Characteristics of innovation-driven interfirm alliances, 1957-2006:

Analysis and research directions

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1 Introduction

Innovation-driven interfirm alliances are formal agreements between otherwise independent firms that contain explicit arrangements for (joint) research and development (R and D) and technology sharing. Descriptive evidence shows that innovation-driven alliances have become dramatically more prevalent over time (Hagedoorn 2002) and the empirical literature has followed suit. Available research is now extensive and centered on understanding alliance formation (e.g., Ahuja 2000b; Powell *et al.* 1996; Stuart 1998) and partner selection (e.g., Gulati 1995; Rothaermel & Boeker 2008; Sytch *et al.* 2011), alliance organization (e.g., Oxley 1997; Oxley & Sampson 2004; Pisano 1989), and the performance consequences of alliances (e.g., Ahuja 2000a; Baum *et al.* 2000; Frankort 2016; Gomes-Casseres *et al.* 2006; Hagedoorn & Schakenraad 1994; Mowery *et al.* 1996; Rothaermel & Deeds 2004; Stuart 2000).

The majority of the existing studies examining innovation-driven alliances have focused on establishing the consistency of empirical data with testable implications derived from theory. Far fewer provide a more basic description of the empirical data per se, and we are aware of no study methodically documenting a range of transaction-level alliance characteristics over time and across sectors. A comprehensive inventory of key facts about the characteristics of innovation-driven alliances is valuable, however, because it can broaden insight into this consequential phenomenon as well as uncovering trends, patterns, and relationships in need of explanation and further understanding.

To make headway in this area, we use data drawn from the Cooperative Agreements and Technology Indicators (CATI) data set to document temporal trends and sectoral patterns in, as well as relationships among, four key alliance characteristics. Specifically, we summarize and analyze transaction-level data on cooperative form, sectoral scope, the number of partners, and geographic scope in a sample of 14,377 innovation-driven alliances established across a dozen

broad sectoral categories during the fifty-year period from 1957 to 2006. In a more forward-looking fashion, we subsequently use our descriptive analyses to explore possible avenues for further research.

We focus specifically on cooperative form, sectoral scope, the number of partners, and geographic scope in innovation-driven alliances because these characteristics are of substantive importance to partnering firms. Cooperative forms, as well as the governance structures they imply, have long been viewed as important levers conditioning collaborative benefits (e.g., Oxley 1997; Pisano 1989). Similarly, sectoral scope—i.e., the number of technology fields targeted in an alliance—may constitute an important determinant of ex post cooperation (e.g., Hamel *et al.* 1989; Khanna 1998), while the number of partners in an alliance can also meaningfully alter alliance outcomes (e.g., Davis 2016; Heidl *et al.* 2014; Li *et al.* 2012). Finally, much has been written about the geographic scope of alliances, for example, in terms of the diverging strategic concerns involved in domestic versus international alliances (e.g., Mowery 1998; Reich & Mankin 1986).

By way of motivation, we first review representative prior studies supplying descriptive evidence on innovation-driven alliances. We then define and summarize our sample, after which we describe temporal trends and sectoral patterns in cooperative form, sectoral scope, the number of partners, and geographic scope at the alliance level. Next, we use a multivariate regression framework to explore correlates of, and relationships among, these four transaction-level alliance characteristics. Based on our descriptive analyses, we close by exploring a variety of further research directions.

2 Prior literature and motivation

Following some initial evidence on the existence of formal interfirm alliances focused on R and D (e.g., Berg & Friedman 1977; Harrigan 1985; Mariti & Smiley 1983; Pisano *et al.* 1988),

in the early 1990s scholars began documenting systematic descriptive data on such innovation-driven alliances. Our review of this literature suggests that available evidence furnishes insight predominantly into one or multiple of the following six aspects:

1. *Alliance prevalence*—i.e., how the propensity to engage in innovation-driven alliances varies over time and/or across sectors.
2. *Cooperative form*—i.e., whether innovation-driven alliances are governed by an equity-based joint venture or a nonequity contractual agreement.
3. *Internationalization*—i.e., the extent to which innovation-driven alliances involve partner firms from distinct home countries.
4. *Key players*—i.e., which firms are most actively engaging in innovation-driven alliances?
5. *Motivations*—i.e., what are the major motivations for firms to engage in innovation-driven alliances?
6. *Network structure*—i.e., what are some of the key features of the aggregated network of innovation-driven alliances?

--- Insert Table 1 about here ---

Table 1 shows twenty prior studies providing systematic descriptive evidence on innovation-driven alliances published since 1992, for each indicating which of the above six aspects were covered. The studies have applied sampling windows spanning an average of about fifteen years, often covering the 1980s and 1990s. Also, while cooperative forms and geographic scope have each previously been documented in some detail (i.e., Cooperative forms and Internationalization in Table 1), we note an apparent lack of emphasis on sectoral scope and numbers of partners at the alliance level. Moreover, cooperative forms have typically been treated rather coarsely as discrete governance alternatives (i.e., equity versus nonequity), even though alliances within either governance category can come in distinct forms. Finally, few have

explored relationships among the cooperative form, sectoral scope, number of partners, and geographic scope of innovation-driven alliances.

Based on these observations, we add to available descriptive research by extending the sampling window to a total of fifty years from 1957 to 2006, and by focusing on temporal trends and sectoral patterns in, as well as relationships among, a number of transaction-level characteristics of innovation-driven alliances—specifically, cooperative form, sectoral scope, the number of partners, and geographic scope. We orient our descriptive analyses around two questions. The first is this: *What are some of the major temporal trends and sectoral patterns in cooperative forms, sectoral scope, numbers of partners, and geographic scope in innovation-driven alliances?* In addition, transaction-level alliance characteristics conceivably comprise an interdependent system of decisions (Li *et al.* 2008; Oxley 2009), which perhaps explains some of the broader trends and patterns in the data. Hence our second question: *To what extent are cooperative forms, sectoral scope, numbers of partners, and geographic scope related at the level of individual alliances, and to what extent do such relationships account for the major trends and patterns in innovation-driven alliances?*

3 Data and sample

We use alliance data drawn from the CATI data set, a well-established, comprehensive, and widely-used source of data on innovation-driven interfirm alliances (Hagedoorn 2002). While the CATI data set clearly captures only a sample of innovation-driven alliances, in a recent study Schilling (2009) concluded that the CATI data were strongly consistent with other large data sets (e.g., SDC, RECAP) in sectoral composition, alliance activity over time, and geographic participation. A unique feature of the CATI data set, however, is its unusually extensive longitudinal coverage that starts several decades before most other data sets.

Here, we consider alliances in the CATI data set established during the fifty-year period from 1957 to 2006, and focus specifically on alliances organized under one of the following five cooperative forms, three of which are nonequity forms and two of which are equity forms:

1. The *research and development contract* (RDC), a nonequity alliance in which one firm performs R and D financed by the other.
2. The *joint development agreement* (JDA), a nonequity alliance in which firms collaborate to develop new technology, products, or processes.
3. The *joint research pact* (JRP), a nonequity alliance in which firms undertake research projects with shared resources, such as a new lab.
4. The *joint venture* (JV), an equity alliance with arrangements for the mutual transfer of technology or joint research, in which partner firms (the parents) combine their economic interests in a separate firm (the child).
5. The *research corporation* (RC), an equity alliance with the sole purpose of undertaking specific research programs, in which partner firms (the parents) combine their economic interests in a separate firm (the child).

Across these five cooperative forms, our analysis sample contains a grand total of 14,377 innovation-driven alliances involving 10,254 (mostly business) entities, which hereafter we will simply refer to as 'firms'. A minority of the sampled alliances (698 or 4.86 percent) contain elements of multiple cooperative forms. Among those, the overwhelming majority (686 or 98.28 percent) combine a RDC with a JDA. To obtain five sets of cooperative forms that are mutually exclusive and collectively exhaustive, we categorized such alliances as JDAs, the more intensive of the two forms. In all sampled alliances, 2,087 (14.52 percent) are RDCs; 8,769 (60.99 percent) are JDAs; 286 (1.99 percent) are JRPs; 3,122 (21.72 percent) are JVs; and 113 (0.79 percent) are RCs.

Beyond cooperative form, we also have information on the sectoral focus of each alliance. Sectoral focus is based on an alliance-level coding of the distinct field(s) of technology covered by an individual alliance, which we aggregated into twelve categories: (1) biotechnology and pharmaceuticals; (2) information technology; (3) aerospace and defense; (4) new materials; (5) instruments and medical equipment; (6) automotive; (7) chemicals; (8) consumer electronics; (9) engineering, drilling, and mining; (10) electrical equipment; (11) food and beverage; and (12) other. Importantly, the sectoral focus of an alliance tells us nothing in principle about the industry affiliation(s) of the firms forming that alliance; it captures the sectoral focus of the alliance irrespective of the product market affiliations of the partners. For example, in the period 1985-1994, Eastman Kodak was among the most prolific collaborators in biopharmaceutical alliances (Roijakkers & Hagedoorn 2006, p. 441), despite its predominant affiliation to the photographic equipment and supplies industry. Most alliances have a narrow sectoral scope, focusing their activities on one sector (13,231 or 92.03 percent), while some have a broad sectoral scope, focusing on two sectors (1,078 or 7.50 percent), or three or four sectors (68 or 0.47 percent).

