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The Impact of Partner Organizational Structure on Innovation

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Abstract

Interorganizational partnerships can spur innovation, but their value may be diminished by friction in knowledge flows between firms. We consider how a partner's organizational structure may influence the knowledge that is accessible via partnerships. We focus on how a partner's structure trades off localized autonomy for its managers, which facilitates timelier decision making, and unified control, which facilitates integration. By shaping this balance, centralization of decision rights within the partner organization shapes access to its knowledge. Centralized structures generate wide-ranging internal knowledge pathways that enable access to a broader array of a partner's knowledge. However, the reduced managerial autonomy afforded by centralization makes decision making more cumbersome, which constricts the rate of access to a partner's knowledge. We find evidence of this tradeoff in the context of corporate venture capital relationships between incumbents and startups in the pharmaceutical industry. An increase in the incumbent's diversity of knowledge or in the knowledge required by the startup enhances the value of a greater breadth of access, whereas the degree to which the startup can leverage social ties (affinity) or hierarchical fiat (authority) alleviates the costs of a reduced access rate. Each of these features makes an incumbent organization's centralization more valuable to the startup. By highlighting this tension related to centralization, our findings suggest that new firms striving to maximize their partnership benefits may need to carefully consider their partners' internal structures.

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Interorganizational partnerships can serve as pipes that provide firms access to distinctive sources of knowledge, which is critical for innovation (Podolny, 2001; Lifshitz-Assaf, 2018). However, knowledge flows within such partnerships are also prone to friction, which may narrow the breadth of knowledge accessible or slow the rate of knowledge access (Hughes and Weiss, 2007; Gulati, Sytch, and Mehrotra, 2008). Understanding the origin of such friction is critical as it can substantially limit the innovation-related value of partnerships (Ghosh and Rosenkopf, 2014).

Scholars have suggested that some of this friction in interorganizational knowledge flows may originate within the complex intraorganizational structures in which the managers shaping the knowledge flows operate (Simon, 1991; Gulati, Lavie, and Madhavan, 2011; Puranam, 2018). An organization's structure determines the location of its knowledge, the pathways along which knowledge flows internally, and its employees' incentives to acquire, use, and share knowledge (Argyres, Rios, and Silverman, 2020; Lee, 2022). Several studies have demonstrated that organizations' innovation outcomes are closely linked to their structures (Argyres and Silverman, 2004; Ter Wal et al., 2020; Eklund, 2022), which also impact the value they can derive from external partnerships (Arora, Belenzon, and Rios, 2014; Sytch, Wohlgezogen, and Zajac, 2018; Eklund and Kapoor, 2022). However, the knowledge that firms seek to access via partnerships is embedded in their partners' organizations rather than their own, and how their partners' structures shape firms' access to this knowledge remains an open question.

In examining this question, we focus on the level of autonomy that managers in the partner organization have regarding resource orchestration decisions (Jensen and Meckling, 1992; Burton, Obel, and DeSanctis, 2011; Dattée et al., 2022). The balance between localized autonomy and unified control is a fundamental choice in organization design, and it profoundly influences how an organization accesses and deploys knowledge (Puranam, Singh, and Zollo, 2006; Dattée et al., 2022; Eklund, 2022). While a range of structural elements can shape the autonomy–control balance, a key element that has received significant scholarly attention is centralization (e.g., Mansfield, 1973; Burton, Obel, and DeSanctis, 2011; Joseph, Klingebiel, and Wilson, 2016).[1] Centralization is a fundamental structural choice that all organizations face, which determines the extent to which decision-making authority is concentrated within the head, or center, of the organization (Garicano and Rossi-Hansberg, 2004, 2006). Centralization lowers autonomy but provides greater unified control of the organization's decision making, which facilitates internal knowledge sharing and reduced competition between different parts of the organization (Hounshell and Smith, 1989; Karim and Kaul, 2015). In contrast, decentralization enhances autonomy and facilitates greater localized managerial discretion, thereby enabling responsiveness and more-streamlined decision making (Blau and Schoenherr, 1971; Burton, Obel, and DeSanctis, 2011).

[1] Knowledge access may also be impacted by the other elements of organizational structure that shape the autonomy–control balance, such as formalization and task differentiation, via mechanisms analogous to the ones we describe here. See Discussion section.

Through greater unified control, centralized structures enable the generation of more-extensive and tightly knit knowledge networks within organizations (Argyres, Rios, and Silverman, 2020). We expect these networks to enable external partners to access a greater breadth of an organization's knowledge base by providing more internal pathways through which knowledge can be located and accessed. However, in more-centralized structures, decisions are made farther away from where resources are located and typically must account for more-wide-ranging intraorganizational interdependencies. This can lead to slower, more-complex decision processes regarding knowledge sharing in partnerships, constricting the rate of knowledge flows (Argote, Turner, and Fichman, 1989; Pahnke, Katila, and Eisenhardt, 2015). Therefore, partner centralization is associated with a tradeoff between two forms of friction in knowledge access. Greater centralization in a partner organization will enhance the breadth of its knowledge base that can be accessed but also, on average, will constrict the rate of knowledge access.

Given this theorized tradeoff, it follows that the partner structure most beneficial to a firm's innovation efforts will depend on the relative value of breadth versus the rate of knowledge access to that firm. Contingencies that accentuate the benefits of accessing a greater breadth of a partner's knowledge or that diminish the costs of accessing knowledge at a reduced rate should make partner centralization more effective at offering firms the knowledge required to innovate effectively. We theorize that the value of an enhanced breadth of access should be greater when the diversity of knowledge held by the partner or required by the focal firm is greater, thus making partner centralization more valuable. With regard to the rate of access, extant research highlights two important antidotes to impeded knowledge flows between organizations: informal social ties or affinity (Smith-Doerr and Powell, 2010) and formal hierarchical fiat or authority (Williamson, 1979; Kownatzki et al., 2013). The degree to which a focal firm can leverage each of these should alleviate the negative impact of partner centralization on the rate of knowledge access.

