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Network Synergy

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Abstract
Acquisitions can dramatically reshape interorganizational networks by combining previously separate nodes and allowing the acquirer to inherit the target's ties, potentially creating network synergy. Network synergy is the extent to which combining an acquirer's and a target's networks through node collapse results in a more favorable structural position for the combined firm as the acquirer gains control of the target's existing ties. We hypothesize that the likelihood of selecting a target increases when the expected network synergy is greater. Using data from the biotechnology industry (1995–2007), we find support for this hypothesis by showing that acquirers prefer targets that generate greater expected increases in network status and greater expected access to structural holes—even when we control for other known sources of synergies. We further show that these effects are driven by complementary combinations of the acquirer's and target's networks that go beyond the attractiveness of the target's network per se. By integrating the networks and acquisitions literatures, we introduce a novel source of synergies, provide evidence of a previously unexplored mechanism of network change, and show how firms can exert agency in the process of network change.

Keywords: network node collapse, alliances, acquisitions and network synergy, high-technology industry acquisitions

A firm's position in an interorganizational network affects a variety of performance outcomes (e.g., Zaheer and Bell, 2005; Shipilov, 2006; Gulati, 2007; Kilduff and Brass, 2010), so how firms obtain valuable structural positions becomes an important research question. Despite many approaches to this topic, existing work has focused on how firms add or remove ties as the underlying means of network change (e.g., Buskens and Van de Rijt, 2008; Ahuja, Soda, and Zaheer, 2012; Tatarynowicz, Sytch, and Gulati, 2016). But firms can also alter their networks and obtain valuable structural positions through acquisitions, a very different mechanism. From a networks perspective, when one firm acquires another, the acquirer and target nodes ''collapse,'' and the

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acquirer gains control of the target's contractual external relationships in one transaction. This can suddenly and dramatically modify the position of the combined entity (Hernandez and Menon, 2017), potentially resulting in network synergy, defined as the extent to which combining an acquirer's and a target's networks through node collapse results in a more favorable structural position for the combined firm. Because a more favorable network position can improve firm performance, network synergy may be a significant consideration when companies select acquisition targets.

While the networks literature largely overlooks how acquisitions can alter a firm's position in the external network, the mergers and acquisitions (M&A) literature does not consider changes in network structure as a source of synergy. Synergy arises from a combination of assets that are more valuable together than separate (Shaver, 2006). M&A studies have emphasized internal sources of synergy, in which value comes from resources inside the firms, such as brands, technologies, or human resources (Chatterjee, 1986; Haspeslagh and Jemison, 1991). Studies have also considered external industry factors, such as synergies from combining supply or distribution channels or increasing market power (Porter, 1980; Devos, Kadapakkam, and Krishnamurthy, 2009). Largely unstudied is whether combining nodes and their external relationships creates value in M&A. Yet inasmuch as resources are embedded in networks—i.e., outside instead of inside the firm (Gulati, 1999; Lavie, 2006)—acquisitions should have structural consequences that give rise to network synergies. Some prior work has considered how acquisitions may lead to changes in individual, dyadic ties (Rogan, 2013; Rogan and Sorenson, 2014), but we focus on structural effects in the extra-dyadic sense that the networks literature emphasizes.

Our main proposition is straightforward: if acquisitions produce network synergies, then the likelihood of selecting a target will increase when the expected network synergy is greater. For example, if acquiring firm B increases the structural holes or centrality of A, acquiring B produces a network synergy. And if acquiring B is expected to increase the structural holes or centrality of A more than acquiring C, A should be more likely to acquire B than C. Of course, this applies only when network positions, like centrality or structural holes, are considered valuable by A.

We test our main proposition in the context of the biotechnology industry between 1995 and 2007. Based on prior research on interorganizational networks in high-technology settings such as biotechnology, we expect that positions that enhance access to structural holes or increase status (centrality) in the alliance network will be considered valuable. Structural holes help firms access novel resources to keep up with constantly changing technologies (Tatarynowicz, Sytch, and Gulati, 2016) or gain exclusive control of scarce resources for which competition is high (Burt, 1992). Status in the network allows firms to obtain resources and attract partners under the highly uncertain conditions prevalent in dynamic industries (Stuart, Hoang, and Hybels, 1999; Podolny, 2001). We thus expect that acquirers in the biotechnology industry will prefer targets whose networks, when combined with their own, will increase their structural holes or improve their status.

In our theorizing, we make a key distinction between changes in the acquirer's position driven by complementary combinations of two preexisting networks (synergy) versus similar changes that simply proxy for target quality:

the desirability of the target or its network independent of their complementarity with the acquirer. A deal could increase an acquirer's centrality or structural holes because of true synergies or because the target's status or structural holes are indicators of its quality (e.g., Podolny, 2001). Although both mechanisms can exist, our focus is on the former. Therefore, to provide convincing evidence of our hypotheses we must isolate network synergies from target quality. To do so, we derive three conditions for synergies from structural holes and centrality to arise. First, eliminating redundant ties between the acquirer and target is sufficient to produce structural hole synergies because it makes the acquirer a more exclusive broker. Second, obtaining new ties from the target is necessary but not sufficient to produce status (centrality) synergies—redundant ties cannot produce status synergies. Third, new ties gained from the target that complement the pre-acquisition network or capabilities of the acquirer are sufficient to produce both types of synergies. We design our empirical analyses to explore these three conditions, which allows us to rigorously assess whether firms pursue network synergies when selecting acquisition targets.

NETWORKS AND STRUCTURAL CHANGE THROUGH ACQUISITIONS

We build our theory on two literatures that have developed largely independently: networks and acquisitions, each of which can enrich the other. The networks literature can develop by considering acquisitions as a means by which firms alter their structural positions, while acquisitions research can benefit by considering network structure as a source of synergies. We briefly review each literature as it pertains to developing the concept of network synergy.

The position a firm occupies in a network plays a key role in facilitating or hindering access to valuable resources, which in turn influence organizational performance (for reviews, see Gulati, 1998; Kilduff and Brass, 2010; Phelps, Heidl, and Wadhwa, 2012). Hence interest in how firms obtain value-enhancing positions has grown significantly (for a review, see Ahuja, Soda, and Zaheer, 2012). Work in this space has explored several factors that affect network change, such as homophily (Lin, 2001), avoiding contentious ties (Sytch and Tatarynowicz, 2014), preventing resources from leaking to rivals (Hernandez, Sanders, and Tuschke, 2015), environmental shocks (Koka, Madhavan, and Prescott, 2006), random tie formation (Renyi and Erdos, 1959), small-world behavior (Kogut and Walker, 2001), or increasing returns to scale for central actors (Barabási and Albert, 1999). This list captures only a sampling of the many approaches used to understand how organizational networks evolve.

Regardless of the approach, prior research has largely been based on a common set of building blocks that mechanically modify the network: additions or deletions of ties. Although networks composed of individuals change through these two types of tie modifications, organizations have an additional mechanism available that modifies the nodes: acquisitions. From a networks perspective, an acquisition represents the collapse or fusion of previously separate nodes. Such an event is relevant for the network structure because the combination of nodes allows the acquirer to inherit and legally control the ties of the target in a single transaction, which can dramatically affect the acquirer's structural position, particularly if it seeks opportunities to improve that position (Hernandez and Menon, 2017).

Firms typically undertake acquisitions with strategic purpose and gain legal control over the target's resources, including contractual relationships such as alliances. Thus studying node collapses lets us explore how firms exert agency in the process of network evolution—an important but elusive issue (Emirbayer and Goodwin, 1994; Lin, 2001; Ahuja, Soda, and Zaheer, 2012). We adopt a view "that treats actors as purposeful, intentional agents" with respect to their networks (Nohria and Eccles, 1992: 13). Despite bounded rationality and other constraints, firms often strategically form and dissolve ties (e.g., Bala and Goyal, 2000; Hernandez, Sanders, and Tuschke, 2015; Zhelyazkov, 2018), and agency is a foundational assumption in many prominent theories of social networks (Lin, 2001). For instance, Ahuja, Soda, and Zaheer (2012) emphasized the importance of studying "the potential role of conscious agency by network participants in creating network structures that benefit them."

Some work has explored network motivations for acquisitions. Burt (1983) used the input–output tables of the U.S. economy to measure the extent to which industries (the nodes) depend on or "constrain" each other according to their ties: the amount of output that they buy from and sell to each other. Burt demonstrated that firms are more likely to make acquisitions in sectors that constrain their inputs or outputs as a way of eliminating high resource dependence positions in the macroeconomic network. More recently, Anjos and Fracassi (2015) argued that diversification, which often happens via acquisitions, allows firms to overcome informational asymmetries across sectors of the economy by centralizing access to information within the firm. Using input–output tables, they showed that owning businesses in high-centrality industries improves the performance of diversified firms.

These studies relate to ours in that they view acquisitions as a means of overcoming problems with the firm's network position, but they focused on a different mechanism of value creation, emphasizing the conditions under which internalizing or eliminating activities previously conducted through the buyer–supplier network is valuable. We emphasize the value of maintaining activities in the *external* network and focus on enhancing that value through the combination of two firms' networks to improve the combined firm's structural position. This is distinct from vertical internalization, which is the focus in the prior literature.