In addition, we have information on the number of partners in each alliance and their home countries. In all alliances, most are dyadic alliances established between two firms (12,960 or 90.14 percent); another 946 (6.58 percent) are triadic multipartner alliances established among three firms; and the remaining 471 alliances (3.28 percent) are multipartner alliances among four or more firms. In terms of geographic scope, 6,372 alliances (44.32 percent) are among firms with identical home countries, while 8,005 (55.68 percent) are international alliances in which the partner firms together represent at least two distinct home countries. Firms located in the USA dominate in our sample, as 10,313 alliances (71.73 percent) involve at least one US firm, followed at a distance by Japanese firms, which are involved in 2,527 alliances (17.58 percent).

--- Insert Figure 1 about here ---

Before assessing key alliance characteristics in more detail, we briefly characterize the frequency of alliance formations over time and across sectors. Figure 1 shows annual numbers of newly established alliances from 1957 to 2006, as well as annual shares of alliances in all high-tech sectors (i.e., alliances with a sectoral focus on biotechnology and pharmaceuticals, information technology, aerospace and defense, and/or new materials) in all newly established alliances. The number of newly established alliances has increased markedly over time; innovation-driven alliances were relatively rare until the mid-1970s, while alliance activity began to take serious shape only after 1975. Figure 1 also shows that the share of alliances in high-tech sectors has increased sharply over time, from mostly (well) below fifty percent until the late 1970s to around ninety percent since the early 2000s. Among high-tech sectors, information technology consistently witnessed the highest level of alliance activity until the turn of the century, after which biotechnology and pharmaceuticals took the lead, with numbers of newly established alliances increasing by over 160 percent between 2000 and 2006.

4 Trends and patterns in alliance characteristics

We now turn our attention to alliance characteristics and focus specifically on cooperative form, sectoral scope, the number of partners, and geographic scope. We first outline temporal trends and then discuss sectoral patterns.

4.1 Temporal trends

--- Insert Figure 2 about here ---

Starting with cooperative forms, Figure 2 shows annual shares of equity alliances (JVs and RCs), RDCs, JDAs, and JRPs in all newly established alliances during the sampling window. We combine JVs and RCs into one category due to the low rate of occurrence of RCs even among equity alliances. Equity alliances dominated from 1963 until the end of the 1970s (variance in the period until 1962 is attributable to low numbers of newly established alliances—

four point five on average per year), though the decline in equity alliances signified the progressive prevalence of nonequity alliances since 1966. The share of equity alliances continued to drop until the end of the sampling window, eventually falling consistently below thirty percent since 1990, below twenty percent since 1994, and below ten percent since 2001. Counterbalancing this decline in equity alliances was an increase in nonequity forms, which was initially concentrated in JDAs, reaching a peak in 1995 at about eighty-four percent, after which RDCs rapidly became more prevalent. JDAs consistently represented the most prevalent cooperative form among nonequity alliances, while JRPs were relatively uncommon throughout the sampling window.

--- Insert Figure 3 about here ---

Figure 3 shows how the sectoral scope, number of partners, and geographic scope of alliances evolved over the sampling window. First, the share of multisector alliances—i.e., alliances with a broad sectoral scope, focusing their activities on at least two sectoral categories—was generally low until the beginning of the 1990s but consistently above ten percent since 1995, eventually reaching eighteen percent (163 out of 911 alliances) in 2006. Second, after some early peaks at around thirty percent, the share of multipartner alliances—i.e., alliances among at least three firms—declined gradually over time, stabilizing at around six percent since 1999. Third, the share of international alliances—i.e., alliances in which partner firms together represent at least two home countries—was mostly above fifty percent, with some evidence of a gradual decline between 1976 (seventy-six percent) and 1999 (forty-six percent), yet followed by an increase since, to about fifty-nine percent in 2006.

4.2 Sectoral patterns

Table 2 shows the four alliance characteristics disaggregated by time period in each of the eleven sectoral categories. We omit the ‘other’ category as it contains only thirty-one alliances.

--- Insert Table 2 about here ---

In terms of cooperative forms, two observations stand out. First, the decrease in the share of equity alliances (JVs and RCs) is evident across all sectors and virtually exclusively due to a drop in the prevalence of JVs, with no clearly discernible trend in RCs. Second, while nonequity JDAs compensate for the drop in the share of equity alliances in most sectors, RDCs disproportionally became the nonequity form of choice in biotechnology and pharmaceuticals and, to a lesser extent, chemicals. Together, the data presented in Figures 1 and 2 as well as Table 2 suggest that the steep growth in overall alliance activity was driven mostly by JDAs in biotechnology and pharmaceuticals as well as information technology, and progressively by RDCs in biotechnology and pharmaceuticals, especially since 2000.

The increase in firms' preference for broad-scope, multisector alliances (Figure 3) is evident across all sectors, though it clearly varies in extent. In addition, our categorization of sectors is broad and a more granular division into *sub*sectors would provide additional nuance. For example, even if the activities of an alliance in information technology do not span sectors, they might span IT subsectors such as computers, microelectronics, or software. Because such granular combinations are possible, the 'Multisector' measure in Figure 3 and Table 2 is best viewed as a lower bound on the extent to which alliances spanned fields of technology.

While sector-level shares of multipartner alliances do not show much of a consistent pattern, such alliances were consistently more prevalent in aerospace and defense. Moreover, the relative decline in multipartner alliances in biotechnology and pharmaceuticals appears to have shaped the somewhat negative trend in Figure 3. Finally, over half of all alliances in most sectors were of the international kind, though alliances in biotechnology and pharmaceuticals, information technology, new materials, and instruments and medical equipment were comparatively less likely international.

5 Relationships among alliance characteristics

5.1 Predicting alliance characteristics

Having mapped the cooperative form, sectoral scope, number of partners, and geographic scope of alliances each separately over time and across sectors, we now turn to a more systematic assessment of some possible correlates of these four characteristics at the level of individual transactions. Within a multivariate linear probability framework, we first model the four alliance characteristics as a function of one another, and of sectors, time, and several control variables. Modeling relationships among the alliance characteristics is motivated by the idea that choices regarding cooperative form, sectoral scope, the number of partners, and geographic scope conceivably comprise an interdependent system of simultaneous decisions at the level of individual alliances (Oxley 2009). Subsequently, with additional covariates, we are able to assess whether and how choices regarding cooperative form, sectoral scope, the number of partners, and geographic scope (still) vary over time and across sectors after accounting for possible relationships among the four characteristics.

In general form, we estimate the following system of equations:

$$Equity = \beta_0 + \beta_1 Multisector + \beta_2 Multipartner + \beta_3 International + \beta_4 DSector + \beta_5 DTime + \beta_6 Controls + \varepsilon_1, \quad (1)$$

$$Multisector = \gamma_0 + \gamma_1 Equity + \gamma_2 Multipartner + \gamma_3 International + \gamma_4 DSector + \gamma_5 DTime + \gamma_6 Controls + \varepsilon_2, \quad (2)$$

$$Multipartner = \lambda_0 + \lambda_1 Equity + \lambda_2 Multisector + \lambda_3 International + \lambda_4 DSector + \lambda_5 DTime + \lambda_6 Controls + \varepsilon_3, \quad (3)$$

$$International = \varphi_0 + \varphi_1 Equity + \varphi_2 Multisector + \varphi_3 Multipartner + \varphi_4 DSector + \varphi_5 DTime + \varphi_6 Controls + \varepsilon_4, \quad (4)$$

where *Equity* is an indicator variable that equals one if the alliance is equity based and equals zero otherwise. For parsimony, we collapse the five cooperative forms into two categories of governance structures. In Section 5.2, however, we hone in on more granular differences among the three nonequity forms. *Multisector* is an indicator variable that equals one if the alliance focuses its activities on multiple broad sectoral categories and equals zero otherwise. *Multipartner* is an indicator variable that equals one if the alliance is among more than two partners and equals zero otherwise. *International* is an indicator variable that equals one if the partner firms in the alliance together represent at least two distinct home countries and, similarly, equals zero otherwise. *DSector* is a vector of dummies for high-tech sectors and all other sectors are the reference. Moreover, *DTime* is a vector of dummies for 1970-79, 1980-89, 1990-99, and 2000-06, while 1957-69 is the reference. Finally, *Controls* is a vector of controls for the location of partner firms, general and partner-specific alliance experience, and unobserved firm-level heterogeneity. We define all control variables in the Appendix, and Panel A in Table A1 summarizes all variables.

--- Insert Table 3 about here ---

Table 3 shows seemingly unrelated linear probability estimates of the above system of Eqs. (1) through (4). Seemingly unrelated estimation is preferable because it allows the error terms ε_i to correlate across equations, which amounts to assuming that unexplained variance in an individual equation shares some common component with that in others. Supplementary analyses revealed that logistic regression estimates give similar conclusions, with only few exceptions. To facilitate comparison, Table 3 shows two sets of estimates, one without control variables and another including all controls.

Model 1 shows that equity alliances are more likely to be multisector, multipartner, and international, while multipartner alliances are more likely to be equity based, multisector, and

international, holding all other variables constant. At the same time, multisector alliances are more likely to be equity based and multipartner, while they appear no more or less likely to be international. Similarly, international alliances are more likely to be equity based and multipartner, while appearing no more or less likely to be multisector.

Model 1 also shows that alliances in the four high-tech sectors, compared to all others, are consistently less likely to be equity based and more likely to be multisector, with equity governance least likely in biotechnology and pharmaceuticals, and a broad sectoral scope most likely in new materials. Moreover, alliances in biotechnology and pharmaceuticals are less likely, and those in information technology and particularly aerospace and defense more likely, to be multipartner than those in non-high-tech sectors. Also, alliances in aerospace and defense are more likely, and those in other high-tech sectors less likely, to be international than those in non-high-tech sectors. These sectoral effects appear consistent with the descriptive data in Table 2.