We examine these ideas empirically in the context of entrepreneurial firms' innovation-focused relationships with incumbent firms arising from corporate venture capital (CVC) investments in the life sciences (Katila, Rosenberger, and Eisenhardt, 2008; Pahnke, Katila, and Eisenhardt, 2015). We draw on changes to the structure of the incumbent firms' R&D units in these relationships to examine how startups' access to incumbent firms' knowledge changes if these R&D structures have shifted from centralized to decentralized or vice versa. We find that access to a greater breadth of the incumbent's knowledge base facilitated by centralized structures is more valuable to the startup when the incumbent has greater diversity of knowledge available and when the startup's innovation efforts require a wider variety of expertise. The constricted rate of knowledge flow arising from centralized structures can, in turn, be alleviated when startups' primary sponsors in the incumbent firm (i.e., CVC managers) have greater affinity with other parts of their organization through prior experience working in operational roles or when startups are proximate to the authority of incumbents' senior executives based at the firms' corporate headquarters. These findings support the theorized tension between breadth and rate of knowledge access arising from a partner's organizational structure. In doing so, this study helps to further bridge the literatures on interorganizational and intraorganizational drivers of knowledge flows and innovation.

THEORY

Innovation is a critical determinant of firm performance, and knowledge is the key resource that fuels innovation (Schumpeter, 1934). Several scholars have investigated how firms can obtain valuable knowledge and how they can translate it effectively into innovation (e.g., Fleming, 2001; Fleming and Sorenson, 2004; Chesbrough, 2006). A key insight from this research is that even if two firms have similar knowledge resources, the innovations they develop could be distinct because of differences in how they aggregate and recombine this knowledge internally. A key determinant of these differences is the organizational structure in which each firm's knowledge is embedded (Simon, 1947; Burton, Obel, and DeSanctis, 2011). Organizational structure refers to the solution an organization employs to the fundamental problems of organizing, namely the division of labor and the integration of effort (March and Simon, 1958; Lawrence and Lorsch, 1967; Burton, Obel, and DeSanctis, 2011; Puranam, Alexy, and Reitzig, 2014). In broad terms, an organization's structure encompasses the choices made along four dimensions: task division, task allocation, provision of incentives, and provision of information (Galbraith, 1973; Puranam, Alexy, and Reitzig, 2014). These choices can significantly impact the way an organization's knowledge is stored, shared internally, and applied toward innovation (Denrell, Fang, and Winter, 2003; Eklund, 2022). A range of studies have demonstrated how structural features such as hierarchy (Gavetti, 2005; Csaszar, 2013; Lee, 2022), task differentiation (Dougherty, 1992; Burton and Obel, 2004), and the incentives of employees (Lerner and Wulf, 2007; Manso, 2011) may affect an organization's innovation outcomes. The mechanisms underlying these findings relate to the impact of different structural elements on the ways in which organizations can mobilize knowledge.

However, firms' innovation outcomes are also heavily influenced by their ability to leverage knowledge that exists beyond their boundaries, most commonly via partnerships with other organizations (Powell, Koput, and Smith-Doerr, 1996; Chesbrough, 2006; Lifshitz-Assaf, 2018). Scholars have widely characterized these partnerships as pipes through which firms can draw from the knowledge of partner organizations (Podolny, 2001; Powell et al., 2005). A substantial literature has investigated which types of knowledge-focused partnerships are most valuable to which types of firms and under which conditions (Owen-Smith and Powell, 2004; Phelps, Heidl, and Wadhwa, 2012; Lumineau and Oliveira, 2018). This literature has also highlighted that the knowledge flows in interfirm partnerships are prone to friction, which can restrict a firm's access to its partner's knowledge in significant ways (Ghosh and Rosenkopf, 2014). For instance, valuable knowledge may be dispersed across different parts of the partner organization, leading to variation in the accessibility of different types of knowledge (Kale, Dyer, and Singh, 2002; Helfat and Campo-Rembado, 2010). Kale, Dyer, and Singh (2002: 751) quoted an alliance manager who said, ''We have a difficult time supporting our alliance initiatives, because many times the various resources and skills needed to support a particular alliance are located in different functions around the company.'' As a result, firms' access to their partners' knowledge resources may be narrower than anticipated, i.e., such frictions, whose origins lie in a partner's internal structure, can limit the *breadth of access* a firm has to its partner's corpus of valuable knowledge. Research on partnerships has largely abstracted

away from this form of variation, assuming that the locus of the partnership coincides with the locus of any salient knowledge within the partner organization, i.e., that the partnership pipe has a homogeneous ability to access any part of the partner's knowledge base that is relevant (Puranam, 2018).

Friction can also restrict the *rate of access* to knowledge in partnerships. We know from a wide range of studies that the transmission of knowledge, even within organizational boundaries, can be slow (Szulanski, 1996; Hansen and Haas, 2001). Some studies have highlighted the importance of mechanisms that can accelerate knowledge flows in partnerships (Uzzi, 1997; Dyer and Nobeoka, 2000). Other studies have also suggested that impediments to the rate of knowledge access arising from organizational structure may limit the value of a partnership. Pahnke, Katila, and Eisenhardt (2015: 604) quoted a manager who explained that a partnership failed to create value not because of the unavailability of valuable knowledge but because of the rate at which the knowledge was shared: ''Slow as molasses: resources need to get approved, technical decisions involve modifications in contracts . . . they can't get anything done. And their hierarchy—it's just a pain.''

Yet, as Ghosh and Rosenkopf (2014: 623) highlighted regarding the literature on interorganizational partnerships, ''an implicit assumption of largely unrestricted knowledge flow underlies much of this work.'' Relaxing assumptions about frictionless knowledge flow clarifies the importance of partnering organizations' internal structures as a potential source of variance in the knowledge-driven value that firms can derive from external partnerships (Ghosh and Rosenkopf, 2014; Puranam, 2018). Some recent studies have highlighted the links between the knowledge-acquisition impact of external partnerships and the knowledge-deployment impact of internal organizational structure. Arora, Belenzon, and Rios (2014) showed that firms' internal R&D structures impact their pursuit of external targets for knowledge-focused acquisitions. Firms with more-centralized structures make smaller acquisitions and integrate the acquired companies more closely than do those with decentralized structures. Sytch, Wohlgezogen, and Zajac (2018) showed that firms with matrix-type organizational structures are, on average, likely to seek partnerships of greater functional complexity and to use equity-based governance structures for these partnerships. However, they also found that firms with these complex organizational structures are penalized in terms of stock market performance for entering partnerships that are considered more complex.

These studies demonstrate how an organization's own internal structure may impact its choices in relation to external partnerships, as well as the value it derives from those partnerships. Yet, little scholarly attention has been focused on understanding how the partner organization's structure may shape friction in firms' access to their partners' knowledge and on unpacking how such friction may impact different dimensions of knowledge flow. This is important to understand because firms increasingly rely on partnerships to support their innovation activities, yet without careful consideration of their partners' structures and associated knowledge accessibility, these partnerships may fail to deliver their anticipated value.