Acquisitions and Network Synergy

Synergy, defined as a combination of resources that produce more value together than separately by increasing revenues or reducing costs, is the central concept in the M&A literature (e.g., Haspeslagh and Jemison, 1991; Shaver, 2006). Synergies can stem from a variety of sources (Chatterjee, 1986). When a firm makes an acquisition, it gains legal control over the assets of the target. These assets can be tangible or intangible, such as equipment, brands, technologies, human capital, or knowledge. Although it discusses many sources of synergy, the acquisitions literature tends to overlook external network structure. Research primarily focuses on the benefits of combining or consolidating resources that reside within a firm's boundaries. But because network resources, which reside in the web of external relationships firms have established over time, are also valuable (Gulati, 1999; Lavie, 2006), the

network positions firms inherit when they acquire targets can plausibly be a source of synergy.

A recent simulation study proposed that node collapses and tie changes exhibit three differences in how they affect network change, which underscore why acquisitions give rise to network synergies (Hernandez and Menon, 2017). First, they have a bigger impact per transaction on the network structure because they affect multiple ties at once, while tie changes modify only one tie at a time. Second, they provide exclusive legal control of the target's ties, whereas tie changes do not confer ownership. And third, they provide access to both the internal and external resources of the target. We add to that study in two ways. First, Hernandez and Menon (2017) did not develop the concept of network synergy to explain how node collapses affect acquisition target choices. Second, the prior study assumes that network synergies exist; we empirically document their existence.

The M&A literature contains some considerations relevant from a networks perspective. For example, because the supply chain is a network of vertical ties, acquisitions involving the deletion of a supplier tie (backward integration), of a buyer tie (forward integration), or of a rival (horizontal integration) modify with whom firms are connected. Such changes in ties can create value through efficiencies or market power (Devos, Kadapakkam, and Krishnamurthy, 2009). Other research has explored how a pre-acquisition alliance between an acquirer and a target can improve the odds of post-acquisition success by smoothing the buying and integration process (Porrini, 2004; Zaheer, Hernandez, and Banerjee, 2010). And recent work has demonstrated that horizontal acquisitions can lead to the dissolution of ties with clients (Rogan, 2013; Rogan and Greve, 2014), which may factor into realized synergies after the acquisition. All of these studies showed how acquisitions modify dyadic relationships. Our emphasis is on the extra-dyadic, structural properties that give rise to network resources. Hence, when discussing network synergies, we refer to the improvement in the acquirer's structural network position resulting from the node collapse and the inheritance of the target's ties rather than to synergies from changes in individual ties.

Network Synergy and Acquisition Target Choice

We focus this paper on how expected network synergies affect the acquirer's selection of a target firm. For network considerations to affect target selection, three assumptions must be maintained. First, the firm's network position should affect its performance sufficiently for structural factors to enter the calculus of acquisition target choice. Network position may not be important in all contexts, but it matters greatly when resources are widely distributed across firms, such as in high-technology sectors like biotechnology, semiconductors, and software (Ahuja, 2000; Baum, Calabrese, and Silverman, 2000; Tatarynowicz, Sytch, and Gulati, 2016), or in international activities in which being globally or locally connected to resource providers is essential (Johanson and Vahlne, 2009; Hernandez, Sanders, and Tuschke, 2015).

Second, the acquirer should be aware of the position it currently occupies and be able to estimate how that position would change by combining its network with the target's. This estimate need not be perfect, so this assumption is consistent with bounded rationality. This might appear unrealistic, given that

individuals have inaccurate and biased perceptions of their social networks (Kilduff et al., 2008), but individual networks differ from interorganizational networks in important ways. For instance, alliance ties are publicly announced, and firms have competitive incentives to map the external resource landscape. Research has shown that firms react to other firms' alliance announcements and that these announcements affect rivals' stock market value (Koza and Lewin, 1998; Oxley, Sampson, and Silverman, 2009).

Finally, the acquirer should have a desired network position as an objective, consistent with theories of purposeful network action we discussed earlier. Managers do not use academic network terms like structural holes or status to describe their actions, but research has shown that their goals are manifested in structural outcomes consistent with network constructs. For example, studies have demonstrated that certain principles of attachment or resource-seeking goals (what managers think about) lead to outcomes such as structural holes, status, and other positions that embody network constructs (Buskens and Van de Rijt, 2008; Hernandez, Sanders, and Tuschke, 2015; Tatarynowicz, Sytch, and Gulati, 2016).

In the end, whether these assumptions hold and affect the selection of an acquisition target is an empirical question. We expect to observe the following general effect:

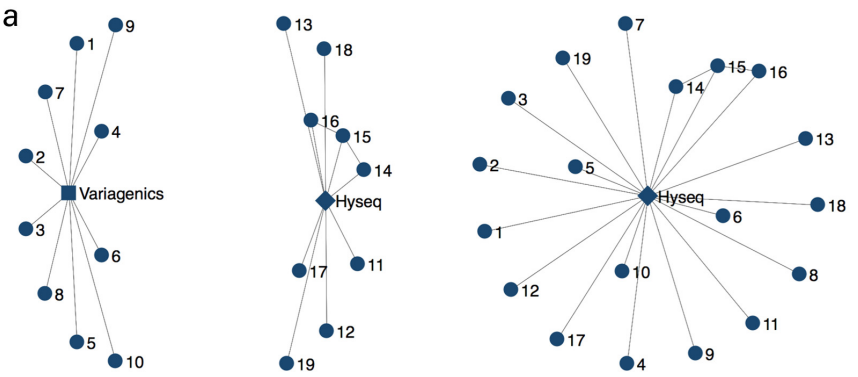
> General proposition: The greater the expected improvement in the acquirer's structural position resulting from the combination of the acquirer's and target's networks, the more likely a firm is to acquire a target.

This proposition can be applied to multiple types of networks and structural positions. To empirically validate the main proposition, we develop hypotheses specific to two network positions in alliance networks, structural holes and status, that enhance value in high-technology industries such as biotechnology.

Structural holes. Firms in technologically dynamic industries tend to seek networks in which they can span structural holes (Tatarynowicz, Sytch, and Gulati, 2016) for two reasons: to obtain novel resources or to secure exclusive access to scarce resources (Burt, 1992). Acquisitions can help with each of these objectives. First, dynamic industries create strong pressures to constantly discover new technologies. In biotechnology one of the most important alliance activities is research and development (R&D) because developing new, patentable molecules is the locus of value creation (Giovannetti and Morrison, 2000). Networks that expose firms to diverse ideas and ways of doing things are more likely to help firms discover disparate bits of knowledge that can be recombined in novel ways (Fleming, 2001; Burt, 2004). Node collapses can help firms accomplish this by allowing an acquirer to inherit a target's ties that expose the acquirer to novel partnerships. Figure 1a illustrates this for the case of Hyseq's 2002 acquisition of Variagenics, which allowed Hyseq to inherit several new and non-redundant ties.

Acquisitions are particularly useful to gain access to multiple novel ties expediently through a single transaction. Simultaneously establishing several new alliances can in principle lead to a similar outcome, but this may be impractical for at least two reasons: the focal firm may lack the influence or resources to

Figure 1a. Node collapse and access to novel ties (constraint declines, centrality increases).

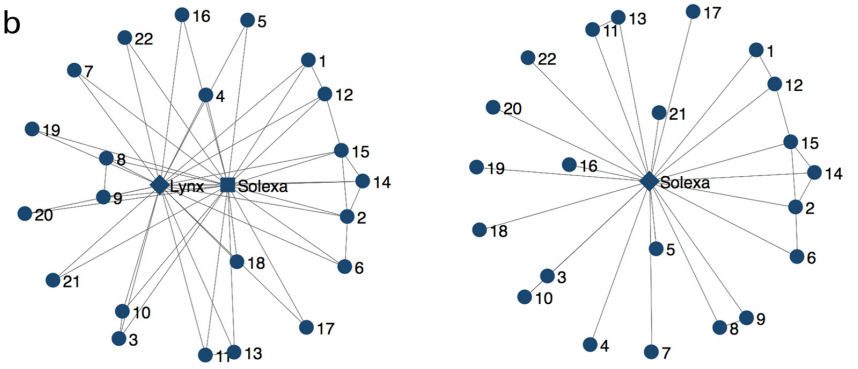


attract all the new partners it desires, and the desired partners may lack the capacity or desire to accept the focal firm as a new partner. Further, in the specific case of the acquisition in figure 1a, establishing ties to all or most of Variagenics' partners without acquiring Variagenics would not be as valuable for Hyseq because both firms would then be competing brokers. In networks parlance, they would each constrain the other. An acquisition circumvents these challenges by giving the acquirer ownership and exclusive control over multiple ties at once (Hernandez and Menon, 2017).

The second reason firms seek control over structural holes in technology-intensive industries is to secure exclusive access to resources for which competition is high. As brokers, firms have influence over who can access scarce network resources and the conditions of access. Formal models show that the value of spanning structural holes declines as alternative brokers become available in the network (Ryall and Sorenson, 2007). In high-technology industries, having unique access to technologies, know-how, or other resources is central to firms' performance (Stuart, 2000; Zaheer and Bell, 2005). Node collapses through acquisitions provide an avenue to secure exclusive brokerage privileges not available through tie additions or deletions: absorbing a firm with many common ties. This eliminates a rival for network resources, offers exclusive access to other firms' network resources, and is manifested in a more open network structure for the acquirer post-acquisition.

