0.210 (0.106)*	0.205 (0.105) +	0.141 (0.105)
Inverse Mills ratio	−1.254 (0.477)**	−1.086 (0.489)*	−1.315 (0.473)**	−1.299 (0.471)**	−0.072 (0.066)	−0.180 (0.082)*	−0.178 (0.081)*	−0.164 (0.080)*
Resource similarity		0.116 (0.079)	0.074 (0.079)	0.071 (0.079)		0.151 (0.074)*	0.123 (0.074) +	0.119 (0.073)
Vertical relatedness			0.287 (0.093)**	0.292 (0.093)**			0.244 (0.087)**	0.251 (0.086)**
Structural embeddedness (network cluster co-location)				0.099 (0.077)				0.187 (0.099) +
Observations	654	654	654	654	654	654	654	654

Notes. M&A = mergers and acquisitions.
[a]Standard errors in parentheses.
[b]Year dummies included but not reported.
***$p < .001$; **$p < .01$; *$p < .05$; + $p < .1$.

However, it parts company with ours as the clusters in the study are identified on the basis of geography rather than network itself. While geographical clusters can reduce *ex ante* information hazards via knowledge spillovers, they have less to do with *ex post* social control typically observed within network clusters (Walker, Kogut, & Shan, 1997). Networks as a set of social relations function as a venue for social interactions and emergent social mechanisms such as reputational sanction which can translate into *ex post* social control (Burt, 2005). In this regard, this study complements the study.

This research adds precision to a resource-based view of the governance of inter-firm resource combinations by bringing to the fore vertical resource relatedness. When only the effects of resource similarity on governance choice were taken into account, our results were consistent with those of prior literature: M&A became the more preferred governance mode when resource similarity was higher. However, our findings revealed that, when vertical relatedness is considered simultaneously, resource similarity loses its explanatory power. This suggests that, at least in the context of the computer industry, a significant portion of inter-firm resource combinations occur along the vertical dimension of resource relatedness.

The overall findings of this study relate to the resource-based and network-based views of the governance choice for inter-firm resource combinations. Since networks shape information and resource flows around focal firms, a resource-based view of governance choice that considers only the resources of focal firms per se has inherently limited explanatory power. At the same time, since the structure of networks moderates the association between resource attributes and governance choice, an inter-firm network analysis that does not account for resource attributes has its own limitations. This observation underscores the necessity of simultaneously considering the structure of networks – structural embeddedness – and the characteristics of nodes – vertical resource relatedness (Phelps, 2010).

From a methodology standpoint, this study contributes to the literature by introducing an advanced method for modeling binary outcomes, the heteroscedastic probit model. Notably, the probit and logit models – the conventional econometric treatments for modeling binary outcomes – suffer from inefficiency because the variances of their probability distributions need to be set to certain fixed values for identification purposes (e.g., 1 for the probit and $\frac{\pi^2}{3}$ the logit model) (Hoetker, 2007; Wooldridge, 2010; Greene, 2012). Inefficiency necessarily translates into low statistical power and thus heightens the likelihood of making type II errors. In other words, statistical inferences based on the conventional models of binary outcomes are less trustworthy. We address concerns of this kind by using the heteroscedastic probit model.

Factors other than resource combinations may affect firms' decisions about governance. For example, managers may prefer M&A to alliances in order to obtain power. M&A confers more power to the managers of a controlling firm after M&A precisely because M&A entails a more hierarchical governance than alliances do. Alliances provide the partners with access to the pooled resources but not full ownership of them. M&A provide the acquiring firm with both access to the combined resources and controlling rights over them. Setting aside such motives for decisions about what governance to pursue, our study focuses rather on the impact of resource combinations and networks on firms' decisions about alliances and M&A. The term governance in this study refers to organizational governance (e.g., Williamson, 1991; Mahoney, 1992; Zajac & Olsen, 1993; Barney, 1999; Leiblein, 2003; Nickerson & Silverman, 2003), which in the field of management is distinguished from corporate governance as a subject of inquiry.

SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/jmo.2016.9

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