Organizational Structure and the Balance Between Central Control and Local Autonomy

We center our study on a foundational characteristic of the partner's organizational design: the degree of autonomy it affords to its constituents (Thompson, 1967; Galbraith, 1977). Structural choices made regarding autonomy promote or restrict managerial discretion in resource orchestration decisions (Pennings, 1976; Bloom, Sadun, and Van Reenen, 2012). On one hand, higher levels of autonomy provide greater managerial discretion. This can enable an organization to be more responsive and to leverage specialized local information in making decisions. On the other hand, structuring the organization with lower levels of localized autonomy and greater levels of unified control can provide important benefits such as economies of scale and scope as well as the integration of knowledge or other resources across the organization (Astley and Zajac, 1991; Raisch and Birkinshaw, 2008; Dattée et al., 2022). The balance between localized autonomy and unified control may be shaped by various elements of an organization's structure, both formal and informal (Child, 1973; Damanpour, 1991; Puranam, Singh, and Zollo, 2006; Damanpour and Aravind, 2012; Dattée et al., 2022).

A core structural choice that organizations need to make in this respect pertains to their degree of centralization (Hage and Aiken, 1967; Sah and Stiglitz, 1986; Argyres and Silverman, 2004). The degree to which an organization is centralized, and the implications thereof, have been the subject of research across a wide range of disciplines, including management (Sengul and Gimeno, 2013), economics (Aghion and Tirole, 1997), sociology (Gould, 1996), and political science (Chhibber and Kollman, 1998). The conceptual foundation common to these literatures is that centralization reflects where decisions are made within an organization. More-centralized organizations are ones in which formal decision rights are retained closer to the center of the organization (Pfeffer and Lammerding, 1981; Cummings, 1995), and by corollary, decentralization reflects ''the extent to which problems are solved at lower levels'' (Garicano and Rossi-Hansberg, 2004: 197). Centralization directly impacts the autonomy–control tradeoff by determining the degree to which the formal authority to make decisions is diffused throughout the organization. We anticipate that the degree to which a partner's organization is centralized will systematically impact the breadth and rate of a firm's access to the partner's knowledge.

While our theory focuses on the formal structural element of centralization, we expect that other elements of organizational structure that shape the autonomy–control balance may also systematically impact the breadth and rate of knowledge access via analogous mechanisms to the ones we describe here.[2] Also, the mechanisms by which we expect formal structure to influence firms' external relationships involve this structure's widely documented role in shaping informal structures and networks within an organization (e.g., Gulati and Puranam, 2009). We therefore conceptualize formal structure as setting the ''boundaries'' that contour informal interactions within organizations, and we highlight the relevant informal mechanisms in our theory (McEvily, Soda, and Tortoriello, 2014: 314).

[2] See Discussion section.

Setting: Startup–Incumbent Corporate VC Partnerships in the Life Sciences

We ground our theorization in a specific setting: partnerships between entrepreneurial ventures in the life sciences and their corporate investors, typically large pharmaceutical firms (Glaser and Strauss, 1967; Barley, 1990). We use this setting for two primary reasons. First, we can focus our theorization and empirical analysis on how variation in the incumbent's structure impacts a startup's performance, as startups' structures will be relatively simple and homogeneous (DeSantola and Gulati, 2017; Burton et al., 2019). Second, the startups' principal aim in these partnerships is to gain critical knowledge from the incumbent to further their innovation goals, making the antecedents of these knowledge flows particularly salient. While the core of the empirical analysis in this study is quantitative, we also carried out 72 interviews with managers from startups in the life sciences, as well as from the R&D and CVC divisions of incumbent pharmaceutical firms, to develop understanding of the mechanisms that operate in this setting. We draw on information gained from these interviews to help illustrate our theoretical arguments (Pontikes and Barnett, 2017; Sytch and Kim, 2021). While focusing on this setting enables us to be more precise in the mechanisms through which a partner's structure can impact a focal firm's access to the partner's knowledge, it does place boundary conditions on our findings, such as at least one partner having a complex structure. We address these boundary conditions in the Discussion section.

Corporate venture capital, the practice of startups receiving equity investment from incumbent firms, has become the most prominent form of collaborative partnering between these two types of firms (Dushnitsky, 2012; Drover et al., 2017). For incumbent firms, relationships with startups are principally a mechanism for learning, intended to serve as a window into the emerging technologies being pioneered by startups (Dushnitsky and Lenox, 2005; Dushnitsky, 2012; Lerner, 2013). Hence, at the point of investment, the startup's basic technology is typically well defined and, in industries for which this is important, protected by patents. On entering these partnerships, startups primarily focus on accessing the knowledge and associated resources of the investing incumbent firm, which can help them to translate these basic technologies into products or applications. We characterize this outcome as the development of *realized inventions*, i.e., prototype applications that can potentially be commercialized (Iansiti and West, 1997; Kapoor and Furr, 2015; Kapoor and Klueter, 2015). This is a critical innovation milestone for startups, as it can serve as an important signal of quality to potential investors and acquirers (Hsu and Ziedonis, 2013).

While startups at the discovery stage may have considerable knowledge of the basic science underlying their technology, transforming this into a realized invention requires expertise in many other areas.[3] These can range from clinical issues such as which therapeutic indication to target and in which type of patient, how human cells will respond, interaction effects with other treatments, which formulation to employ, and a wide range of other issues on which startups

[3] In the United States, prior to commencing phase 1 of trials on a drug candidate, a company must obtain investigational new drug approval for it from the Food and Drug Administration (FDA).

rarely have expertise readily available (Petrova, 2014; Barge-Gil and López, 2015). Incumbent firms typically have a great deal of this expertise and extensive experience dealing with the challenges associated with this stage of the innovation process. The R&D organizations of these firms have primary responsibility for their drug pipelines. This includes the scientific work of invention/discovery of the basic technology but also the subsequent work of transforming that technology into a validated product, which involves expertise in formulation, dosage, toxicology, regulatory precedent, manufacturing, and other areas. These types of expertise make up a key part of the ''D'' of R&D in this industry, and expertise in these areas is typically located within the R&D organization (Barge-Gil and López, 2015).