Figure 1b illustrates such an outcome in the case of Solexa acquiring Lynx Therapeutics in 2004. The deal eliminated the redundancy among both firms' pre-acquisition ties, allowing the combined entity to become a more exclusive broker than when the two were separate entities, which could not be accomplished through tie deletions. It would be unrealistic to expect one firm to persuade or force another firm over which it has no control to terminate all or most of its alliances. Yet the equivalent outcome can occur via an acquisition, because the acquirer gains ownership and thus control of the target's contractual alliances. This is akin to acquisitions that give the acquirer greater market power by eliminating rivals, suppliers, or buyers (Porter, 1980), but it happens through network synergies rather than through internal synergies.

Figure 1b. Node collapse and elimination of redundant ties (constraint declines).



Thus we posit that acquisitions can help increase an acquirer's structural holes by providing access to novel, non-redundant ties or by eliminating preexisting, redundant ties. This should be manifested in the following empirical observation:

Hypothesis 1 (H1): Firms are more likely to acquire a target when the expected increase in access to structural holes resulting from the combination of the acquirer's and target's networks is greater.

Status. Firms in technologically dynamic industries benefit from occupying positions of high status. Status enhances access to resources in uncertain environments (Podolny, 2001), and high-technology industries exhibit particularly high uncertainty. Although status correlates with the objective quality of an organization, its value arises from the fact that true quality and status are imperfectly correlated. This becomes especially useful under uncertainty: when evaluating quality is difficult, status serves as a signal of unobservable quality to external resource providers (Podolny, 2001). In networks, status is manifested through the sorting of firms into central (high-status) and peripheral positions (Sauder, Lynn, and Podolny, 2012). Research in the biotechnology industry has shown that network status helps firms access valuable resources, such as partnerships with firms producing promising technologies or funding from external investors (Baum, Calabrese, and Silverman, 2000; Sytch and Bubenzer, 2008). Therefore, in our context we expect firms to strive to increase their network status.

Acquisitions can be particularly useful in enhancing centrality (the usual indicator of status in networks) because they allow the inheritance, ownership, and control of multiple new relationships in one transaction. Accomplishing this through other means, such as a series of tie additions, would be harder because it would involve persuading multiple potential partners over which the focal firm has no direct control to ally with the focal firm. This is particularly difficult if the desired partners are prominent and powerful firms. Legally acquiring a target connected to prominent partners offers a way around this conundrum. Of course, acquisitions always increase an acquirer's centrality if the target

brings new ties to the combined entity. This is not very interesting, nor is it falsifiable. Yet the counterfactual of our hypothesis lies in comparing the increase in status from acquiring one target relative to the increase in centrality that would have resulted from acquiring another target the firm considered but did not acquire.[1] We thus expect to observe the following:

> Hypothesis 2 (H2): Firms are more likely to acquire a target when the expected increase in network status resulting from the combination of the acquirer's and target's ties is greater.

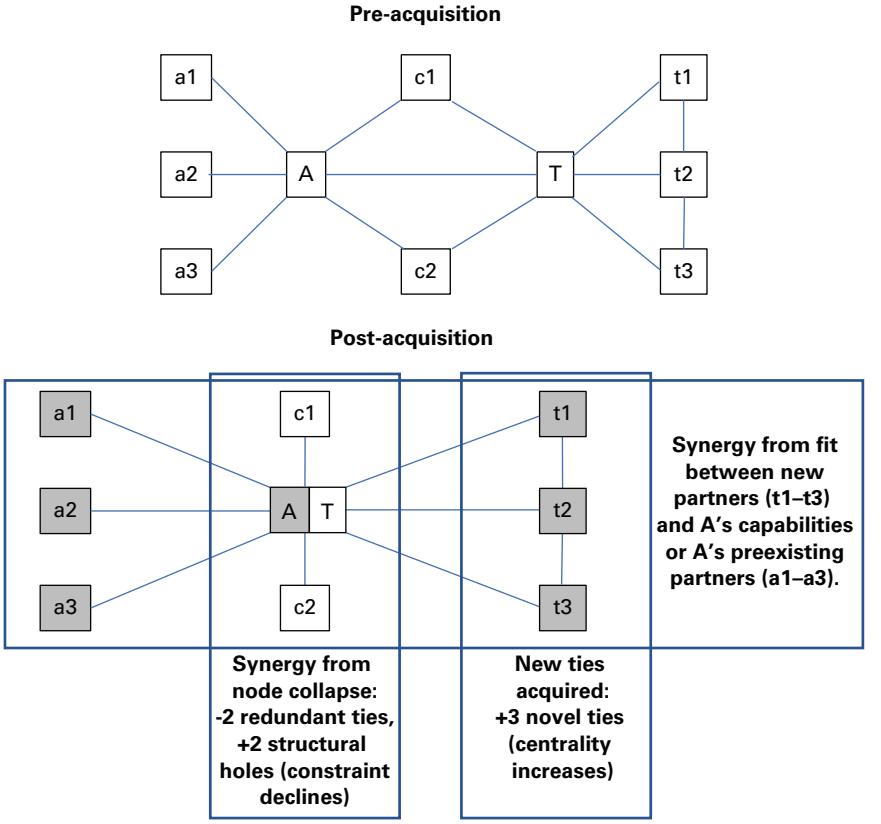
Network synergy vs. alternative explanations. Observing that firms select targets that increase structural holes or status is consistent with, but does not offer definitive evidence of, network synergies. The most plausible alternative explanation is that increases in a desirable network metric proxy for the quality of the target or the target's network per se. Acquiring a quality target or a quality network is a valuable reason to make an acquisition, but it is not sufficient to claim the existence of a network synergy. We thus need to isolate choices of targets driven by the value of the combination of the acquirer's and target's networks (synergy) from those driven by the value of the target's network by itself. Figure 2 provides a stylized example that aids in identifying the existence of network synergies if A acquires T. The figure shows that synergies can arise from either eliminating redundant ties via node collapse or taking control of new ties that have a complementary fit with the acquirer's preexisting network or capabilities.

To illustrate the first source of synergy, the node collapse eliminates the redundancy in the A-c1-T and A-c2-T pre-acquisition triads, making the acquirer a more exclusive broker. This is a true synergy because it can arise only from the A + T combination—not from the quality of the target's network by itself. The case of c1 and c2 also illustrates another point: there is no enhancement in A's centrality (and thus status) from c1 and c2 because A was already tied to them. Any synergistic status enhancements must come from acquiring new partners. If the acquirer were picking a target only because of the quality signal embodied in the target's centrality, inheriting new ties would not matter as much. In figure 2, the acquisition brings three new partners (t1, t2, and t3), but these are not necessarily sources of synergy. These new partners must also bring with them something that complements the acquirer's preexisting network or capabilities. This is indicated with the shaded background, showing that something about how t1, t2, or t3 fits with A (e.g., its capabilities) or with a1, a2, or a3 is required for synergy.

Drawing from this example, we derive three empirical expectations that aid us in isolating network synergies from other mechanisms, which we will test in our analysis. First, eliminating redundant ties between an acquirer and target is sufficient to generate structural hole synergies. Second, acquiring ties to new partners is necessary but not sufficient to generate status (centrality) synergies; such ties could still be a network-driven reason to make the acquisition,

[1] Centrality could be capturing access to resources rather than purely status in this context, as highly central partners are likely to have many resources. We have followed the standard interpretation of this measure (status), but our core arguments still apply if this measure is interpreted as enabling access to more resources.

Figure 2. Illustration of network synergy sources if A acquires T.



even if they do not produce synergy. Third, acquiring targets that bring new ties that complement the preexisting capabilities or network of the acquirer is a sufficient condition to generate structural hole or status synergies.

EMPIRICAL ANALYSIS

An effective test of our hypotheses requires the following. First, we need a setting in which network effects are valuable. Second, we need variance in the key constructs of our hypotheses. This includes whether a firm acquires a specific target versus an alternative target (i.e., we must define a choice set) and to what extent acquiring a potential target would alter the network structure (i.e., we must measure expected network synergies). Third, we must account for other factors correlated with network synergies that might influence target choice and otherwise lead to spurious inference. Finally, we need an empirical method designed to focus on variance across potential choices within each discrete target decision. We addressed each of these research design elements in our analysis.

Industry and Sample

We tested our hypotheses in the biotechnology industry, which is suitable for a number of reasons. First, it is a technologically complex and dynamic setting in

which alliances and acquisitions are common because the knowledge required to develop compounds into products is widely distributed (Higgins and Rodriguez, 2006; Sytch and Bubenzer, 2008). Second, firms are aware of the alliance network because it is the means of accessing new technologies and ideas. Third, a significant body of research exists on alliance networks and acquisitions in this industry (e.g., Arora and Gambardella, 1990; Powell, Koput, and Smith-Doerr, 1996; Baum, Calabrese, and Silverman, 2000; Higgins and Rodriguez, 2006; Rothaermel and Hess, 2007), and these precedents provide results that guide our empirical design and facilitate the interpretation of our findings. Fourth, high-quality data on alliances are available for this industry, which offers reasonable confidence that we have nearly complete network data.