In terms of temporal effects, even after accounting for relationships among the four alliance characteristics as well as sectors, Model 1 shows that alliances over time became progressively less likely to be equity based and eventually less likely to be multipartner, while initially becoming less but eventually more likely to be multisector relative to 1957-69, the reference period. Finally, alliances became progressively more likely to be international, holding other variables constant. Like the sector effects, the temporal effects are remarkably consistent with the descriptive data shown in Figures 2 and 3, the temporal trend for *International* presenting the only exception. Supplementary analyses revealed that the ambiguous trend in geographic scope (Figure 3) turns positive as soon as we account for the simultaneity of geographic scope with decisions on cooperative form, sectoral scope, and the number of partners.

More conservatively, Model 2 accounts for a number of control variables, leaving most results unchanged, with three exceptions. First, the coefficient for the information technology

dummy in Eq. (3), the *Multipartner* equation, reduces considerably in magnitude. Second, the slight reduction in the probability of an alliance being multisector in the 1980s disappears and apparently captured previously uncontrolled effects of partner-specific experience and a number of sources of firm-level heterogeneity. Third, the reduction in the probability of a multipartner alliance now has an earlier onset, in the 1990s. Despite their decreasing likelihood, however, a supplementary analysis revealed that multipartner alliances still involved as much as sixteen percent of all firms establishing alliances during 2000-06.

The results in this section suggest two conclusions. First, reciprocal and positive relationships among most of the four alliance characteristics underscore the notion that these characteristics are part of an interdependent system of simultaneous decisions (Oxley 2009). Second, temporal trends and sectoral patterns persist that cannot be attributed to relationships among the four alliance characteristics, firm location, firms' general and partner-specific alliance experience, or unobserved heterogeneity in firm-level tendencies to establish alliances with particular characteristics.

5.2 Predicting nonequity forms

Among other things, Section 5.1 shows that a number of factors systematically predict whether or not an alliance is organized under an equity-based form of governance. However, among nonequity alliances in particular, more granular differences exist in the kinds of cooperative forms that firms choose (Figure 2 and Table 2). Therefore, we now focus on the sampled nonequity alliances, by modeling partner firms' choice among the three nonequity forms as a function of sectoral scope, numbers of partners, and geographic scope, as well as sectors, time, and several control variables. Specifically, we estimate the following multinomial logistic regression specification:

$$\ln(P_i / P_0) = \beta_0 + \beta_1 Multisector + \beta_2 Multipartner + \beta_3 International + \beta_4 DSector + \beta_5 DTime + \beta_6 Controls + \varepsilon, \quad (5)$$

where P_0 is the probability that the alliance is an RDC, while P_i is the probability that the alliance is of cooperative form *i*, possible cooperative forms being the JDA (*i* = 1) and the JRP (*i* = 2). *Multisector*, *Multipartner*, *International*, and *DSector* are defined as in Section 5.1. *DTime* is a vector of dummies for 1980-89, 1990-99, and 2000-06. Thus, we now use 1957-79 as the reference because variation in some outcome categories is negligible across 1957-69 and 1970-79. Finally, *Controls* remains a vector of controls for the location of partner firms, general and partner-specific alliance experience, and unobserved firm-level heterogeneity. However, we adjust controls for partner-specific experience and unobserved heterogeneity to align with the new set of outcome categories. We document these adjustments in the Appendix, and Panel B in Table A1 summarizes all variables.

--- Insert Table 4 about here ---

Table 4 shows multinomial logistic regression estimates of Eq. (5). Similar to Table 3, we show two sets of estimates, one without control variables and another including all controls. Model 1 shows that multisector and multipartner alliances are more likely to be JDAs rather than RDCs, while multipartner and international alliances are more likely to be JRPs rather than either alternative form. Multisector alliances appear no more or less likely than narrow-scope, single-sector alliances to be JRPs rather than RDCs. Model 1 also shows systematic sector effects: alliances in biotechnology and pharmaceuticals are relatively more likely to be RDCs, while those in information technology and new materials are progressively more likely to be JDAs and JRPs. Time dummies show that, over time, alliances became less likely to be JDAs or JRPs compared to RDCs. These findings are broadly consistent with the descriptive data in Figure 2 and Table 2.

Model 2 includes all control variables, which affects two results. First, the coefficient for the biotechnology and pharmaceuticals sector in the JRP column reduces considerably in magnitude. Supplementary analysis revealed that, in this sector, systematic differences in the probability that an alliance is an RDC versus a JRP are due to underlying factors captured by partner-specific and firm-level experience effects. Second, the temporal trends all but disappear, except for the fact that JRPs are less likely than RDCs to be the cooperative form of choice during 2000-06 relative to 1957-79. Therefore, a comparison with Table 3 implies that though a strong temporal trend exists in firms' broad choice of equity versus nonequity forms, when looking at the choice among nonequity forms per se (Table 4), variance appears largely due to more micro, relational or firm-level, factors.

6 Further research directions

In this section, we build on insights from our descriptive analyses to explore a variety of further research directions.

6.1 Progressive dominance of nonequity alliances

The surge in innovation-driven alliances has overwhelmingly been due to an increase in the formation of nonequity alliances in biotechnology and pharmaceuticals as well as information technology sectors. Prior studies have suggested that the general preference for nonequity rather than equity alliances in high-tech sectors may reflect firms' desire for comparatively flexible arrangements that enable efficient responses to uncertain sector dynamics (e.g., Santoro & McGill 2005). However, with limited systematic evidence to suggest that sectors have broadly become more dynamic (e.g., McNamara *et al.* 2003), why has the share of nonequity alliances in all newly established alliances continued to increase so dramatically (Figure 2 and Table 3) and across all sectors (Table 2)?

One might argue that the general and partner-specific experience accumulated by firms and their negotiators and legal counsel has perhaps led to more detailed alliance contracts with additional contingency clauses (Ryall & Sampson 2009), substituting the need for more hierarchical governance structures, such as equity joint ventures. Yet, Model 2 in Table 3 accounts for general and specific experience effects, while the temporal pattern in governance structures persists. Therefore, we suspect that formal and informal institutional forces play an important role, either by supplying outside mechanisms shifting the comparative costs of governance (Williamson 1991), or by affecting perceptions of the lawfulness and appropriateness of alternative interorganizational forms (Scott 2014).

In terms of formal institutions, for example, intellectual property protection has improved in major alliance markets, such as the US, Japan, and Europe (Park 2008). Moreover, in the early 1980s US antitrust and EU competition authorities began treating pre-competitive collaborative R and D more leniently, allowing a greater variety of cooperative forms beyond traditional joint ventures, and later also a broader range of downstream joint development efforts (Lundqvist 2015). Informal institutional forces too can play a role. For example, the growing network of alliances may serve as a reputation mechanism that allows firms to substitute nonequity for equity alliances (Frankort 2013), while mimetic isomorphism may have impelled firms to follow early adopters of nonequity governance structures.

Overall, the dramatic change in the nature of alliance governance, while the subject of some narrative speculation, has received limited systematic attention and we believe it would be valuable to juxtapose a handful of plausible explanations. Such research can advance insight into the historical contingency of alliance governance, while also improving the understanding of the diverse channels through which the broader institutional environment interacts with the mechanisms of (alliance) governance.

6.2 Heterogeneity in nonequity alliances

The proliferation of nonequity alliances was largely the result of increases in RDCs and JDAs, while the choice among nonequity forms does not reveal a clear temporal pattern once accounting for other factors. The progressive dominance of nonequity alliances suggests the need for a more granular understanding of differences *within* the class of nonequity alliances.

From a governance perspective, for example, one might ask where kinds of nonequity alliances can be placed on the governance continuum (Williamson 1991). Among the forms we were able to distinguish, RDCs would be less hierarchical than JDAs and JRPs, the latter two which can rely on in-kind hostage exchanges (Oxley 1997). It is less clear a priori how JDAs and JRPs, which tend to cover distinct activity domains, differ in their governance attributes. JDAs typically join diverse perspectives (e.g., see the effects of *Multisector* in Table 4) for downstream development, while JRPs often concern pre-competitive joint research. We expect to find great variance in governance attributes both within and across these nonequity forms, as a function of the specific adaptation requirements of the alliance partners.

Identification of such governance attributes may ultimately require the study of alliance contracts, which is a promising way to develop a more granular and systematic understanding of heterogeneity in nonequity alliances (e.g., Reuer & Devarakonda 2016; Ryall & Sampson 2009). By revealing governance attributes that influence the adaptive capacities of contract-based nonequity alliances, the study of contracts can lead to more refined applications of the governance continuum. For example, Reuer and Devarakonda (2016) identified administrative committees as one way of introducing administrative controls into nonequity alliances, showing that partners were more likely to devise administrative committees where the need for coordinated adaptation was greater. We believe such refinements also permit useful analyses of performance heterogeneity among nonequity alliances. For example, opportunities exist to

connect governance attributes of nonequity alliances (e.g., the presence of an administrative committee) to relevant outcomes (e.g., interfirm knowledge transfer).

Beyond governance attributes, apparently similar nonequity alliances can vary greatly in their underlying objectives and we know less about whether and how collaborative tasks are organized in distinct ways as a consequence. We believe there is intrinsic value in a more systematic categorization of objectives in innovation-driven alliances that goes beyond an upstream-downstream dichotomy. In parallel, we concur with Albers *et al.* (2016) in encouraging work that develops a greater understanding of the organizational designs of alliances (as distinct from their legal basis per se) that can help achieve such objectives.