Access to the Incumbent's Knowledge: Why Breadth and Rate of Access Matter

Effectively accessing knowledge and associated resources from an incumbent firm can be difficult. Startups' need for a wide breadth of the incumbent's expertise during development arises for two reasons. First, at this very early stage, most molecules (i.e., technologies) have a range of potential therapeutic applications. Identifying which is the most promising is often challenging for the startup, as it can require domain expertise in those specific therapeutic areas. As one pharmaceutical R&D executive highlighted, ''I have a number of indications I might want to go after with this molecule; certain molecules can be used in lots of different ways.'' An entrepreneur described the challenges this way: ''Figuring out what tumors to go after, and what to combine with was really hard . . . I found that was the most valuable thing they (the incumbent firm) could contribute. Access to people who had expertise we didn't have.'' Typically, the expertise needed to investigate these different application areas comes from different parts of the incumbent firm. One entrepreneur stated,

> [I]n one instance where you're delivering these nanoparticles to cells you've got this concern about immunogenicity and things so you might want to be talking to the immunology group, but at the same time, the cargo that you're carrying is acting on a target in the cytoplasm that's implicated in cancer and in each of those instances you're talking to somebody either in a rare disease group or you're talking to somebody in the oncology group, and so you know you may have three or four different conversations with three or four different teams inside one of these big pharma firms.

Second, achieving the benchmarks of safety and efficacy to receive regulatory approval to commence human clinical trials (i.e., phase 1) on a drug can be hugely challenging because it requires expertise in many domains. A significant advantage of having an incumbent firm as an investor is that it can serve as a one-stop shop for most of this expertise. However, the value to startups in this regard comes not from sustained engagements with a small group of people over a long period but from more-focused, short-term engagement with a wider range of experts. For instance, expertise in toxicology is likely to come from a different source than will expertise in drug formulation, and startups

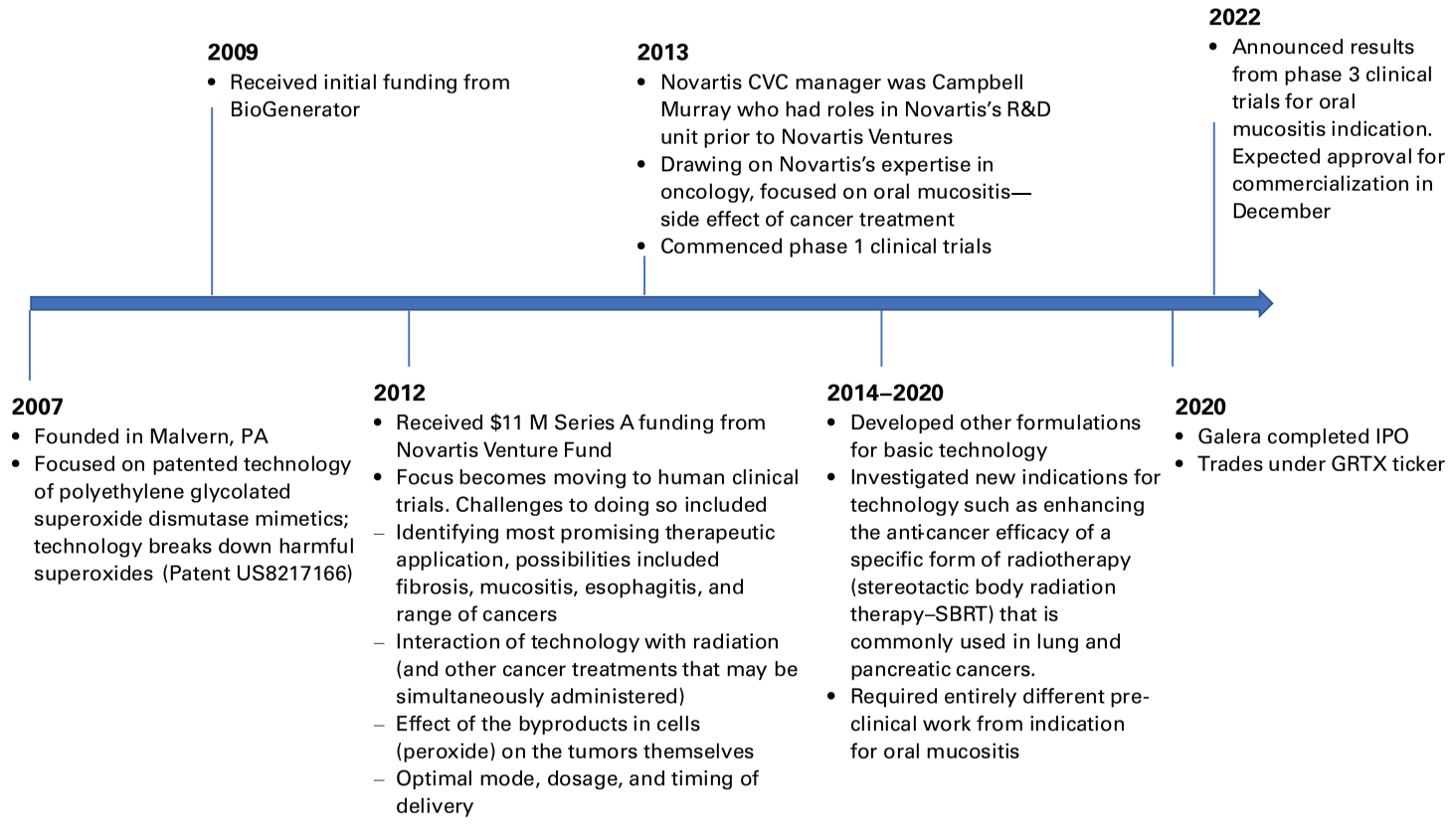
likely need access to both. This varied expertise is typically widely scattered across the R&D organization, which can make locating it difficult for the startup. To further illustrate these challenges, we summarize a case study in Figure 1, which we further elaborate in Online Appendix A. The subject of the case study, a startup named Galera Therapeutics, received CVC funding from Novartis and had a core technology that it sought to apply to various therapeutic areas.

In addition, the rate at which knowledge is accessible can be a concern for startups. Leveraging an incumbent firm's knowledge and associated resources requires the support of internal stakeholders who exercise control over those resources. These individuals are typically not directly incentivized to support startups, and the internal champions of the startup may not have sufficient decision-making authority or have suitable relationships through which they can persuade such individuals to provide this support (Dushnitsky and Shapira, 2010; Lerner, 2013). Decisions on providing access to suitable knowledge and resources can often require the approval of multiple stakeholders, especially when there are greater interdependencies (Levinthal, 1997; Raveendran, Silvestri, and Gulati, 2020). Thus, the startup often has to navigate substantial organizational complexity, as Pahnke, Katila, and Eisenhardt (2015: 604) highlighted: ''Helpful resources exist within corporations, but dispersed authority, complex and slow organizational processes, and internal conflicts . . . complicate ventures' access to these resources.'' This was a challenge that came up repeatedly in our interviews. As one entrepreneur commented, ''[W]e always say you know, a pharmaceutical conference room is where good ideas go to die.'' Another entrepreneur similarly expressed that the ''problem is partly risk-averse culture, partly multiple layers of management. [There is] always somebody to say no. . . . [You] can spend a whole career in pharma saying no, there is no opportunity cost.''