Network considerations in biotechnology acquisition announcements. An important question is whether managers in this industry consider a target's alliances when making acquisitions. Evidence from acquisition announcements suggests that they do. One example is the 2004 deal in which QLT acquired Atrix Laboratories. The press briefing mentioned the expected synergies coming from ''economies of scale, distribution synergies, [and] complementary product portfolios'' (PR Newswire, 2004), but it also added that Atrix's ''established strategic alliances with such pharmaceutical companies as Pfizer, Novartis, Sanof-Synthelabo, Fujisawa and Aventis'' were important sources of value for QLT (PR Newswire, 2004). And consistent with network synergy, ''this transaction will accelerate both companies' strategic initiatives [through] multiple partnered commercial and near commercial products . . . beyond what either company might have achieved independently'' (PR Newswire, 2004). Another example is the case of Allelix acquiring NPS Pharmaceutical in 1999. The press release discussed how the combined entity would have partnered R&D programs with firms such as Amgen, Kirin, SmithKline Beecham, Janssen, and Pharm-Eco in a variety of technological areas. These partnerships resulted from combining the alliances of the two firms and are discussed as a key reason why the merger would create value by providing access to new resources and opportunities (PR Newswire, 1999a). These examples convey an intent to access novel resources by combining the acquirer's and target's alliance networks.

Press releases may also convey a desire to gain alliances with prominent partners. The announcement of Purdue Pharma's 1999 purchase of Cocensys mentioned the target's development alliances with Wyeth-Ayerst, Warner-Lambert, Senju Pharmaceuticals, and other large firms. The press release then emphasized, ''Purdue Pharma expects to benefit from the merger through enhanced research and development capabilities and strengthened ties with leading pharmaceutical companies'' (PR Newswire, 1999b). The announcement of the acquisition of Maxim Pharma by Epicept in 2005 made a similar claim by stating that ''several of the product candidates [gained through the acquisition] are partnered with respected industry leaders'' (Business Wire, 2005). Similar points were made about an acquisition by Emergent Biosolutions: ''Microscience [the target] brings significant collaborations with respected international research organizations and a number of important commercial relationships and out-licensing agreements and opportunities with large

pharmaceutical companies'' (Adler, 2005). Such language conveys not only a desire to obtain new alliances but also a concern with the reputation and visibility of the alliance partners of the target.

These examples make it clear that acquirers pay attention to potential targets' alliances. Establishing this first-order consideration is an important basis for exploring whether the more complex second-order considerations of network structure and synergy are at play.

Data sources. We obtained alliance data from the Recombinant Capital (RECAP) database and acquisition data from the SDC Platinum database. We began the sample in 1995 because SDC Platinum data are most reliable and complete starting in the 1990s. Because we followed a standard assumption that alliances have a five-year lifespan (Gulati, 1999), we started collecting alliance data in 1991 yet restricted our analyses from 1995 to 2007 so that in the first year of our analyses we have a five-year window of alliance formation. The last year of observation is 2007 because that is the last year for which we had access to RECAP data. We collected patent data from the IQSS Patent Network Dataverse (Lai et al., 2011). We matched patent assignees to firm names in the RECAP database using a series of computer programs and manual techniques. Per standard practice, we used only patents that were granted but deemed the date of application as the moment in which the technology was developed.

Creating the Choice Set

Identifying firms that were acquired and a set of firms that were not acquired, yet could have been acquired instead, is central to our research design. How we defined this choice set affects the counterfactual that underlies our empirical test. We initially downloaded from SDC Platinum 1,357 controlling acquisitions involving both an acquirer and a target in the biotechnology sector from 1995 to 2007. We relied on SDC Platinum rather than RECAP for the initial acquisition sample because the former provides more details about each deal, including whether it was a controlling acquisition (in which we are interested) or a minority purchase (in which we are not interested). We verified that the names of both the acquirer and target were listed in RECAP, to ensure that firms were involved in biotechnology activities at some point in their history.

Having identified realized acquisitions, we then needed to construct a set of firms that were not acquired, yet could plausibly have been acquired instead, to fill out the choice set. Although we could not directly observe the set of potential targets considered by an acquirer, we could generate a set of counterfactual targets with observable characteristics similar to those of the actual target. We used four criteria: total patents, similarity in patenting classes, similarity in disease areas (e.g., cancer vs. diabetes), and similarity in medical technologies (e.g., drug delivery vs. diagnostics). These criteria reflect conversations with R&D managers in this industry about factors affecting whom to acquire, as well as prior research on biotechnology acquisitions (e.g., Higgins and Rodriguez, 2006).

We favored this matching approach to defining the choice set for three reasons. First, it creates a meaningful counterfactual to our test: that technological

and therapeutic factors are central considerations in the choice of a target, whereas network structure is not. Second, alternative ways to define the choice set are less appealing. Prior studies have often assumed that acquirers choose among all other firms in the industry or that they choose randomly among all such firms (e.g., Yu, Umashankar, and Rao, 2016), but this does not reflect what we learned about how acquisition decisions are made in our context. Third, using the strictest matching criteria possible makes our empirical tests conservative by narrowing the range of post-matching variance ''left over'' in the data to test our hypotheses.

Given the four matching criteria, we had to eliminate 980 of the original 1,357 deals for which we had no information about the target firm's therapeutic activities (from RECAP) or in which the target had no record of patenting (from IQSS). Of the dropped deals, 500 targets had no record of either patenting or therapeutic activity prior to the focal year—there is no way to form a choice set based on observable attributes for these 500 firms. Of the remaining 480 dropped cases, 235 targets had no patenting activity but did have a history of alliances in at least one therapeutic activity, and 127 targets had at least one patent but no alliance history.[2] A further 118 acquisitions were dropped for two reasons. First, we eliminated 93 because the acquirer had no patenting record, and many important covariates described later require patenting data. Second, 25 cases involved the re-acquisition of a target that had previously been acquired by another firm (e.g., A acquired Z in 2003, and B acquired Z in 2007). It was impossible to assign the patents and alliances of the original target or the original owner to the second acquirer, so we opted not to include re-acquisitions in our sample.

We were left with 377 usable acquisitions with information about the patenting and therapeutic activities of targets. For each of those 377 acquired targets, we identified counterfactual targets that were similar along the four dimensions mentioned previously. The initial pool of potential targets included all firms listed in RECAP that had not been acquired at the time each deal was observed. We created a yearly record of these firms' accumulated activities in the four areas covered by the matching criteria: total patent count, patenting along seven biotechnology classes (per Rothaermel and Hess, 2007), activity in 38 disease areas (from RECAP), and activity along 45 medical technologies classes (from RECAP)—over 90 variables. The list of potential targets was updated yearly, and firms were included as matching candidates only if they had alliance activity within five years. When creating firms' patent and alliance portfolios, we included any patents or alliances obtained via acquisitions. Whenever a firm acquired a target, we added the target's past patents and active alliances (within the five-year lifespan) to the acquiring firm's organically developed portfolio of patents and alliances.

Because the matching data have many zeroes, we used propensity score matching, which can estimate probability scores even if the data are not continuous (Dehejia and Wahba, 2002). To ensure that the procedure worked, we conducted a series of balance tests comparing the acquired vs. matched targets in each year along each matching variable. Of the nearly 1,000 t-tests involved, only five had *p*-values less than .05, and only 17 had *p*-values less

[2] Our results are robust if we do not drop these 480 acquisitions from the sample, as explained later.

Table 1. Example of Matched Choice Set for Acquirer Hyseq Pharmaceuticals in 2002

Target (actual or potential)	Target choice	Propensity score	Difference
Variagenics	1	48.549%	n/a
Gensci Regeneration Sciences	0	47.908%	0.641%
Solexa	0	46.229%	2.319%
Epimmune	0	45.229%	3.320%
Ibah	0	44.667%	3.882%
Orchid Cellmark	0	43.083%	5.466%
Tularik	0	36.270%	12.279%
Access Pharmaceuticals	0	35.909%	12.640%
Lynx Therapeutics	0	33.314%	15.235%
Cephalon	0	28.681%	19.867%
Avid	0	28.557%	19.992%

than .10 (results available upon request). We used the top ten closest matches in our primary analysis whenever possible (Rogan and Sorenson, 2014). We were able to find ten matches for 264 acquisitions, nine matches for 98 deals, and eight matches for the remaining 15 cases. The final dataset thus has 4,019 rows (10*264 + 9*98 + 8*15) broken into 377 panels (each panel consists of an actual deal matched to counterfactuals). We used several possible matches instead of just one (or very few) because it makes it more likely that we included relevant choices considered by the acquirer. The results are robust to using significantly fewer than eight to ten counterfactuals, as we report later.

Dependent variable. Based on these procedures, the dependent variable is *target choice*$_{ij}$, coded as 1 if a firm *i* acquired target *j*, and 0 otherwise. Table 1 shows one of the resulting matched choice sets in our sample. In that case, Hyseq Pharmaceuticals acquired Variagenics in 2002. Based on technological and therapeutic criteria, the propensity score model estimated the probability of Variagenics being acquired at 48.5 percent. What matters most, however, is how similar the ten counterfactual targets are to Variagenics. The next best match was Gensci Regeneration Sciences, estimated to be 47.9 percent likely to be acquired—only .64 percent less likely than Variagenics. Each remaining firm in the choice set is a progressively worse match.