6.3 Determinants and consequences of sectoral scope

Alliances with broad sectoral scope have increased over time. Nevertheless, empirical evidence is limited and mainly focused on *vertical* scope—i.e., whether one or multiple functional domains, such as R and D, manufacturing, or marketing, are part of a single alliance (Oxley & Sampson 2004). We are unaware of systematic research examining the number of technology fields targeted in an alliance (for an exception, see Oxley [1997]) and believe the determinants and consequences of the sectoral, *horizontal* scope of alliances constitute highly relevant open questions. Various alliance data sets, including CATI and RECAP, contain information on technology fields targeted in alliances, readily facilitating measurement of this dimension of alliance scope. While we have focused on broad sectors here, it would also be worthwhile for researchers to develop more granular measures of horizontal alliance scope.

Alliance scope can materially affect alliance outcomes (Khanna 1998) and so sectoral scope plausibly has systematic implications at the transaction level. For example, a narrow sectoral scope may help bound exchange hazards in innovation-driven alliances (e.g., Hamel *et al.* 1989) and so a broad sectoral scope might be more likely where fewer hazards are anticipated.

In addition, it would be valuable to examine how sectoral scope shapes the extent and nature of the knowledge transferred between partners, as well as the technologies, products, and processes flowing from alliances.

Additional questions emerge about the effects of sectoral scope at the relationship as well as firm levels. How is a multisector alliance between two firms similar to or different from multiple alliances between the same firms, each with a narrow scope yet in a different technology field? When looking for multisector collaboration, is it better to work with one partner in a number of technology fields, to form a broad-scope multipartner alliance, or to have a portfolio of targeted, narrow-scope alliances with multiple partners? We believe exploring these questions is worthwhile because it can yield new insights into the complex tradeoffs that firms face among strategic alternatives at fundamentally different levels—i.e., alliance, relationship, and portfolio.

We also speculate that trends and patterns in the sectoral scope of alliances can be linked to processes of sectoral convergence. Examples include the convergence of telecom and computers sectors as well as the emergence of 'neutraceuticals' and functional foods that have progressively straddled biopharmaceuticals and food and beverage sectors (Hacklin *et al.* 2013). In these and other cases, are changes in the sectoral scope of alliances among the drivers of sectoral convergence, or are such changes precipitated by sectoral convergence instead? The literature on interfirm alliances can fruitfully connect to broader research on the dynamics of market categories (Negro *et al.* 2010) to uncover the collaborative underpinnings and consequences of emerging as well as waning sectoral categories.

6.4 Interdependence among alliance characteristics

Choices regarding cooperative form, sectoral scope, the number of partners, and geographic scope comprise an interdependent system of simultaneous decisions. This finding underscores the inherently systemic nature of alliance organization that we believe empirical

alliance research has yet to take more seriously (for an exception, see Li *et al.* [2008]). For example, in the spirit of suggestions by Oxley (2009), we encourage research more rigorously addressing why, when, and how various alliance characteristics co-occur.

It would also be valuable for studies of alliance performance to embrace causal complexity and explore the importance of configurations of multiple interdependent alliance characteristics to outcomes. Such investigations can exploit developments in configurational theory and qualitative comparative analysis to theorize and analyze how outcomes depend on multidimensional constellations of characteristics (Albers 2010; Misangyi *et al.* 2017). Among the opportunities presented by a configurational perspective is the potential to identify equifinal causal relations, where multiple distinct configurations of alliance characteristics generate similar outcomes. By offering great flexibility to consider not only multiple alliance characteristics but also relevant firm-level and external contingencies, a configurational approach can help close the gap between the complex reality faced by alliance practitioners and available evidence.

Apart from studying configurations of characteristics and their consequences in samples of realized alliances, broader questions emerge about alliance characteristics in relation to search and selection processes inside firms. By taking as given a particular alliance partner, for example, existing studies implicitly conceive of alliance characteristics as disconnected from partner choice (Reuer *et al.* 2013), even as both may be endogenous to firms' broader search and selection processes. Opportunities exist for integrating research on alliance management and governance with literatures on partner selection and organizational search to uncover the firm-level processes that drive variation in the characteristics of realized alliances and their outcomes. Such research can also enhance the understanding of how partners are selected and alliances designed for their fit with a firm's pre-existing strengths and weaknesses as well as its broader innovation portfolio, both within and beyond the alliance domain.

7 Conclusion

Motivated by the objective to provide a comprehensive descriptive inventory of key facts about the characteristics of innovation-driven alliances, we have analyzed a sample of 14,377 such alliances established during the fifty-year period from 1957 to 2006. We have placed the phenomenon of innovation-driven alliances front and center, while treading carefully in not letting specific theoretical lenses dictate our description of the data. We have also explored a variety of further research directions and hope that these, along with the descriptive evidence, offer an impetus for new empirical and theoretical research that extends and deepens our understanding of innovation-driven alliances.

References

Ahuja, G. (2000a). Collaboration networks, structural holes, and innovation: A longitudinal study. *Administrative Science Quarterly,* 45: 425-455.

Ahuja, G. (2000b). The duality of collaboration: Inducements and opportunities in the formation of interfirm linkages. *Strategic Management Journal,* 21: 317-343.

Albers, S. (2010). Configurations of alliance governance systems. *Schmalenbach Business Review,* 62: 204-233.

Albers, S., Wohlgezogen, F., & Zajac, E.J. (2016). Strategic alliance structures: An organization design perspective. *Journal of Management,* 42: 582-614.

Barley, S.R., Freeman, J., & Hybels, R.C. (1992). Strategic alliances in commercial biotechnology. In N. Nohria and R.G. Eccles, eds., *Networks and Organizations: Structure, Form, and Action*. Boston, MA: Harvard Business School Press, pp. 311-347.

Baum, J.A.C., Calabrese, T., & Silverman, B.S. (2000). Don't go it alone: Alliance network composition and startups' performance in Canadian biotechnology. *Strategic Management Journal,* 21: 267-294.

Berg, S.V. & Friedman, P. (1977). Joint ventures, competition, and technological complementarities: Evidence from chemicals. *Southern Economic Journal,* 43: 1330-1337.

Bojanowski, M., Corten, R., & Westbrock, B. (2012). The structure and dynamics of the global network of inter-firm R&D partnerships 1989-2002. *Journal of Technology Transfer,* 37: 967-987.

Cainarca, G.C., Colombo, M.G., & Mariotti, S. (1992). Agreements between firms and the technological life cycle model: Evidence from information technologies. *Research Policy,* 21: 45-62.

Cloodt, M., Hagedoorn, J., & Roijakkers, N. (2006). Trends and patterns in interfirm R&D networks in the global computer industry: An analysis of major developments, 1970-1999. *Business History Review,* 80: 725-746.

Cloodt, M., Hagedoorn, J., & Roijakkers, N. (2010). Inter-firm R&D networks in the global software industry: An overview of major trends and patterns. *Business History,* 52: 120-149.

Davis, J.P. (2016). The group dynamics of interorganizational relationships: Collaborating with multiple partners in innovation ecosystems. *Administrative Science Quarterly,* 61: 621-661.

Frankort, H.T.W. (2013). Open innovation norms and knowledge transfer in interfirm technology alliances: Evidence from information technology, 1980-1999. *Advances in Strategic Management,* 30: 239-282.

Frankort, H.T.W. (2016). When does knowledge acquisition in R&D alliances increase new product development? The moderating roles of technological relatedness and product-market competition. *Research Policy,* 45: 291-302.

Gomes-Casseres, B., Hagedoorn, J., & Jaffe, A.B. (2006). Do alliances promote knowledge flows? *Journal of Financial Economics,* 80: 5-33.

Gulati, R. (1995). Social structure and alliance formation patterns: A longitudinal analysis. *Administrative Science Quarterly,* 40: 619-652.

Hacklin, F., Battistini, B., & von Krogh, G. (2013). Strategic choices in converging industries. *MIT Sloan Management Review,* 55: 65-73.

Hagedoorn, J. (1993). Understanding the rationale of strategic technology partnering: Interorganizational modes of cooperation and sectoral differences. *Strategic Management Journal,* 14: 371-385.

Hagedoorn, J. (1995). A note on international market leaders and networks of strategic technology partnering. *Strategic Management Journal,* 16: 241-250.

Hagedoorn, J. (2002). Inter-firm R&D partnerships: An overview of major trends and patterns since 1960. *Research Policy,* 31: 477-492.

Hagedoorn, J. & Narula, R. (1996). Choosing organizational modes of strategic technology partnering: International and sectoral differences. *Journal of International Business Studies,* 27: 265-284.

Hagedoorn, J. & Schakenraad, J. (1992). Leading companies and networks of strategic alliances in information technologies. *Research Policy,* 21: 163-190.

Hagedoorn, J. & Schakenraad, J. (1994). The effect of strategic technology alliances on company performance. *Strategic Management Journal,* 15: 291-309.

Hamel, G., Doz, Y.L., & Prahalad, C.K. (1989). Collaborate with your competitors—and win. *Harvard Business Review,* 67: 133-139.

Harrigan, K.R. (1985). *Joint Ventures, Alliances, and Corporate Strategy*, Washington, D.C.: Beard Books.

Heckman, J.J. & Borjas, G.J. (1980). Does unemployment cause future unemployment? Definitions, questions and answers from a continuous time model of heterogeneity and state dependence. *Economica,* 47: 247-283.