The Impact of Centralization on Breadth Versus Rate of Knowledge Access

In considering how an incumbent's organizational structure affects the breadth and rate of knowledge access for a startup, we focus on whether the incumbent firm's R&D organization is centralized or decentralized (DeSanctis, Glass, and Ensing, 2002). We distinguish centralized and decentralized R&D units based on the allocation of decision rights (Jensen and Meckling, 1992). Managers leading a centralized R&D unit have decision rights across the complete portfolio of firms' inventions and hierarchical authority over the parts of the organization working on these inventions; for example, they can readily shift resources between different R&D projects. In decentralized R&D units, managers have decision rights only for the relevant sub-portfolio of inventions and hierarchical authority over the parts of the organization creating and developing those inventions, so they can shift resources between projects within their sub-portfolios but not across different units (Burton, Obel, and DeSanctis, 2011). Thus, in a centralized R&D unit reporting to the firm's head of R&D, issues are considered and decisions are made at a cross-organizational level. With decentralized R&D units, issues are considered and decisions are made at

Figure 1. Development Timeline for Galera Therapeutics*



* Also see Online Appendix A.

the individual sub-portfolio level, with limited consideration of other R&D activities.[4] We focus on centralized R&D structures and describe their advantages and disadvantages for startups, compared to decentralized R&D structures.

Centralized structures tend to embody greater integration of an organization's disparate knowledge resources (Zhang, Baden-Fuller, and Mangematin, 2007; Argyres, Rios, and Silverman, 2020). Research has documented how centralized structures incentivize managers to engage in greater knowledge sharing and to pursue projects whose benefits accrue to the overall firm rather than to just their unit or division (Kay, 1988; Hounshell and Smith, 1989; Zhang, Baden-Fuller, and Mangematin, 2007). Competition between managers from different parts of the firm is lower in centralized structures, meaning that these managers are more likely to be collaborative (Karim and Kaul, 2015). As a result, having a centralized structure leads to more-extensive interconnections in the organization's internal networks. Argyres, Rios, and Silverman (2020) demonstrated this empirically, showing that firms with centralized R&D have more-densely interconnected inventor co-authorship and citation networks. Our fieldwork also helped to ground this expectation. The stated purpose of centralization in incumbent firms' R&D organizations was often explicitly to facilitate internal knowledge sharing. For startups, these interconnections in the partner organization make it easier to locate the knowledge and resources that may be valuable to them. While the knowledge search process for the startup is partly goal-driven, it may also have an element of serendipity in that by engaging with the different parts of the incumbent firm, the startup may identify solutions or innovation opportunities via a process more akin to the garbage can model of Cohen, March, and Olsen (1972). A more integrated structure makes this more likely to occur since managers in the incumbent firm are more aware of the expertise in other areas of the firm that may be relevant to the startup. The entrepreneurs we interviewed who had engaged with these incumbent firms' centralized structures frequently commented on the breadth of the resources they could access as an impressive feature of these relationships, using phrases such as ''very deep organization'' or highlighting the ''intellectual scale'' of the incumbent firms. One such entrepreneur, reflecting on their engagement with an incumbent firm's centralized R&D organization, highlighted the value of the dense internal networks: ''[They] have contacts all over the place. They typically know people . . . and connect you to them, they have strong relationships that you could take advantage of, and that was freely offered to us.''

More-decentralized structures are characterized by higher levels of autonomy, with decision rights more widely dispersed to different parts of the organization (Wiedner and Mantere, 2019). As a result, these structures promote responsiveness and streamlined decision making (Blau, 1972; Raveendran, Silvestri, and Gulati, 2020). Centralized structures, in contrast, are associated with greater bureaucracy and more-cumbersome decision processes (Blau and Schoenherr, 1971; Argote, Turner, and Fichman, 1989). For two reasons, this can impede startups' rate of access to valuable resources.

[4] Centralized and decentralized R&D represent two ideal types. Firms may combine some features of centralized structures into a decentralized R&D unit or vice versa. As in prior research, we focus on the dichotomous classification (while empirically controlling for other design features) as this allows us to more clearly discern the principal mechanism underlying the relationships of interest.

First, by definition, in centralized structures decision-making authority is more centrally concentrated, typically at a higher level in the organization (Burton, Obel, and DeSanctis, 2011; Garicano and Wu, 2012). This need to push decisions up the organization is likely to slow down decision making and make it more complex, since it now involves a greater number of actors. In its simplest form, such decision making would involve the actor who is directly responsible for the resource in question and the actor who has the authority to make decisions about sharing the resource. For a startup, accessing the resource means getting the buy-in of both actors.

Second, centralized structures tend to be more integrated than decentralized structures, which tend to be more modular (Lawrence and Lorsch, 1967). In other words, decentralized structures typically have limited dependencies across units, whereas in centralized structures hierarchical authority is the tool employed to manage those interdependencies, which tend to be greater (Baldwin, 2007). This means that the breadth of concerned parties to any decision grows, and a prospective decision concerning one part of the organization is more likely to draw protest from another part whose activities may be perceived to be impacted in some way (Blau, 1972; Raveendran, Silvestri, and Gulati, 2020). Hence, for startups, centralized structures on average mean having to obtain the buy-in of a wider range of stakeholders in the incumbent firm, both vertically and horizontally, compared to decentralized structures. Interviews with pharmaceutical executives highlighted these limitations: ''Centralized structures often may have a lack of clarity of roles and who is responsible for what, so decision making can be tough.'' The CEO of a startup dealing with an incumbent firm with a centralized structure noted that decision making is a challenge ''[p]artly because of the layers of organization that they have and the kind of centralized management, which means that they can't get out of their own way.'' This CEO added that ''there is always somebody that is going to suggest something. . . . It's extraordinary, the level to which you have to jump through hoops to get things done.''