Measuring Expected Network Synergy

Testing our hypotheses requires that we measure the structural change in the network generated by acquiring the ultimate or counterfactual targets in the choice set. We describe the overarching approach before delving into the specific measures. Our first step was to assess the network structure in the year prior to the acquisition. We then constructed the resulting network if the acquirer's node and the ultimate target's node were collapsed into one, with the acquirer inheriting the target's ties. We measured the resulting change in the acquirer's structural position relative to the pre-acquisition year. Next, we ''reset'' the network to what it looked like prior to the acquisition. We then reconstructed the resulting network if the acquirer's node and the node corresponding to the next-most-similar firm in the choice set were collapsed into

one. We measured the resulting change in the acquirer's structural position for this potential choice. Then we reset the network and repeated this process for all potential options in the choice set.[3]

Our approach allowed us to assess how acquisitions change any network metric of interest. Guided by the hypotheses, we measured changes in structural holes and in network status as indicators of network synergy. We used Burt's (1992) constraint measure of structural holes and Bonacich's (1987) eigenvector centrality measure of network status. Declining constraint indicates an increase in access to structural holes, while increasing eigenvector centrality indicates an improvement in network status. We labeled the measures *change in constraint* and *change in status*. Both capture the proportional change in the relevant measure as follows: [(post-acquisition measure – pre-acquisition measure)/pre-acquisition measure]. We opted to use the proportional change because the impact of the change on the acquirer's standing in the network depends on its initial position. For instance, a decline in constraint of .25 is more meaningful for a firm that had an initial constraint score of .50 (50 percent change) than for one that had an initial score of .75 (33 percent change).

Controls

We accounted for factors that, if omitted, might correlate with the network change variables and confound our inference that network synergy determines target choice. For all measures involving patents or alliances, we always accounted for any acquired patents or alliances from acquisitions made in years prior to the focal year. We controlled for previously documented, non-network sources of synergy. In biotechnology, such synergies are most strongly driven by complementarities in technological capabilities or therapeutic areas (Schweizer, 2005; Higgins and Rodriguez, 2006), which we verified in discussions with industry experts. We thus controlled for *overlap in patent classes*, measured as the number of patent classes in which the target has ever patented and in which the acquirer has also patented. We also controlled for *overlap in disease areas*, measured as the number of disease areas in which the target has worked collaboratively and in which the acquirer has also conducted any kind of collaborative activity (e.g., research, commercialization, licensing, acquisitions) within the preceding five years.[4]

Relational history between the acquirer and target can enhance the odds of an acquisition, as the acquirer may be able to obtain more accurate information about the target, or the two may have developed a degree of trust that augurs

[3] The network had to be ''reconstructed'' 4,019 times, once for each row in the dataset (i.e., for each potential acquisition across all choice sets). Given the intensity of the calculations involved, we built a custom program using Python that automatically collapsed nodes, calculated metrics of interest, and reset the network for the next collapse. The authors are willing to share the program upon request.

[4] RECAP captures firms' projects in collaboration with others (e.g., alliances, acquisitions, licensing) but not firms' internal, non-collaborative projects. Hence *overlap in disease areas* may miss the activities of firms that do not actively collaborate. This control is sufficient for our purposes, however, as it relates to the types of synergies from external activities of main interest in this paper. Further, given the high rate of collaboration in this industry, we expect that internal and external activities are likely to be highly correlated.

a successful integration process (e.g., Zaheer, Hernandez, and Banerjee, 2010). Hence we included *pre-acquisition tie*, coded as 1 if the acquirer and target had an alliance in the five years prior to the deal and 0 otherwise.

As anticipated based on our analysis from figure 2, the number of *common partners* between the acquirer and target pre-acquisition will play an important role as a contingency variable to help us ascertain whether network synergies or other mechanisms affect the likelihood of acquisition. We also included this measure as a control because prior research has argued that overlapping networks can affect tie formation and stability (Gulati and Gargiulo, 1999; Polidoro, Ahuja, and Mitchell, 2011).

We included a count of the *target's total patents* up to the year of acquisition to proxy for the target's accumulated technological capabilities. We also controlled for the average *stage* of development of the target's various R&D alliances, as research has shown that firms tend to pay higher premiums for targets with internal activities near commercialization (Higgins and Rodriguez, 2006), and acquirers may value targets with either early- or late-stage alliance portfolios depending on their objectives (e.g., research vs. marketing). We captured the stage of development based on nine phases identified by RECAP: formulation, discovery, lead molecule, preclinical, phase 1, phase 2, phase 3, BLA/NDA (Biologic License Application/New Drug Application) filed, and approved. Each is progressively closer to commercialization. Our measure captures the average (on a scale of 0 to 8) of all the firm's collaborative activities in the previous five years as identified in RECAP. The results are similar if we include counts of activity in each of the eight phases as separate variables instead of the average stage.

Firms active in many technological domains are likely to have networks with many structural holes. Buying such firms would enhance the acquirer's access to structural holes, but this would be a reflection of the desire to purchase technologically diversified targets and not necessarily of the pursuit of network synergies. We thus added the following controls: *disease diversification* and *patent class diversification*, which capture the number of distinct disease areas in which the target has engaged in collaborative projects within the prior five years and the number of distinct classes in which the target has patented, respectively.

The propensity to acquire another firm may be related to geographical considerations, so we included the indicator *same country* to capture whether the acquirer and potential target are headquartered in the same (= 1) or a different (= 0) country. Acquiring foreign firms is more difficult due to liabilities of foreignness (e.g., Zaheer, Hernandez, and Banerjee, 2010), so we expect acquisitions among same-country firms to be more likely. Finally, we added the number of *prior acquisitions by the target* before the focal year. Acquisitions are a key means of obtaining valuable internal or external resources, and the attractiveness of a potential target may be affected by its degree of involvement in the corporate market.

We did not include two potentially relevant controls: structural holes and eigenvector centrality of the target, pre-acquisition. Ideally, including these would allow us to separate the effects of network synergies from the effects of the desirability of the target's network per se. But any change in the

acquirer's position resulting from the acquisition (i.e., network synergies) reflects, in part, the target's pre-acquisition position. Thus the two are collinear.[5] Because of this empirical challenge, we relied on the theoretical guidance from our previous discussion of how to distinguish network synergies from alternative explanations to guide our efforts in isolating network synergy (see figure 2).

With respect to controlling for other factors, the estimation procedure we used directly accounts for attributes of the acquirer and for contextual factors not specific to a given target (e.g., timing, industry conditions, opportunity environment) that affect the acquirer's decision.

Estimation

We employed McFadden's (1974) conditional logit estimator, a form of discrete choice analysis suited for when actors choose from a ''menu'' of alternatives with varying attributes (see Rogan and Sorenson, 2014, for an application to acquisition target choice). Underlying the estimator is an unobserved equation, $\pi_{ij} = \beta x_{ij} + \varepsilon_{ij}$, where π_{ij} is the expected benefit firm *i* gets from acquiring target *j*, x_{ij} is a series of attributes firm *i* observes in target *j*, and ε_{ij} is a random error capturing imperfect decision making by the acquirer and unobservable target attributes that affect the benefit of acquiring target *j*. Based on this unobserved π_{ij} and assuming that ε_{ij} is a Type I extreme-value independent random variable, the probability that firm *i* acquires target *j* (i.e., target *j* results in the highest expected benefit for acquirer *i*) can be expressed in a logit equation: $\Pr(y_i = j) = e^{\beta x_{ij}} / \sum_j e^{\beta x_{ij}}$. The conditional logit estimator uses variation across potential choices ''within chooser'' to obtain estimates. This differs markedly from unconditional logit estimators because an acquirer's characteristics and other factors not related to a specific target are conditioned out (and thus controlled for) by the conditional estimator.

The β captures whether a potential target's characteristics increase or decrease the likelihood of being acquired relative to other firms in the choice set. For example, a positive coefficient for *change in status* is interpreted as an acquirer being more likely to choose a firm as a target if that target is more likely to increase the acquirer's status. Unlike in a linear model, β does not represent the marginal effect on the probability of selecting a target. The magnitude of a variable's effect can be calculated only when all choice sets in the sample consist of identical alternatives (Greene, 2008). This does not apply in our case because each acquirer considers an idiosyncratic set of targets. To assess the magnitude of the effects, we reestimated the results using linear probability models (LPM) with investment fixed effects.[6] These will be unbiased yet less efficient relative to the conditional logit. All models include robust standard errors.

[5] The correlation between *change in eigenvector centrality* (our network synergy measure) and the centrality of the target prior to acquisition is over .96. The correlation between *change in constraint* (our network synergy measure) and the constraint of the target prior to acquisition is over .59. In sensitivity analyses, specifications that include both measures exhibit results with unstable coefficient estimates that reflect collinearity.

[6] The LPM results also give us a straightforward way to interpret coefficient estimates in specifications that include interaction terms, which are challenging to interpret in linear models.