Heidl, R.A., Steensma, H.K., & Phelps, C. (2014). Divisive faultlines and the unplanned dissolutions of multipartner alliances. *Organization Science,* 25: 1351-1371.

Khanna, T. (1998). The scope of alliances. *Organization Science,* 9: 340-355.

Li, D., Eden, L., Hitt, M.A., & Ireland, R.D. (2008). Friends, acquaintances, or strangers? Partner selection in R&D alliances. *Academy of Management Journal,* 51: 315-334.

Li, D., Eden, L., Hitt, M.A., Ireland, R.D., & Garrett, R.P. (2012). Governance in multilateral R&D alliances. *Organization Science,* 23: 1191-1210.

Li, J. & Zhong, J. (2003). Explaining the growth of international R&D alliances in China. *Managerial and Decision Economics,* 24: 101-115.

Lincoln, J.R. (1984). Analyzing relations in dyads: Problems, models, and an application to interorganizational research. *Sociological Methods & Research,* 13: 45-76.

Link, A.N. (1996). Research joint ventures: Patterns from *Federal Register* filings. *Review of Industrial Organization,* 11: 617-628.

Lundqvist, B. (2015). *Joint Research and Development under US Antitrust and EU Competition Law*, Cheltenham, UK: Edward Elgar Publishing.

Mariti, P. & Smiley, R.H. (1983). Co-operative agreements and the organization of industry. *Journal of Industrial Economics,* 31: 437-451.

McNamara, G., Vaaler, P.M., & Devers, C. (2003). Same as it ever was: The search for evidence of increasing hypercompetition. *Strategic Management Journal,* 24: 261-278.

Misangyi, V.F., Greckhamer, T., Furnari, S., *et al.* (2017). Embracing causal complexity: The emergence of a neo-configurational perspective. *Journal of Management,* 43: 255-282.

Mowery, D.C. (1998). The changing structure of the US national innovation system: Implications for international conflict and cooperation in R&D policy. *Research Policy,* 27: 639-654.

Mowery, D.C., Oxley, J.E., & Silverman, B.S. (1996). Strategic alliances and interfirm knowledge transfer. *Strategic Management Journal,* 17: 77-91.

Negro, G., Koçak, Ö., & Hsu, G. (2010). Research on categories in the sociology of organizations. *Research in the Sociology of Organizations,* 31: 3-35.

Oxley, J.E. (1997). Appropriability hazards and governance in strategic alliances: A transaction cost approach. *Journal of Law, Economics, & Organization,* 13: 387-409.

Oxley, J.E. (2009). Alliances and performance. *Advances in Strategic Management,* 26: 147-164.

Oxley, J.E. & Sampson, R.C. (2004). The scope and governance of international R&D alliances. *Strategic Management Journal,* 25: 723-749.

Park, W.G. (2008). International patent protection: 1960-2005. *Research Policy,* 37: 761-766.

Pisano, G.P. (1989). Using equity participation to support exchange: Evidence from the biotechnology industry. *Journal of Law, Economics, & Organization,* 5: 109-126.

Pisano, G.P., Russo, M.V., & Teece, D.J. (1988). Joint ventures and collaborative arrangements in the telecommunications equipment industry. In D.C. Mowery, ed., *International Collaborative Ventures in U.S. Manufacturing*. Cambridge, MA: Ballinger Publishing Company, pp. 23-70.

Powell, W.W., Koput, K.W., & Smith-Doerr, L. (1996). Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly,* 41: 116-145.

Powell, W.W., White, D.R., Koput, K.W., & Owen-Smith, J. (2005). Network dynamics and field evolution: The growth of interorganizational collaboration in the life sciences. *American Journal of Sociology,* 110: 1132-1205.

Reich, R.B. & Mankin, E.D. (1986). Joint ventures with Japan give away our future. *Harvard Business Review,* 64: 78-86.

Reuer, J.J. & Devarakonda, S.V. (2016). Mechanisms of hybrid governance: Administrative committees in non-equity alliances. *Academy of Management Journal,* 59: 510-533.

Reuer, J.J., Tong, T.W., Tyler, B.B., & Ariño, A. (2013). Executive preferences for governance modes and exchange partners: An information economics perspective. *Strategic Management Journal,* 34: 1104-1122.

Roijakkers, N. & Hagedoorn, J. (2006). Inter-firm R&D partnering in pharmaceutical biotechnology since 1975: Trends, patterns, and networks. *Research Policy,* 35: 431-446.

Rosenkopf, L. & Schilling, M.A. (2007). Comparing alliance network structure across industries: Observations and explanations. *Strategic Entrepreneurship Journal,* 1: 191-209.

Rothaermel, F.T. & Boeker, W. (2008). Old technology meets new technology: Complementarities, similarities, and alliance formation. *Strategic Management Journal,* 29: 47-77.

Rothaermel, F.T. & Deeds, D.L. (2004). Exploration and exploitation alliances in biotechnology: A system of new product development. *Strategic Management Journal,* 25: 201-221.

Ryall, M.D. & Sampson, R.C. (2009). Formal contracts in the presence of relational enforcement mechanisms: Evidence from technology development projects. *Management Science,* 55: 906-925.

Santoro, M.D. & McGill, J.P. (2005). The effect of uncertainty and asset co-specialization on governance in biotechnology alliances. *Strategic Management Journal,* 26: 1261-1269.

Schilling, M.A. (2009). Understanding the alliance data. *Strategic Management Journal,* 30: 233-260.

Schilling, M.A. (2015). Technology shocks, technological collaboration, and innovation outcomes. *Organization Science,* 26: 668-686.

Schilling, M.A. & Phelps, C.C. (2007). Interfirm collaboration networks: The impact of large-scale network structure on firm innovation. *Management Science,* 53: 1113-1126.

Scott, W.R. (2014). *Institutions and Organizations: Ideas, Interests, and Identities*, 4th edn., Thousand Oaks, CA: SAGE Publications, Inc.

Stuart, T.E. (1998). Network positions and propensities to collaborate: An investigation of strategic alliance formation in a high-technology industry. *Administrative Science Quarterly,* 43: 668-698.

Stuart, T.E. (2000). Interorganizational alliances and the performance of firms: A study of growth and innovation rates in a high-technology industry. *Strategic Management Journal,* 21: 791-811.

Sytch, M., Tatarynowicz, A., & Gulati, R. (2011). Toward a theory of extended contact: The incentives and opportunities for bridging across network communities. *Organization Science,* 23: 1658-1681.

Tatarynowicz, A., Sytch, M., & Gulati, R. (2016). Environmental demands and the emergence of social structure: Technological dynamism and interorganizational network forms. *Administrative Science Quarterly,* 61: 52-86.

Vonortas, N.S. (1997). Research joint ventures in the US. *Research Policy,* 26: 577-595.

Williamson, O.E. (1991). Comparative economic organization: The analysis of discrete structural alternatives. *Administrative Science Quarterly,* 36: 269-296.

Figure 1: Newly established alliances and shares of alliances in high-tech sectors, 1957-2006

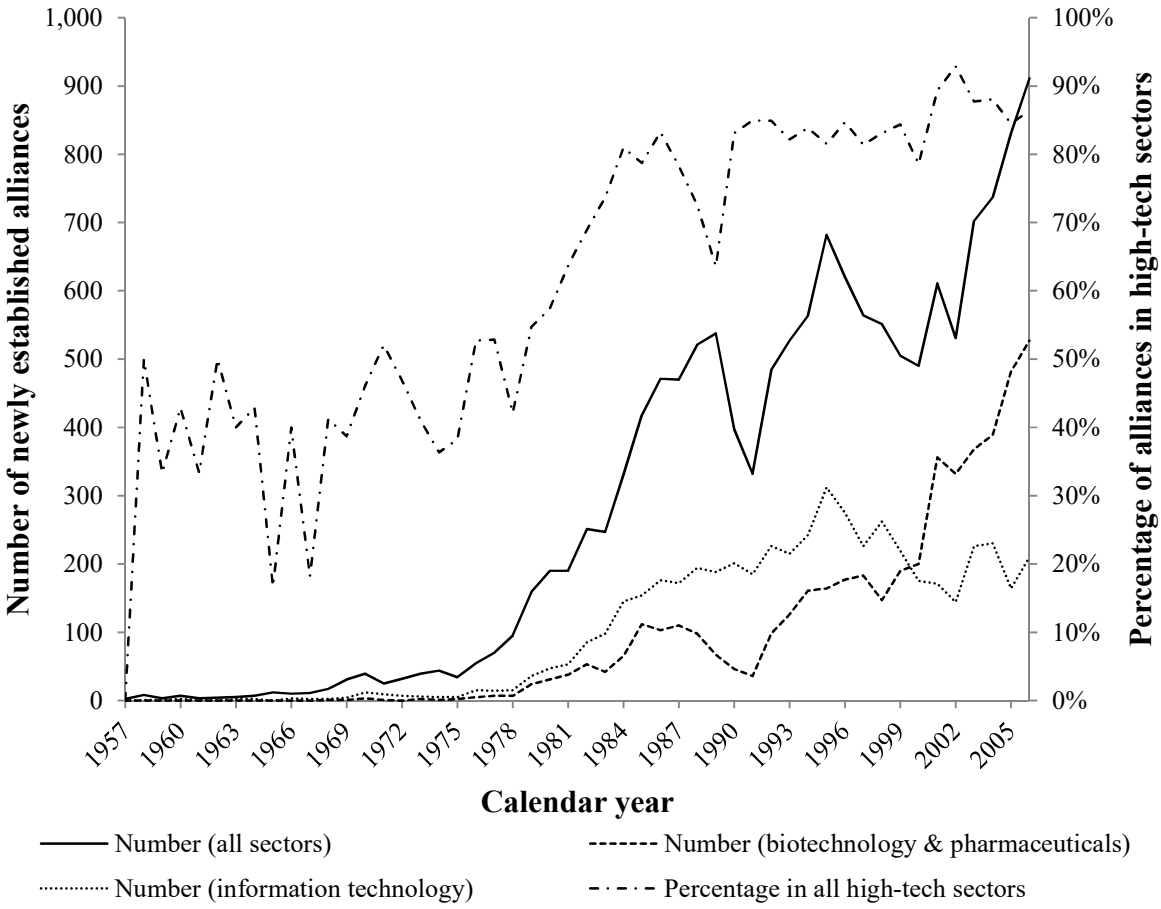

Figure 2: Shares of equity alliances, RDCs, JDAs, and JRPs in all newly established alliances, 1957-2006