Thus, although centralization may provide more pathways through which knowledge can flow, this flow can become constricted by additional decision-making complexity. Centralization of a partner's organizational structure will facilitate access to a greater breadth of this organization's corpus of knowledge but concomitantly will impede the rate at which this knowledge can be accessed. Whether a firm will benefit more from its partner having a centralized or decentralized structure will depend on the extent to which the knowledge value of the partnership relies on the breadth versus the rate of knowledge access. We focus our hypotheses on factors that can shift the balance in this tradeoff with respect to partner structure—factors that can enhance the value of having access to a greater breadth of the partner's knowledge or alleviate the costs of having a lower rate of access to that knowledge. Identifying these factors allows us to develop specific theoretical predictions about conditions that should make partner centralization more valuable, which we can test empirically.

Factors Enhancing the Value of Breadth of Access

The greater integration resulting from an incumbent firm's centralized structures can enable a startup to potentially tap into a wider swath of the firm's knowledge base. If that knowledge base is more diverse, spanning a

broader array of domains, the additional pathways through which knowledge can reach the startup become even more valuable as a more diverse (and non-redundant) array of knowledge becomes accessible (Pfeffer and Sutton, 1999; Tortoriello and Krackhardt, 2010). In addition, a major driver of the benefit of centralized structures arises from their managers being more cognizant of expertise in other parts of the firm and having relationships with the sources of that expertise.

Less overlap in knowledge may also diminish internal knowledge sharing, making the existence of knowledge silos in the firm more likely (Zahra and George, 2002). A decentralized structure with disconnected autonomous units would exacerbate these divisions. Startups would then be less likely to locate valuable expertise, whether they were seeking something specific or through the more network-driven, serendipitous process of knowledge matching. Together these arguments suggest the following hypothesis:

> **Hypothesis 1 (H1):** The relationship between R&D centralization of the corporate investor and the number of realized inventions that startups develop is more positive as the diversity of the corporate investor's technological expertise increases.

The degree to which accessing a wider swath of the incumbent's expertise will be valuable to the startup will also depend on the startup's knowledge needs. Some startups focus on a narrow knowledge domain with which to translate their technologies into realized inventions, whereas other startups span a broader range of domains. The expertise needed to progress along different technological domains is likely to be distinct and located in different parts of the incumbent firm. For instance, targeting a molecule toward gastrointestinal tumors will draw on expertise distinct from that needed to target the molecule toward brain or upper respiratory tumors. Startups with technologies focusing on a wider range of application areas are likely to benefit more from having access to a wider array of expertise. If this is the case, the marginal benefits of having pathways to a wider array of the incumbent firm's R&D organization because it has a centralized R&D structure will also be greater:

> **Hypothesis 2 (H2):** The relationship between R&D centralization of the corporate investor and the number of realized inventions that startups develop is more positive as the diversity of the startup's knowledge needs increases.

Factors Counteracting the Impeded Rate of Access

Our theorized limitations to the rate of knowledge access from partners with centralized structures relate to the complex decision processes that arise from the more integrated structures. Existing research has broadly highlighted two forms of solutions to these constraints: affinity, which is the ''role of informal networks as an antidote to formal organization practices and structures'' (Smith-Doerr and Powell, 2010: 379), and authority, which is the use of formal hierarchical fiat to override competing interests and accelerate decision making (Williamson, 1979; Kownatzki et al., 2013). We consider how each solution eases constrictions to the rate of knowledge access when partners have centralized structures.

Affinity. Incumbent firms typically have a specific group of employees tasked with making and managing their venture capital investments. These individuals are the primary points of contact between the startup and incumbent firms, and they play a critical role in shepherding startups through these firms by advocating for them internally and helping them access resources (Dushnitsky and Shapira, 2010; Lerner, 2013). A substantial body of research studies the role of boundary spanners, individuals who serve as the interface between an organization and its environment, in facilitating information exchange between firms (e.g., Adams, 1976; Aldrich and Herker, 1977). This literature highlights that such individuals become particularly important in shaping outcomes in relationships in which the necessary exchanges between firms are more uncertain, i.e., undefinable, ex ante. Various studies have characterized boundary spanners' positions within their own organizations as a crucial determinant of how effectively they facilitate access to resources, highlighting, for instance, their internal connectedness (e.g., Tushman and Scanlan, 1981), functional background (e.g., Clark and Maggitti, 2018), and tenure with the organization (e.g., Perrone, Zaheer, and McEvily, 2003).

We draw on these precedents to examine the role of incumbent firms' CVC managers, who serve as boundary spanners for the firms' relationships with startups. Given that monetary incentives to support startups' activities are rare in the R&D organization, CVC managers rely on informal mechanisms to facilitate startups' access to resources. These individuals are rarely part of the organization's senior management (for instance, members of the C-suite or management board); hence, they typically cannot drive resource access for startups purely via fiat (Strebulaev and Wang, 2021). Consequently, CVC managers' ability to persuade their R&D colleagues to share relevant knowledge with the startup is contingent to a significant degree on their own social capital within the incumbent firm. This aspect of CVC managers' influence was highlighted by an entrepreneur we interviewed:

> You work with your investor representative (i.e., CVC manager) to help you navigate the larger organization and based on the cultural impact that they have had, those [incumbent firm] resources are willing to dedicate some time to you . . . but there is nothing from an incentives perspective compelling them to do so.

Prior research on boundary spanners has highlighted the importance of their connections within their own company as a critical determinant of their ability to effectively carry out their roles (e.g., Perrone, Zaheer, and McEvily, 2003). A critical distinction here is between managers who have prior experience working in the firm in operational roles and those who were externally hired specifically to work in the CVC division. The former are likely to have developed more social capital within the incumbent firm (Burt, 2005) and to better understand the decision-making processes of the incumbent firm and potential ways to circumvent or accelerate them (e.g., Kelly, Medina, and Cameron, 2014; Lungeanu and Zajac, 2019). This experience should enhance a CVC manager's ability to ease impediments to the rate of knowledge flow that startups face in centralized structures. Hence, we argue,

> **Hypothesis 3 (H3):** The relationship between R&D centralization of the corporate investor and the number of realized inventions that startups develop is more

positive when more of the corporate investor's VC managers have prior experience working in the firm in operational (i.e., non-CVC) roles.