Table 2. Descriptive Statistics

Variable	(1) Mean (full sample)	(2) Mean (acquired)	(3) Mean (not acquired)	(4) S.D. (full sample)	(5) S.D. (within choice sets)	(6) S.D. (between choice sets)	(7) Min. (full sample)	(8) Max. (full sample)
Target choice	.094	1	0	.292	.292	.005	0	1
Change in constraint	−.271	−.309	−.267	.272	.163	.219	−.972	.250
Change in eigen. centrality	.009	.013	.009	.015	.013	.008	−.007	.208
Common partners	.217	.886	.148	1.069	.972	.452	0	25
Pre-acquisition tie	.027	.159	.013	.161	.151	.056	0	1
Overlap in disease areas	.388	.503	.376	.414	.292	.293	0	1
Overlap in patent classes	.758	.799	.754	.351	.179	.302	0	1
Stage (target)	1.302	1.402	1.292	1.729	1.615	.616	0	8
Total patents (target)	21.30	39.94	19.37	77.52	73.18	25.40	1	3559
Same country	.476	.647	.458	.499	.378	.327	0	1
Prior acquisitions (target)	.225	.332	.214	.744	.682	.300	0	22
Disease diversification (target)	2.884	3.607	2.809	2.814	2.303	1.627	0	27
Patent class diversification (target)	3.287	3.531	3.262	1.855	1.685	.776	1	8

RESULTS

Table 2 provides descriptive statistics. Columns 5 and 6 include the standard deviations of the variables within and across choice sets, respectively. This shows that there is sufficient variation in the measures within the choice sets to provide statistical traction and addresses a plausible concern that variation in network synergies exists only across observed (but not counterfactual and observed) deals. Columns 2 and 3 include the means of the variables for the 377 acquired deals and the 3,642 counterfactual deals. Within the acquired deals (column 2), the average change in constraint is negative (–.309), and the average change in eigenvector centrality is positive (.013). These changes are significantly different from zero ($p < .01$ in both cases). The average change in constraint is more negative for the acquired firms (–.309, column 2) than for the non-acquired counterfactuals (–.267, column 3) ($p < .01$). Similarly, the average increase in status is greater for the acquired than the non-acquired groups (.013 compared with .009, $p < .01$). Although not sufficient to provide inference, these descriptive statistics are consistent with our hypotheses. The fact that the means of our variables of interest are similar in size and magnitude across realized and counterfactual acquisitions suggests that the matching procedure grouped firms with similar network characteristics, reducing unobserved heterogeneity. This makes our empirical tests conservative by narrowing the range of variance compared with using less stringent matching criteria. Table A1 in the Online Appendix (http://journals.sagepub.com/doi/suppl/10.1177/xxxxxxxxxxxxxxxx) summarizes the correlations among the variables.

Table 3 includes a summary of the results for the main effects. Model 1 includes only the control variables and reinforces our expectation that

Table 3. Conditional Logit (Main Effects)*

Variable	Model 1 Controls	Model 2 Constraint	Model 3 Eigen. centrality	Model 4 Full model (main effects)
Change in constraint		−.9536•••		−.7497••
		(.3313)		(.3729)
Change in eigen. centrality			9.7289•••	5.7521•
			(3.7075)	(4.3085)
Pre-acquisition tie	2.7835•••	2.8309•••	2.8042•••	2.8319•••
	(.2663)	(.2698)	(.2674)	(.2693)
Overlap in disease areas	1.1953•••	1.1907•••	1.2010•••	1.1946•••
	(.1947)	(.1981)	(.1948)	(.1975)
Overlap in patent classes	1.2895•••	1.3142•••	1.2958•••	1.3129•••
	(.3397)	(.3498)	(.3396)	(.3477)
Stage of activities (target)	.0235	.0143	.0226	.0156
	(.0335)	(.0352)	(.0340)	(.0353)
Total patents (target)	.0022•••	.0023•••	.0021••	.0022•••
	(.0008)	(.0008)	(.0009)	(.0008)
Same country	1.3943•••	1.3840•••	1.3970•••	1.3877•••
	(.2031)	(.2063)	(.2044)	(.2066)
Prior acquisitions (target)	.0880	.0745	.0819	.0737
	(.0641)	(.0618)	(.0627)	(.0615)
Disease diversification (target)	.0657•••	.0465••	.0434•	.0372
	(.0225)	(.0225)	(.0226)	(.0228)
Patent class diversification (target)	.0213	.0129	.0171	.0124
	(.0367)	(.0374)	(.0373)	(.0376)
Model chi^2	224.55•••	233.10•••	226.83•••	234.02•••
Log likelihood	−726.75•••	−723.14•••	−724.24•••	−722.42•••
Pseudo R^2	.1849	.189	.1878	.1898

•$p < .10$; ••$p < .05$; •••$p < .01$; one-tailed for independent variables, two-tailed for control variables.
*Sample size = 4,019 and number of acquisitions = 377 for all models. Robust standard errors are in parentheses.

technological and therapeutic considerations influence target selection. Firms are significantly more likely to acquire targets that work in the same patent and disease areas and that have stronger patenting records. Having an alliance with a firm also enhances the likelihood of later acquiring it. Firms are also more likely to acquire domestic targets and those that have high levels of diversification across disease areas, although this latter effect disappears in subsequent models.

Main effects. In models 2–4 of table 3 we progressively add the measures of network synergy. In model 2, we find that firms are more likely to acquire targets that produce expected declines in network constraint (i.e., increase structural holes). In model 3, we find that firms are more likely to acquire targets that produce expected increases in eigenvector centrality (i.e., improve status). When we include both measures in model 4, they keep the same signs. The decline in constraint remains significant, while the increase in eigenvector centrality becomes marginally significant.

To assess effect sizes, we turn to the linear probability model (LPM) estimates; see model 4a in table A2 in the Online Appendix. The LPM is a less efficient estimator than the conditional logit, so the significance level of some

coefficient estimates is expectedly lower. A one-unit decline in network constraint increases the probability of choosing that target by about 6 percent, while a one-unit change in eigenvector centrality increases that target choice by about 45 percent. To better calibrate these effects, we assess how a change from one standard deviation below to one standard deviation above the sample mean affects the predicted probability of a target being acquired.[7] Such a decline in constraint increases the probability of acquisition by 3.49 percent, while such an increase in eigenvector centrality increases the probability of acquisition by 1.41 percent. As a reference, a similar change in a target's total patents (i.e., a target with just over 90 patents vs. one with a single patent) enhances that target choice by 2.75 percent. Similar standard deviation changes for overlap in disease areas and patent classes have effects of 6.97 percent and 8.79 percent, respectively. These comparisons suggest that expected network changes make a meaningful difference in the choice of an acquisition target, comparable with other factors known to be important from prior literature. Also important is that the effect sizes are not so large as to be implausible.

Assessing the hypothesized mechanism. Models 5–11 of table 4 present our tests to isolate network synergies from target quality, based on the expectations derived from figure 2. First, the more common partners the acquirer and target have, the more the acquisition should produce structural hole synergies but the less it should produce status (centrality) synergies. Models 5 and 6 show results consistent with this expectation. Controlling for *common partners* in model 5 decreases the magnitude and significance of *change in eigenvector centrality*. In contrast, the negative effect of *change in constraint* remains similar in magnitude and statistically significant. This suggests that acquirers value targets with overlapping ties as a means to decrease constraint. The interaction in model 6 reinforces this interpretation. More common partners between the acquirer and target enhance the preference for constraint-reducing targets but weaken the preference for status-enhancing targets, supporting the notion that structural hole synergies arise from the collapse of the acquirer and target into a single node. They also provide evidence that centrality synergies cannot arise from common partners. We confirmed these findings using the LPM (models 5a and 6a of table A2 in the Online Appendix), with the magnitude of a decline in constraint roughly doubling for each common partner between the acquirer and target (from -5.4 percent to -10.1 percent). The marginal effect of increasing eigenvector centrality goes from 59 percent to zero with approximately two common partners.

Second, new ties are necessary but not sufficient to produce status synergies. To do so, any new ties must also complement the acquirer's preexisting capabilities or network relationships. To empirically assess this, we posit that targets with three attributes should be especially desirable to produce status-based synergies: (1) they bring new types of prominent partners that the acquirer did not have before (complementarity), (2) they are otherwise hard to obtain if not for the acquisition, and (3) the new relationship is likely to endure post-acquisition (inheriting the ties matters). Alliances with universities meet

[7] Some variables are not normally distributed. If the minimum or maximum was closer to the mean than one standard deviation below or above the mean, respectively, we used the minimum or maximum, respectively.