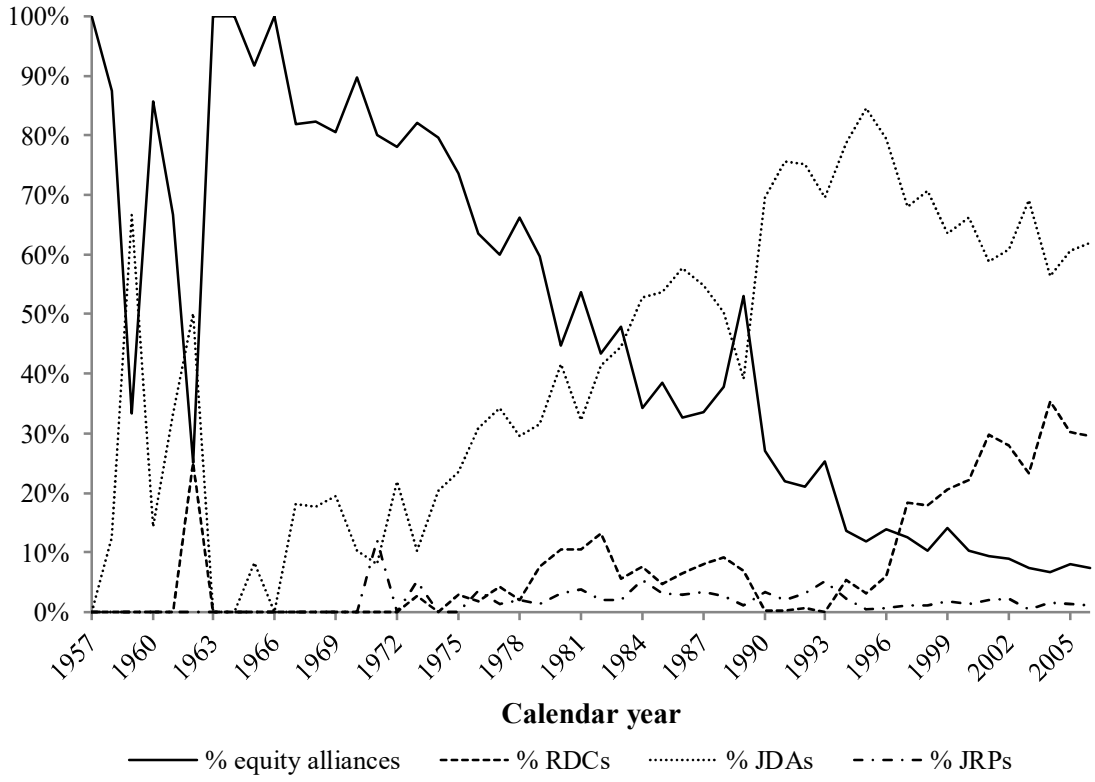

Figure 3: Shares of alliances by characteristic in all newly established alliances, 1957-2006

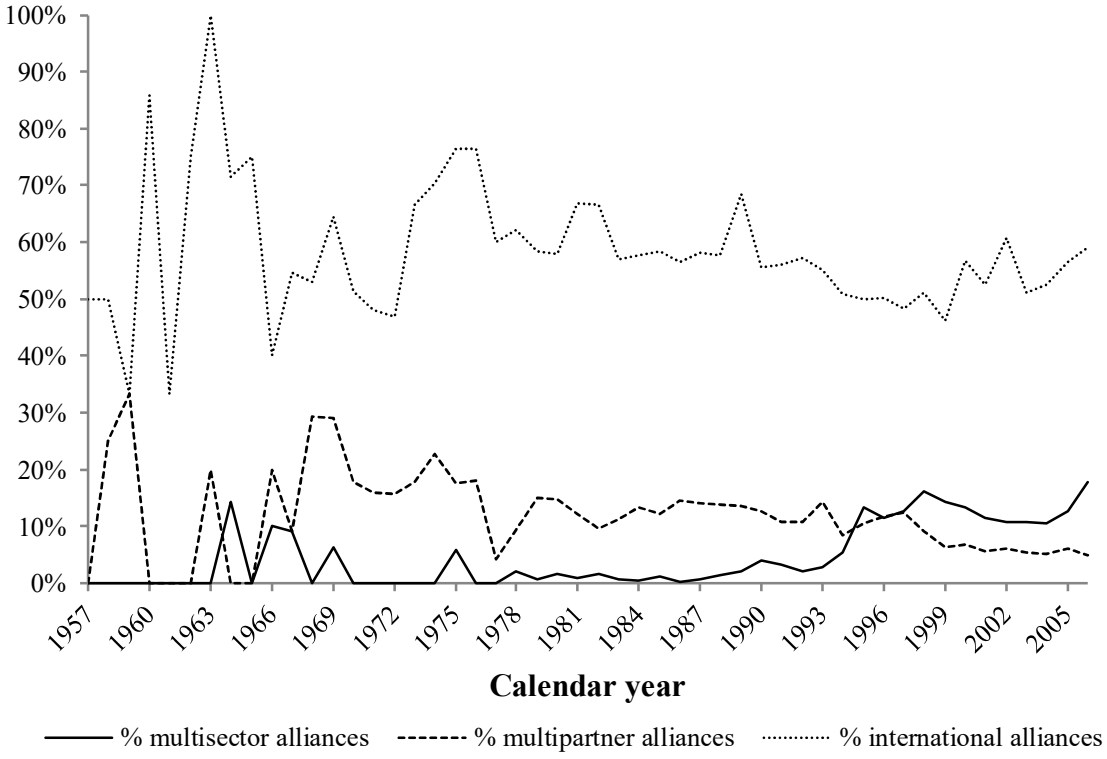

Table 1: Descriptive evidence on innovation-driven alliances

Author(s)	Publication year	Sectors	Sampling window	Aspects of innovation-driven alliances					
				Alliance prevalence	Cooperative forms	Internationali-zation	Key players	Motivations	Network structure
Barley *et al.*	1992	Biotechnology	1971-1989	X	X	X	X		
Cainarca *et al.*	1992	Information technology	1980-1986		X	X			
Hagedoorn & Schakenraad	1992	Information technology	1980-1989				X		X
Hagedoorn	1993	Multiple sectors	1980-1989		X			X	
Hagedoorn	1995	Multiple sectors	1980-1989				X		
Hagedoorn & Narula	1996	Multiple sectors	1980-1993		X	X			
Link	1996	Multiple sectors	1985-1994	X				X	
Vonortas	1997	Multiple sectors	1985-1995	X		X	X	X	
Hagedoorn	2002	Multiple sectors	1960-1998	X	X	X			
Li & Zhong	2003	Multiple sectors	1995-2000	X	X	X			
Powell *et al.*	2005	Biotechnology	1988-1999	X					X
Cloodt *et al.*	2006	Computers	1970-1999	X	X		X		
Roijakkers & Hagedoorn	2006	Biopharmaceuticals	1975-1999	X	X				X
Rosenkopf & Schilling	2007	Multiple sectors	2001-2003						X
Schilling & Phelps	2007	Multiple sectors	1990-2000						X
Schilling	2009	Multiple sectors	1990-2005	X		X			
Cloodt *et al.*	2010	Software	1970-1999	X			X		X
Bojanowski *et al.*	2012	Multiple sectors	1989-2002						X
Schilling	2015	Multiple sectors	1990-2005	X					X
Tatarynowicz *et al.*	2016	Multiple sectors	1983-1999						X

Table 2: Alliance characteristics by sector, 1957-2006[a]