Authority. Hierarchical fiat is an important tool to precipitate organizational action (Williamson, 1979; Kownatzki et al., 2013), and on average, decision making is likely to accelerate in the presence of an impetus created by hierarchical authority. Centralized organizational structures, by definition, are characterized by more-concentrated authority. More control in these structures is likely to be localized at the firm's headquarters, compared to decentralized structures, in which authority is more widely dispersed (e.g., Van de Ven et al., 2012). The value of geographic proximity to the authority situated at an organization's corporate headquarters has been widely discussed in prior studies. Research has highlighted how proximity to headquarters can facilitate greater attention from those with authority (Bouquet and Birkinshaw, 2008; Giroud, 2013) and, in turn, how this attention can enhance outcomes such as survival (Kalnins and Lafontaine, 2013), investment (Kim, Cunningham, and Joseph, 2023), and innovation (Bernstein, Giroud, and Townsend, 2016).

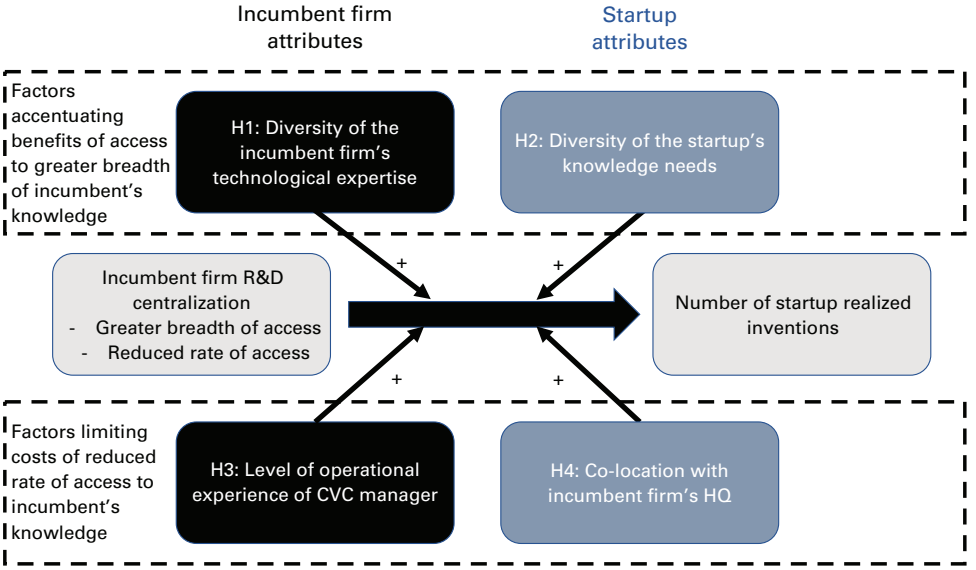
We argue that the deployment of this authority in the startup's favor is likely to lead, on average, to quicker resolution of disagreement and, therefore, to easing of the constrictions to the knowledge flow rate. A vast body of research across the social sciences demonstrates the value of propinquity for access and relationship building (Festinger, Schachter, and Back, 1950; Jaffe, Trajtenberg, and Henderson, 1993; Cai and Szeidl, 2018). A startup that is near an incumbent firm's headquarters will likely more effectively gain the attention of the firm's managers (Kim, Cunningham, and Joseph, 2023). Such attention should enable startups to leverage that authority to ease resource access constrictions that exist in centralized structures. Prior research on CVC relationships has also documented this mechanism. Alvarez-Garrido and Dushnitsky (2016: 824) described a startup CEO who attributed the value his company derived from their CVC partnership as driven substantially by his company offices' location within a ''five-minute walk'' from the incumbent firm's corporate headquarters, which eased constraints to resources access.

Because startups typically must obtain the assent of a range of organizational stakeholders to access valuable resources in centralized structures, we argue that having a more-senior manager use their authority to advocate for the startup should, on average, help the startup obtain this access faster than it would without that support. For incumbents that have more-decentralized structures in which authority lies lower down the organization, the marginal benefits to startups of being located closer to a firm's headquarters will be lower:

Hypothesis 4 (H4): The relationship between R&D centralization of the corporate investor and the number of realized inventions that startups develop is more positive when the startup is geographically colocated with the corporate investor's headquarters.

Figure 2 summarizes our theorized relationships.

Figure 2. Summary of Theorized Relationships



METHODS

Research Context and Sample

The context for this study is the U.S. life sciences industry between 1995 and 2012. This was a period of significant expansion of corporate venture capital investments by large pharmaceutical companies in biotechnology startups. We started the data collection from 1995 because access to structural data from companies' annual reports prior to that period is more challenging to obtain. We obtained venture capital data from Venture Xpert, which Kaplan and Lerner (2016) reported has the widest coverage of funding events of any commercially available venture capital database. Because it represents well-defined industry-wide milestones, the progression of drug candidates through clinical trials allows comparison of firms' development outcomes. We obtained these development data from the Pharmaprojects database (e.g., Chandy et al., 2006; Kapoor and Klueter, 2015). We also used patent data obtained from the European Patent Office Worldwide Patent Statistical (PatStat) database and USPTO's Patentsview database. We hand collected incumbents' organizational structural data from companies' 10-K, 20-F, and DEF14A SEC filings and annual reports. We provide more detail on this process below.

We started with a sample of 49 incumbent firms. The sample is based on annual prescription drug sales as defined by *Pharmaceutical Executive* magazine's top 50 pharmaceutical companies in 2004–2006, which is the midpoint of the sample period (e.g., Klueter, Monteiro, and Dunlap, 2017).[5] In this period, 64 separate firms appeared in the top 50 in one or more years. The 15 firms over that period that we excluded are either private firms or did not

[5] The top 20 pharmaceutical firms by R&D spend represented 60 percent of industry R&D spend, and the top 20 pharmaceutical firms by prescription sales represented 64 percent of industry sales in 2015.

provide sufficient information in their public filings. These firms were in the lower half (26–50 ranking in pharmaceutical sales) in one or more of the three years in the 2004–2006 period. Using the sample's midpoint allowed us to examine firms that had at least 10 years of history within the sample time frame. Thirty-three of the 49 sample firms were still in the top 50 pharmaceutical firms in 2015, 13 firms had been acquired by other firms, and three firms had divested their pharmaceutical businesses. Data on these now-defunct firms for many of our variables (CVC managers, for instance) proved to be difficult to obtain over time; hence, we also excluded these firms from the sample. We then used Venture Xpert to identify the CVC investments made by these 33 incumbent firms in startups based in the United States over the study period. We found that 18 of these firms had made at least one CVC investment, with a total of 398 startups having received investments from these firms over this period. These were the basis for the dyads that make up our final sample.