Table 4. Conditional Logit (Interaction Effects)*

Variable	Model 5 Common part. (control)	Model 6 Common part. (interaction)	Model 7 Univ. ties	Model 8 First univ. ties	Model 9 Diversified acq. (disease)	Model 10 Diversified acq. (patent)	Model 11 Diversified acq. (disease, patent)
Change in eigen. centrality × Ties to univ. (target Y, acquirer N)				17.5317•••			
				(7.4603)			
Ties to university (target Y, acquirer N)				−.5972••			
				(.2463)			
Change in eigen. centrality × Ties to univ. (target)			13.0504••				
			(7.2009)				
Ties to university (target)			-0.2164				
			(0.2048)				
Change in constraint × Acquirer tech. div. (disease) high					−2.6619•••		
					(.9015)		
Change in constraint × Acquirer tech. div. (patent) high						−1.8640•••	
						(.7349)	
Change in Constraint × Acquirer tech. div. (patent & disease) high							−2.4836•••
							(.9689)
Change in constraint × Common partners		−1.3002••					
		(.5986)					
Change in eigen. centrality × Common partners		−8.3529••					
		(3.6300)					
Change in constraint	−.8493••	−.6102•	−.9984••	−1.1462•••	−.5696•	−.3242	−.6370••
	(.3775)	(.3789)	(.4014)	(.4035)	(.3871)	(.4183)	(.3844)
Change in eigen. centrality	2.9213	7.4542•	−2.5150	−3.5800	.5996	.0823	.8446
	(4.5089)	(4.6301)	(6.0599)	(5.9264)	(4.8380)	(4.6994)	(4.7883)
Common partners	.4187•••	.3570•••	.4190•••	.4128•••	.3885•••	.4109•••	.3868•••
	(.1050)	(.1311)	(.1047)	(.1060)	(.1042)	(.1057)	(.1046)
Pre-acquisition tie	2.4583•••	2.4405•••	2.4841•••	2.4996•••	2.4782•••	2.4870•••	2.4786•••
	(.3047)	(.3109)	(.3064)	(.3076)	(.3036)	(.3066)	(.3039)
Overlap in disease areas	1.1726•••	1.1849•••	1.1764•••	1.1802•••	1.1680•••	1.1715•••	1.1715•••
	(.2008)	(.2033)	(.2001)	(.1997)	(.2044)	(.2022)	(.2029)
Overlap in patent classes	1.2166•••	1.2120•••	1.2162•••	1.2334•••	1.1880•••	1.1546•••	1.1785•••
	(.3457)	(.3493)	(.3441)	(.3443)	(.3379)	(.3360)	(.3396)
Stage of activities (target)	.0160	.0147	.0172	.0145	.0169	.0178	.0178
	(.0355)	(.0357)	(.0354)	(.0352)	(.0358)	(.0356)	(.0356)
Total patents (target)	.0023•••	.0023•••	.0021••	.0020••	.0022••	.0022••	.0021••
	(.0009)	(.0009)	(.0009)	(.0009)	(.0009)	(.0009)	(.0009)
Same country	1.3767•••	1.3511•••	1.3854•••	1.3945•••	1.3715•••	1.3699•••	1.3786•••
	(.2089)	(.2117)	(.2100)	(.2097)	(.2070)	(.2094)	(.2090)
Prior acquisitions (target)	.0773	.0698	.0711	.0656	.0754	.0691	.0768
	(.0613)	(.0609)	(.0596)	(.0595)	(.0588)	(.0624)	(.0595)
Disease diversification (target)	.0183	.0220	.0188	.0197	.0081	.0118	.0112
	(.0242)	(.0249)	(.0245)	(.0243)	(.0247)	(.0243)	(.0246)
Patent class diversification (target)	.0051	.0040	.0056	.0096	.0060	.0045	.0069
	(.0377)	(.0376)	(.0377)	(.0376)	(.0378)	(.0381)	(.0378)
Model chi^2	207.31•••	236.33•••	206.65•••	212.36•••	221.47•••	210.05•••	216.31•••
Log likelihood	−710.72•••	−706.26•••	−709.40•••	−707.57•••	−706.77•••	−707.48•••	−707.76•••
Pseudo R^2	.2029	.2079	.2044	.2065	.2073	.2066	.2062

•$p < .10$; ••$p < .05$; •••$p < .01$; one-tailed for independent variables, two-tailed for control variables.

*Sample size = 4,019 and number of acquisitions = 377 for all models. Robust standard errors are in parentheses.

these criteria for biotechnology firms. Compared with alliances with for-profit entities, ties to universities are more focused on basic science (e.g., Edwards, Murray, and Yu, 2003; Stuart, Ozdemir, and Ding, 2007), whose longer development cycles result in more enduring alliances (Edmondson et al., 2012). University ties are harder to establish because they require cultivating relationships with individual academic scientists or because institutions lack established procedures for alliances (Zucker, Darby, and Armstrong, 2002). Hence universities form fewer alliances than for-profit partners that have professional managers (Santoro and Betts, 2002; Edmondson et al., 2012). These factors make academic alliances hard to obtain through typical alliance formation channels (Mindruta, 2013).

We explored whether this holds in the data with two steps. First, we interacted *change in eigenvector centrality* with an indicator of whether the *target has a tie to a university* in model 7 of table 4, and the interaction is significant. This is consistent with our expectation, but targets with ties to universities could also be of particularly high quality in the first place. We thus went a step further to get at the value of the *complementarity* between the acquirer's and target's networks. To do so, we created an indicator of whether the *target has a tie to a university but the acquirer does not*. In that case, the target's ties complement the acquirer's by providing novel university access.[8] We interacted that indicator with *change in eigenvector centrality* in model 8 and found it to be positive and significant. We confirmed these results in an LPM; see table A2 in the Online Appendix, models 7a and 8a.

Third, a complementary fit between the acquirer's capabilities and the combined, post-acquisition network is sufficient to produce structural hole synergies. To get at this, we investigated whether acquirers modify their preferences for constraint-reducing targets depending on their strategic needs. Some firms in the biotechnology industry follow focused strategies by working on one or a few therapeutic or technological areas; others follow diversified strategies by doing the opposite. Focused firms should have a lower need for networks rich in structural holes than diversified firms because the latter strategically need to develop more diverse networks to access novel resources. Models 9–11 in table 4 support this conjecture. We developed three indicators of acquirers' technological diversification, categorizing firms by whether the number of disease areas (model 9) or patenting classes (model 10) in which they are actively involved, or both (model 11), are above (= 1) or below (= 0) the sample median. In all cases, we found a negative interaction between the indicator of acquirer diversification and *change in constraint*. We found similar results for the interaction terms in the LPM, and the marginal effects are meaningful. For instance, model 11a in table A2 in the Online Appendix shows that acquirers with highly diversified disease and patent portfolios are about 23 percent more likely to choose constraint-reducing targets than technologically focused acquirers.

Sensitivity to changes in the choice set matching criteria. We assessed the robustness of the results to using two alternative criteria to match actual

[8] Complementarities can exist if an acquirer and a target both have university ties. By focusing on only one indicator of complementarity, however, we advance a more conservative test.

targets to counterfactual targets. The first alternative matches were based on (1) the number of patents, (2) overlap in patenting classes, and (3) number of alliances in the firm's history, which differs from our preferred criteria by dropping consideration of overlap in disease areas and therapeutic technologies.[9] We present results using this ''patents only'' matching in table A3 in the Online Appendix. The second alternative matches were based on (1) overlap in disease areas, (2) overlap in therapeutic technologies, and (3) the number of patents, which differs from our preferred criteria by dropping consideration of patent class overlap. We present these results in table A4 in the Online Appendix. These two alternatives do not limit the sample size based on firms being listed in both the RECAP and patent databases. Rather, they limit the sample based only on one database but not the other.[10] This helps assess any biases from lacking data on either patents or therapeutic activities. As the two tables show, the results remain robust. One deviation arises in table A3 (patents only), as the interaction of *change in eigenvector centrality* with partners' ties to universities is not significant.

Assuming tie inheritance. A key assumption in the calculation of the network change measures is that the acquirer inherits all of the target's alliances. We based this assumption on the notion that relationships do not disappear after acquisitions and on the expectation that keeping preexisting assets—whether tangible or intangible—for a reasonable period after the acquisition is core to creating value from synergies. During due diligence, acquirers would make sure that partnered projects giving rise to network synergies remain. Biotechnology alliance contracts can include clauses by which the acquisition of one party may trigger the option for the non-acquired party to terminate the alliance. If these clauses were systematically invoked at the time of an acquisition, our assumption of tie inheritance would be violated.

We found no evidence that this occurred in our sample. We conducted a systematic search of news surrounding the 377 acquisitions in the main sample. We looked for evidence of alliances, ties, or collaborative activities being terminated as a result of the acquisitions, which would be material information for shareholders. We found no mentions of alliance terminations, congruent with our assumption of tie inheritance.[11] Instead, we found frequent mentions denoting that the expected value of the acquisition was coming from the

[9] We did not originally match based on the number of alliances because it is collinear with the count of activity in diseases and therapeutic areas. We include it here to maintain an indicator of prior collaborative interfirm activity.

[10] For the ''patents only'' matching, if a firm has no recorded alliances in RECAP we counted the number of past alliances as zero. For the ''therapeutics only'' matching, if a firm has no recorded patents we counted the number of past patents as zero. This removes the restriction of having to have activity recorded in both databases, recovering 480 of the acquisitions we dropped for the main analysis.