Sector	Years	N	Cooperative forms					Multisector	Multipartner	International
			RDC	JDA	JRP	JV	RC			
Biotechnology & pharmaceuticals	1957-69	2	0.00	0.50	0.00	0.50	0.00	0.50	0.00	1.00
	1970-79	52	0.29	0.37	0.02	0.33	0.00	0.04	0.12	0.42
	1980-89	719	0.23	0.50	0.05	0.19	0.03	0.01	0.06	0.49
	1990-99	1,328	0.21	0.64	0.02	0.12	0.01	0.11	0.04	0.55
	2000-06	2,654	0.47	0.50	0.00	0.03	0.00	0.10	0.02	0.53
Information technology	1957-69	20	0.00	0.20	0.00	0.80	0.00	0.10	0.20	0.55
	1970-79	124	0.01	0.26	0.04	0.69	0.01	0.01	0.16	0.49
	1980-89	1,312	0.04	0.58	0.04	0.33	0.02	0.01	0.14	0.59
	1990-99	2,363	0.02	0.85	0.02	0.10	0.01	0.10	0.12	0.45
	2000-06	1,320	0.03	0.81	0.04	0.12	0.00	0.24	0.10	0.58
Aerospace & defense	1957-69	12	0.08	0.50	0.00	0.33	0.08	0.08	0.50	0.67
	1970-79	72	0.01	0.64	0.06	0.28	0.01	0.00	0.22	0.54
	1980-89	216	0.09	0.73	0.02	0.16	0.00	0.00	0.25	0.56
	1990-99	419	0.04	0.70	0.01	0.25	0.00	0.13	0.26	0.67
	2000-06	205	0.08	0.80	0.00	0.12	0.00	0.28	0.28	0.67
New materials	1957-69	10	0.00	0.10	0.00	0.80	0.10	0.10	0.20	0.80
	1970-79	36	0.00	0.19	0.00	0.81	0.00	0.03	0.08	0.69
	1980-89	423	0.03	0.47	0.02	0.44	0.04	0.04	0.14	0.52
	1990-99	358	0.02	0.66	0.02	0.29	0.01	0.38	0.13	0.54
	2000-06	184	0.07	0.76	0.02	0.15	0.01	0.71	0.11	0.53
Instruments & medical equipment	1957-69	6	0.00	0.00	0.00	1.00	0.00	0.17	0.17	0.33
	1970-79	13	0.00	0.08	0.00	0.77	0.15	0.00	0.08	0.54
	1980-89	91	0.07	0.47	0.03	0.43	0.00	0.07	0.05	0.74
	1990-99	161	0.09	0.78	0.01	0.12	0.00	0.57	0.10	0.43
	2000-06	311	0.13	0.79	0.01	0.07	0.00	0.55	0.04	0.45
Automotive	1957-69	6	0.00	0.33	0.00	0.67	0.00	0.17	0.00	0.67
	1970-79	39	0.08	0.49	0.03	0.41	0.00	0.03	0.21	0.72
	1980-89	209	0.02	0.36	0.01	0.60	0.00	0.04	0.12	0.77
	1990-99	240	0.02	0.67	0.02	0.28	0.01	0.21	0.20	0.52
	2000-06	246	0.04	0.65	0.02	0.27	0.01	0.24	0.11	0.67
Chemicals	1957-69	29	0.00	0.00	0.00	1.00	0.00	0.07	0.07	0.86
	1970-79	148	0.00	0.04	0.01	0.94	0.01	0.02	0.08	0.72
	1980-89	346	0.02	0.13	0.01	0.83	0.01	0.03	0.13	0.79
	1990-99	481	0.14	0.53	0.01	0.31	0.01	0.26	0.05	0.64
	2000-06	207	0.27	0.57	0.01	0.14	0.01	0.43	0.05	0.54
Consumer electronics	1957-69	7	0.00	0.00	0.00	1.00	0.00	0.14	0.00	0.86
	1970-79	29	0.00	0.31	0.00	0.69	0.00	0.03	0.10	0.83
	1980-89	66	0.00	0.29	0.00	0.71	0.00	0.08	0.15	0.82
	1990-99	87	0.00	0.83	0.01	0.14	0.02	0.54	0.23	0.49
	2000-06	134	0.01	0.78	0.04	0.16	0.00	0.65	0.09	0.60
Engineering, drilling, & mining	1957-69	17	0.00	0.12	0.00	0.88	0.00	0.00	0.29	0.47
	1970-79	25	0.00	0.36	0.00	0.64	0.00	0.00	0.16	0.60
	1980-89	113	0.07	0.45	0.00	0.48	0.00	0.02	0.17	0.67
	1990-99	157	0.03	0.82	0.00	0.13	0.03	0.44	0.20	0.58
	2000-06	99	0.20	0.69	0.01	0.10	0.00	0.68	0.06	0.53
Electrical equipment	1957-69	13	0.00	0.23	0.00	0.77	0.00	0.00	0.15	0.15
	1970-79	37	0.00	0.14	0.00	0.86	0.00	0.03	0.32	0.73
	1980-89	123	0.03	0.44	0.02	0.49	0.02	0.04	0.24	0.72
	1990-99	75	0.00	0.79	0.03	0.19	0.00	0.24	0.16	0.52
	2000-06	73	0.08	0.75	0.01	0.14	0.01	0.30	0.07	0.60
Food & beverage	1957-69	3	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.67
	1970-79	18	0.00	0.00	0.00	1.00	0.00	0.00	0.11	0.72
	1980-89	39	0.00	0.15	0.00	0.85	0.00	0.08	0.05	0.56
	1990-99	45	0.00	0.60	0.00	0.40	0.00	0.09	0.00	0.51
	2000-06	40	0.25	0.48	0.00	0.28	0.00	0.65	0.00	0.55

a. For each sector in each time period, the table shows the number of newly established alliances, shares of alliances of a particular cooperative form, and shares of multisector, multipartner, and international alliances in all alliances formed in that sector and that time period. RDC = research and development contract; JDA = joint development agreement; JRP = joint research pact; JV = joint venture; RC = research corporation.

Table 3: Seemingly unrelated linear probability models of alliance characteristics, 1957-2006[a]

	(1)				(2)			
Dependent variable:	Equity	Multisector	Multipartner	International	Equity	Multisector	Multipartner	International
Equity		0.058***	0.030***	0.314***		0.054***	0.025***	0.230***
		[0.006]	[0.007]	[0.011]		[0.006]	[0.006]	[0.010]
Multisector	0.122***		0.068***	0.000	0.097***		0.055***	-0.018
	[0.012]		[0.010]	[0.016]	[0.012]		[0.009]	[0.015]
Multipartner	0.048***	0.051***		0.115***	0.045***	0.047***		0.072***
	[0.011]	[0.007]		[0.014]	[0.011]	[0.008]		[0.013]
International	0.177***	0.000	0.041***		0.132***	-0.003	0.029***	
	[0.006]	[0.004]	[0.005]		[0.006]	[0.004]	[0.005]	
Biotechnology & pharmaceuticals	-0.232***	0.110***	-0.051***	-0.034**	-0.194***	0.108***	-0.028***	-0.046***
	[0.009]	[0.006]	[0.007]	[0.012]	[0.009]	[0.006]	[0.007]	[0.011]
Information technology	-0.181***	0.142***	0.021**	-0.060***	-0.136***	0.147***	0.007	-0.028**
	[0.008]	[0.006]	[0.007]	[0.011]	[0.009]	[0.006]	[0.006]	[0.011]
Aerospace & defense	-0.209***	0.142***	0.155***	0.045*	-0.185***	0.145***	0.122***	0.058***
	[0.014]	[0.009]	[0.011]	[0.018]	[0.014]	[0.009]	[0.010]	[0.017]
New materials	-0.048***	0.314***	0.003	-0.092***	-0.054***	0.308***	0.007	-0.087***
	[0.013]	[0.009]	[0.011]	[0.018]	[0.013]	[0.009]	[0.010]	[0.017]
1970s	-0.113**	-0.033	-0.025	0.053	-0.153***	-0.024	-0.031	-0.030
	[0.037]	[0.025]	[0.029]	[0.049]	[0.036]	[0.025]	[0.027]	[0.046]
1980s	-0.346***	-0.056*	-0.017	0.148**	-0.343***	-0.037	-0.029	0.045
	[0.034]	[0.024]	[0.027]	[0.046]	[0.034]	[0.023]	[0.025]	[0.043]
1990s	-0.552***	0.033	-0.038	0.143**	-0.486***	0.043	-0.051*	0.091*
	[0.034]	[0.024]	[0.027]	[0.046]	[0.034]	[0.024]	[0.026]	[0.043]
2000s	-0.617***	0.085***	-0.065*	0.212***	-0.533***	0.077**	-0.063*	0.154***
	[0.034]	[0.024]	[0.028]	[0.046]	[0.034]	[0.024]	[0.026]	[0.043]
USA					-0.062***	-0.000	-0.007	0.076***
					[0.007]	[0.005]	[0.005]	[0.009]
Japan					-0.021*	-0.003	-0.002	0.244***
					[0.009]	[0.006]	[0.006]	[0.011]
General alliance experience					-0.020***	-0.013***	-0.016***	-0.051***
					[0.003]	[0.002]	[0.002]	[0.003]
Partner-specific nonequity experience					-0.047***			
					[0.010]			
Partner-specific equity experience					0.052***			
					[0.013]			
Partner-specific alliance experience						0.002	0.221***	
						[0.005]	[0.005]	
Autoregression (equity)					0.339***			
					[0.017]			
Autoregression (multisector)						0.441***		
						[0.023]		
Autoregression (multipartner)							0.067***	
							[0.019]	
Autoregression (international)								0.580***
								[0.015]
Constant	0.770***	-0.082***	0.103***	0.349***	0.854***	-0.079**	0.109***	0.308***
	[0.034]	[0.024]	[0.027]	[0.046]	[0.042]	[0.024]	[0.026]	[0.045]
R^2	0.214	0.119	0.043	0.017	0.256	0.145	0.173	0.160

a. Standard errors in brackets; *** p<0.001, ** p<0.01, * p<0.05; N = 14,377.