[11] One might worry that alliance terminations are not announced in this industry as a general rule (whether around acquisitions or in the regular course of business), but our media search does not validate that possibility. Because the status of external collaborations is material news that significantly affects investors' perceptions, firms frequently provide updates about their alliances. For example, on April 22, 2007 ''AtheroGenics Inc. announced that AstraZeneca has notified the Company that it is ending their collaboration to develop and commercialize AGI-1067'' (BioSpace, 2007) even though the two firms were not involved in any acquisitions in that time period. Hence, finding no evidence of terminations triggered by the acquisitions in our sample is meaningful.

continuation of partnered projects brought by the target, similar to the press releases we described earlier. Not finding mentions of tie terminations surrounding acquisitions does not invalidate the mechanism of eliminating redundant ties to common partners as a source of synergy illustrated in figure 2. When both firms have ties to the same partner, the acquirer assumes the target's original contractual alliance. The original tie is preserved, not eliminated, but it is not redundant anymore.

We also considered two empirical issues with respect to tie inheritance. First, a systematic loss of ties due to acquisitions would lower the odds of finding support for the hypotheses because expectations of network synergies would play an unimportant role in selecting a target. Second, all the alliance contracts we reviewed that contained clauses triggering potential termination due to acquisitions involved R&D activities, so R&D alliances may be the most susceptible to violating the tie inheritance assumption. We found that the results remain robust if we replicate our analysis using only R&D alliances. One exception is that the interaction between common partners and change in constraint becomes insignificant, because the R&D network has a much lower incidence of common partners among firms than the broader network.

Additional sensitivity analyses. We investigated the impact of redefining the choice set to include fewer than eight to ten of the most similar matches. The pattern of results, including the main and interaction effects, remains robust at the $p < .05$ level when reducing the number of matches to the two closest counterfactuals, and it remains at the $p < .10$ level when using only the single closest counterfactual match. Our findings are robust if we drop any deals involving ''isolate'' acquirers that did not participate in the biotechnology alliance network before the acquisition (i.e., degree centrality of zero). The results also remain significant if we use bootstrapped standard errors (based on 1,000 repetitions) or standard errors clustered by acquirer instead of robust standard errors.

DISCUSSION

By exploring the concept of network synergy, we integrate the literatures on networks and acquisitions. Although these are among the most active fields of management research, prior work on acquisitions has not focused on how changes in external network structure can be a source of synergy, and the literature on networks has not considered acquisitions as a source of structural change. Our empirical tests reveal that firms make acquisition target choices consistent with the existence of network synergies. The implications of these findings for the literatures on networks and acquisitions are intriguing.

For networks scholars, this study raises the possibility that acquisitions can help explain network origins and dynamics. Existing work almost exclusively emphasizes tie additions and deletions as the mechanics by which organizations modify their positions, and clearly tie changes explain a great deal of change for organizational networks. But the management literature has overlooked that organizations engage in other actions, such as acquisitions, that modify the nodes—instead of the ties—in the network. Perhaps this is a vestige from the origins of social networks research in studies of individuals, whose nodal

identity remains constant across time. One difference between node collapses and tie changes is that the former arguably have more impact per transaction because they allow a firm to inherit multiple ties at once (Hernandez and Menon, 2017). We illustrated this in figure 1a, as a single acquisition allowed Hyseq to inherit ten new ties in one transaction. But node collapses are not simply ''super additions'' or ''super deletions''; they have unique qualities because they offer exclusive control of the target's contractual relationships to the acquirer. This was illustrated in figure 1b: the acquisition drastically reduced the level of redundancy to allow the acquirer to increase the exclusivity of its brokerage position. For this reason, acquisitions and tie changes play different roles in the evolutionary path of networks (Hernandez and Menon, 2017). This suggests the value of further assessing how other corporate events (industry entries or exits, divestitures, significant reorganizations) modify network structure.

Studying acquisitions allows us to theorize about and empirically document purposeful behavior in network dynamics. Agency cannot explain all network change, but it is a fundamental and understudied aspect of network dynamics. As a result, we see this study as beginning to provide empirical evidence of its operation (Lin, 2001; Ahuja, Soda, and Zaheer, 2012). Firms make acquisitions with strategic objectives in mind and gain legal control over the inherited resources of the target, including contractual relationships such as alliances. Therefore, network-related considerations in the choice of a target likely reflect the acquirer's goals. This contrasts with other means of structural change, such as tie additions and deletions, in which firms' ability to orchestrate network change may be more limited by the two-sided nature of cooperative ties (Mindruta, Moeen, and Agarwal, 2016).

Our focus on synergies stemming from increases in the structural holes or the status of the focal firm revealed two distinct mechanisms by which network change produces value for a firm: structural improvement or dependency reduction (cf. Ahuja, Soda, and Zaheer, 2012). Structural improvement is reflected in synergies that bring new and complementary ties, by purchasing targets that link acquirers to high-status alters or that provide access to non-redundant partners. Dependency reduction is reflected in synergies from acquiring targets whose networks, when combined with that of the acquirer, eliminate redundancies in the ties of the two firms and make the acquirer a more exclusive broker (Ryall and Sorenson, 2007). This latter mechanism shows that node collapses are a means of achieving the control benefits of brokerage, which have long been discussed (Burt, 1992) but rarely tested empirically. This addresses a broader gap in networks research in management, which focuses on cooperative actions more than competitive actions. We hope this paper encourages more studies to consider both types of actions.

Despite the agentic focus of this study, we recognize that acquisitions can also cause networks to be restructured purely for mechanical reasons. A firm could be pursuing a non-network synergy (e.g., economies of scale) when acquiring another firm but still inherit the target's ties as a side effect. The impact on network structure exists whether firms engage in M&A to intentionally change their position or whether network effects are epiphenomenal to the deal, though the implications are different in each scenario. The evidence of synergies we offer is consistent with the intentional combination of networks via acquisitions, because that was our purpose. But future research should also consider settings in which network change is epiphenomenal, perhaps in

industries in which networks are not as valuable for firms' performance, such as those in which technological dynamism is low (e.g., food processing).

For research on M&A, our study provides a novel rationale for business combinations. Although the concept of synergy allows for multiple sources of value, we focus on a source that has not received attention. We systematically derived and tested two types of conditions that give rise to network synergies: eliminating redundant ties through node collapses and gaining new ties that complement the acquirer's preexisting network or capabilities. The former condition parallels the market power synergies discussed in prior M&A studies. In our case, firms gain network rather than market power. This raises an interesting implication: firms may not only use networks to gain resources that make them competitive in the marketplace but also may compete for network position in the process. Future research could explore this issue more deeply, for instance by considering whether firms engage in network-changing actions (including acquisitions) to undermine their rivals' structural positions. Network synergies from new complementary ties parallel internal synergies gained from combinations of internal assets, but the two are likely different. For example, the acquirer does not fully control network resources, which may affect expectations about the durability of network vs. internal synergies. This distinction raises several questions: How do the premiums paid for each type of synergy differ? How does the post-acquisition integration process vary when different types of synergies are most salient? How do various kinds of synergies affect the performance of acquirers?

Acquiring targets for their networks has its costs. Internalizing a network is not always warranted if it means inheriting the constraints of the target firm's preexisting position (Burt, 1983). Our results reflect that costs can discourage acquisitions. A network synergy is the net effect (benefits – costs) of collapsing the nodes of the acquirer and target plus inheriting the target's ties. Because the net effect arises from the combination of two networks, instead of being only a function of the target's preexisting network, the acquirer does not inherit the benefits and costs of the target's network as they were before the acquisition. We can assess the new network position only after the recombination, so our indicators of network synergy (*change in constraint* and *change in eigenvector centrality*) reflect both the benefits and costs of network change. For instance, if a potential target brings many new ties (a benefit) but results in an overall increase in constraint (a cost), this will be reflected as a negative change in constraint and, according to our results, has a negative marginal effect on the likelihood of acquisition. We hope additional research documents the costs of node collapses more directly, such as their effects on the premium paid or on the subsequent performance of the combined firms.

Another issue raised by this study is whether and how investors react to network synergies. We focus on the preferences of managers choosing a target from among a set of potential targets. Investors react later, once the actual target has been announced, so it is unclear whether they factor network considerations into their valuations. In industries in which network resources matter, investors should react positively to acquisitions that create network synergies. Nevertheless, investors are generally not privy to the consideration set of potential targets that managers evaluated and thus may have different criteria than managers to estimate the expected benefits of a business combination. This is an empirically testable implication of our study.

Our study has limitations and boundary conditions. Our analysis provides evidence of the existence of network synergies, but there could be other mechanisms and motives for acquiring targets associated with changes in the network that we could not rule out. Settings in which external resources have little effect on performance may not be amenable to network synergies. Network attributes other than structural holes and status may be more important in different contexts as well. Moreover, biotechnology has several particularities compared with other dynamic sectors of the economy (Giovannetti and Morrison, 2000; Cohen, 2010), so the findings may not be generalizable to other industries. Further, while the concept of network synergy and the general proposition are applicable to multiple types of interorganizational ties, we have focused our hypotheses on alliance networks. It would be interesting to study whether firms pursue network synergies in other networks (e.g., board interlocks) and whether they follow a unified strategy to obtain them from their entire portfolios of ties or use acquisitions to gain distinct network synergies from different types of network ties.

By providing empirical evidence that firms make acquisitions with network synergies in mind, this study offers insights about network dynamics gained by combining research on networks and acquisitions. Our findings create significant opportunities for furthering our understanding of how organizations use acquisitions to create value through their network positions and to manage network dynamics strategically.

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Supplemental Material

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