Table 4: Multinomial logistic regression models of nonequity forms, 1957-2006[a]

	(1)		(2)	
Outcome category:	JDA	JRP	JDA	JRP
Multisector	0.369**	0.095	0.239*	-0.071
	[0.115]	[0.280]	[0.117]	[0.285]
Multipartner	0.799***	1.991***	0.467**	1.380***
	[0.165]	[0.214]	[0.172]	[0.232]
International	0.089	0.414**	-0.005	0.297*
	[0.055]	[0.134]	[0.059]	[0.138]
Biotechnology & pharmaceuticals	-1.468***	-1.051***	-1.000***	-0.218
	[0.086]	[0.221]	[0.090]	[0.233]
Information technology	1.183***	1.758***	1.064***	1.537***
	[0.112]	[0.213]	[0.115]	[0.219]
Aerospace & defense	0.188	-0.351	0.142	-0.503
	[0.164]	[0.350]	[0.166]	[0.360]
New materials	0.785***	1.095**	0.648**	0.900**
	[0.208]	[0.343]	[0.209]	[0.347]
1980s	-0.215	-0.541	-0.136	-0.460
	[0.254]	[0.397]	[0.261]	[0.412]
1990s	0.251	-0.862*	0.358	-0.704
	[0.251]	[0.397]	[0.258]	[0.418]
2000s	-0.729**	-1.946***	-0.309	-1.303**
	[0.248]	[0.404]	[0.256]	[0.421]
USA			-0.251***	-0.640***
			[0.072]	[0.152]
Japan			0.419***	-0.024
			[0.101]	[0.194]
General alliance experience			-0.018	0.207***
			[0.028]	[0.062]
Partner-specific RDC experience			0.129	0.770
			[0.251]	[0.676]
Partner-specific JDA experience			0.933***	1.097***
			[0.211]	[0.261]
Partner-specific JRP experience			0.221	0.039
			[0.847]	[0.882]
Partner-specific equity experience			1.053*	1.336**
			[0.463]	[0.496]
Autoregression (RDC)			-2.577***	-6.707***
			[0.153]	[0.973]
Autoregression (JDA)			-0.069	-0.977**
			[0.120]	[0.308]
Autoregression (JRP)			2.079**	5.125***
			[0.773]	[0.965]
Constant	2.185***	-1.089**	2.282***	-0.794
	[0.254]	[0.410]	[0.264]	[0.431]
Log likelihood	-5,366.55		-5,080.24	
Pseudo R^2	0.192		0.235	

a. Standard errors in brackets; *** p<0.001, ** p<0.01, * p<0.05; N = 11,142. The base category is the RDC (research and development contract).

Table A1: Summary statistics

	Panel A: Full sample for analyses in Table 3 (N = 14,377)				Panel B: Sample of nonequity alliances for analyses in Table 4 (N = 11,142)			
Variable	Mean	SD	Min	Max	Mean	SD	Min	Max
Equity	0.225	0.418	0	1	-	-	-	-
Research and development contract (RDC)	-	-	-	-	0.187	0.390	0	1
Joint development agreement (JDA)	-	-	-	-	0.787	0.409	0	1
Joint research pact (JRP)	-	-	-	-	0.026	0.158	0	1
Multisector	0.080	0.271	0	1	0.086	0.281	0	1
Multipartner	0.099	0.298	0	1	0.088	0.283	0	1
International	0.557	0.497	0	1	0.518	0.500	0	1
Biotechnology & pharmaceuticals	0.331	0.470	0	1	0.390	0.488	0	1
Information technology	0.357	0.479	0	1	0.375	0.484	0	1
Aerospace & defense	0.064	0.245	0	1	0.066	0.248	0	1
New materials	0.070	0.256	0	1	0.057	0.232	0	1
1970s	0.041	0.199	0	1	-	-	-	-
1980s	0.252	0.434	0	1	0.193	0.394	0	1
1990s	0.363	0.481	0	1	0.392	0.488	0	1
2000s	0.335	0.472	0	1	0.397	0.489	0	1
USA	0.717	0.450	0	1	0.755	0.430	0	1
Japan	0.176	0.381	0	1	0.149	0.356	0	1
General alliance experience	1.836	1.401	0	5.628	1.893	1.417	0	5.628
raw count	15.617	26.909	0	277	16.695	28.204	0	277
Partner-specific nonequity experience	0.130	0.438	0	5.037	-	-	-	-
raw count	0.431	3.226	0	153	-	-	-	-
Partner-specific RDC experience	-	-	-	-	0.012	0.095	0	1.386
raw count	-	-	-	-	0.018	0.148	0	3
Partner-specific JDA experience	-	-	-	-	0.119	0.417	0	4.860
raw count	-	-	-	-	0.368	2.480	0	128
Partner-specific JRP experience	-	-	-	-	0.022	0.165	0	3.258
raw count	-	-	-	-	0.049	0.511	0	25
Partner-specific equity experience	0.072	0.311	0	4.977	0.061	0.288	0	4.977
raw count	0.194	1.799	0	144	0.163	1.749	0	144
Partner-specific alliance experience	0.169	0.509	0	5.697	-	-	-	-
raw count	0.625	4.817	0	297	-	-	-	-
Autoregression (equity)	0.185	0.226	0	1	-	-	-	-
Autoregression (multisector)	0.037	0.094	0	1	-	-	-	-
Autoregression (multipartner)	0.109	0.147	0	1	-	-	-	-
Autoregression (international)	0.380	0.288	0	1	-	-	-	-
Autoregression (RDC)	-	-	-	-	0.107	0.188	0	1
Autoregression (JDA)	-	-	-	-	0.415	0.289	0	1
Autoregression (JRP)	-	-	-	-	0.020	0.054	0	1

Appendix: Control variables and summary statistics

A.1 Predicting alliance characteristics: Table 3

Our first set of multivariate analyses models the four alliance characteristics as a function of one another, and of sectors, time, and a number of control variables. Panel A in Table A1 summarizes all variables included in the analyses shown in Table 3.

--- Insert Table A1 about here ---

Control variables fall into three categories. First, we control for the geographic location of the partner firms to account for the preponderance of alliances involving US and Japanese firms. Specifically, *USA* is an indicator variable that equals one if at least one of the partners in an alliance has the USA as its home country and equals zero otherwise, while *Japan* is an indicator variable that equals one if at least one of the partners in an alliance has Japan as its home country and, similarly, equals zero otherwise.

Second, we account for experience effects that might influence the characteristics of a focal alliance. *General alliance experience* captures the average of the cumulative number of alliances established across the partner firms before the year in which the focal alliance is established, logged to reduce skew. This variable captures systematic differences in the characteristics of alliances established among more compared to less experienced firms. We also control for partner-specific experience variables to absorb differences in the characteristics of alliances due to partner-specific learning effects and otherwise unobserved relational heterogeneity (Heckman & Borjas 1980). In Eq. (1), the *Equity* equation, *Partner-specific nonequity experience* captures the logarithm of the total number of nonequity alliances established among two or more of the partner firms before the year in which the focal alliance is established. Similarly, in the same equation, *Partner-specific equity experience* captures the logarithm of the total number of equity alliances established among two or more of the partner

firms before the year in which the focal alliance is established. In Eqs. (2) and (3), the *Multisector* and *Multipartner* equations, *Partner-specific alliance experience* captures the logarithm of the total number of alliances established among two or more of the partner firms before the year in which the focal alliance is established. We do not control for partner-specific experience in Eq. (4), the *International* equation, as firms' home location is time invariant.

Third, we include four control variables to account for non-independence across individual alliances, attributable to the fact that over 3,500 of the sampled firms appear as a partner in multiple alliances. We use Lincoln's (1984) autoregression specification. In Eq. (1), *Autoregression (equity)* captures the mean of *Equity* for all alliances in which the partner firms appeared up until and including the focal year, yet excluding the focal alliance. In Eq. (2), *Autoregression (multisector)* captures the mean of *Multisector* for all alliances in which the partner firms appeared up until and including the focal year, yet excluding the focal alliance. In Eq. (3), *Autoregression (multipartner)* captures the mean of *Multipartner* for all alliances in which the partner firms appeared up until and including the focal year, yet excluding the focal alliance. In Eq. (4), *Autoregression (international)* captures the mean of *International* for all alliances in which the partner firms appeared up until and including the focal year, yet excluding the focal alliance. These four autoregression variables plausibly capture otherwise unobserved firm-level costs and benefits associated with establishing an alliance with particular characteristics.

A.2 Predicting nonequity forms: Table 4

Our second set of multivariate analyses models partner firms' choice among the three nonequity forms as a function of sectoral scope, numbers of partners, and geographic scope, and of sectors, time, and a number of control variables. Our sample reduces to 11,142 alliances

because we focus exclusively on nonequity alliances. Panel B in Table A1 summarizes all variables included in the analyses shown in Table 4.

Control variables again fall into three categories, and controls for the geographic location of the partner firms and general alliance experience remain unaltered. However, with one exception (*Partner-specific equity experience*), we replace all controls for partner-specific experience as well as non-independence to align with the new set of outcome categories. *Partner-specific RDC experience* captures the logarithm of the total number of RDCs established among two or more of the partner firms before the year in which the focal alliance is established. *Partner-specific JDA experience* captures the logarithm of the total number of JDAs established among two or more of the partner firms before the year in which the focal alliance is established. *Partner-specific JRP experience* captures the logarithm of the total number of JRPs established among two or more of the partner firms before the year in which the focal alliance is established.

Moreover, *Autoregression (RDC)* captures the average share of RDCs in all alliances in which the partner firms appeared up until and including the focal year, yet excluding the focal alliance. *Autoregression (JDA)* captures the average share of JDAs for all alliances in which the partner firms appeared up until and including the focal year, yet excluding the focal alliance. *Autoregression (JRP)* captures the average share of JRPs in all alliances in which the partner firms appeared up until and including the focal year, yet excluding the focal alliance.