We supplemented this primary archival analysis with 43 interviews with executives in strategy and R&D roles from all the sample incumbent firms. The interviews were semi-structured and lasted between 30 and 90 minutes. The focus of these interviews was to evaluate the validity of the organizational structure measures, to discuss how these firms managed their external relationships, and to evaluate the mechanisms that can facilitate or hinder resource flow between incumbents and startups in CVC partnerships. We also conducted an additional 29 interviews with startup-focused industry informants, including founders/managers of startups that had received venture capital from incumbents, the employees of incumbents responsible for making and managing these investments (i.e., CVC managers), and independent (i.e., non-corporate) VC investors who co-invested with corporate investors. These interviews focused on the types of exchanges that could arise between incumbent firms' and startups' personnel post investment, the organizational antecedents of these, and how they could influence the startups' innovation decisions. We conducted these interviews to help us ground our theory and understand our empirical observations. They were not meant to represent a rigorous qualitative research exercise (e.g., Eisenhardt, 1989).

Empirical Design and Estimation

The unit of analysis for this study is the incumbent firm–startup dyad. We developed a panel dataset to examine each dyad on an annual basis between 1995 and 2012. The first year for each dyad is the year the relationship was formed, i.e., the year the corporate VC investment was made. We tracked this dyad every subsequent year until the startup either exited, i.e., was acquired or listed its shares on the public markets, or ceased to exist (Kaplan and Lerner, 2016). Since our data on startup dissolution are likely to be incomplete, we assumed that a startup ceased operations if it did not exit but also did not raise new capital for three years continuously.

Leveraging changes to R&D structure. To identify our effects of interest, we relied on reorganizations within the incumbent firms that led to them shifting from a centralized to decentralized R&D structure or vice versa. We

examined how the outcomes for startups changed corresponding to these structural changes in the incumbent firms, relative to dyads in which there was no such structural change over the same period. Focusing on shifts in structure rather than comparing dyads in which structures remained stable over time offered us the considerable advantage of reducing the threat of unobserved heterogeneity between different incumbent firms being the driver of the relationships we observe. Furthermore, as we describe below, these structural shifts in the R&D organizations were not driven by considerations relating to the firm's CVC relationships with startups.

We identified the shifts based on changes in the composition of the top management team in which an R&D role changed, either expanding from one to multiple roles or vice versa, i.e., centralized R&D to decentralized R&D or the reverse. We then validated these changes through a detailed investigation of the relevant incumbent firms' annual reports, press releases, and the internet archive (web.archive.org) to ensure that the R&D structure did indeed change, and we confirmed the directionality of the change and identified the rationale for the change.

Over the study period, 10 of the 18 incumbent firms underwent at least one restructuring of their R&D units, and as a result, 19.1 percent of the dyads in our sample experienced a change in an incumbent's R&D structure. These 10 incumbent firms underwent 18 R&D restructuring events, nine of which were from centralized to decentralized R&D and nine from decentralized to centralized R&D units. Table 1 provides the full list of the 18 structural changes. These changes in R&D structure occurred for various reasons, such as mergers and acquisitions, the departure of key R&D personnel, or a desire to focus on specific product categories.

In a few instances, incumbent firms underwent multiple structural changes in relatively short periods, which raises the question of what real impact they may have had. Given the rationales for these changes, and considering our interviews, we do not believe that any of these changes were necessarily anticipated as temporary. However, we also verified that these back-and-forth changes are not fundamental to our findings, by checking their robustness to dropping all dyads containing multiple changes, i.e., in which the incumbent firm underwent more than one structural change (see the discussion of robustness checks and Online Appendix B). In Online Appendix A, we also summarize the findings from more-detailed qualitative investigations of the impact of these structural changes for six of these events, focusing on our mechanisms of interest (Table A1).

Effect of R&D shifts on CVC activity. We did not find explicit reference to CVC investments as a driver or a concern in relation to any of the R&D reorganization events, perhaps, in part, because CVC investments generally represent a very small proportion of incumbent firms' innovation activities. For example, Novartis had an annual R&D budget of approximately $9 billion in 2020 and spends approximately $30 million per year on CVC investments; CVC represents less than 1 percent of its R&D budget.[6] Other elements of R&D are therefore more likely to shape the structure of this unit than are CVC

[6] Based on the Novartis 2020 annual report and Crunchbase data.

Table 1. List of 18 R&D Structural Changes in the Sample*

#	Year	Firm	Change	Reason
1	1999	Takeda	Centralized to decentralized R&D	Internal reorganization of research from single to multiple units focused on different elements of the R&D process
2	2000	Novo Nordisk	Decentralized to centralized R&D	Divestiture of enzymes business prompted internal consolidation of remaining R&D into a single unit
3	2000	Glaxo	Centralized to decentralized R&D	Decentralization following a merger, split R&D into multiple technology-focused units
4	2001	Takeda	Decentralized to centralized R&D	Internal reorganization of multiple research units into one pharmaceutical research division under a single head
5	2001	Bristol Myers Squibb	Centralized to decentralized R&D	Split of R&D along technological lines after departure of chief scientific officer from the company
6	2001	J&J	Decentralized to centralized R&D	Amalgamation of multiple R&D groups into one under a single head ''to facilitate the sharing of scientific knowledge across the company''
7	2002	Glaxo	Decentralized to centralized R&D	Departure of two senior R&D executives led to the unification of R&D under a single head
8	2003	Amgen	Centralized to decentralized R&D	Acquisition prompted split of R&D organization
9	2003	Merck	Decentralized to centralized R&D	Internal reorganization following the retirement of one senior R&D executive and departure of another
10	2003	Bristol Myers Squibb	Decentralized to centralized R&D	Death of previously most senior R&D executive (who was head of the largest division) prompted unification of the organization under a new appointee
11	2003	Pfizer	Centralized to decentralized R&D	R&D was split into multiple divisions focused on basic science or more function-specific applications of science
12	2004	Amgen	Decentralized to centralized R&D	Consolidation and restructuring of company led to unification of R&D under a single head
13	2006	Pfizer	Decentralized to centralized R&D	Arrival of new CEO and retirement of a senior R&D executive prompted a reorganization into a single R&D organization
14	2007	Pfizer	Centralized to decentralized R&D	Raft of leadership changes among senior R&D executives: 2 left the company, 2 promoted, and 4 externally recruited led to R&D being split again into multiple units
15	2009	Roche	Centralized to decentralized R&D	An acquisition resulted in the split of R&D into three distinct physically separated units
16	2010	Glaxo	Centralized to decentralized R&D	Imperative to provide more resources and autonomy to specific areas (e.g., vaccines) led to a split of the R&D organization

(continued)

Table 1. (continued)

#	Year	Firm	Change	Reason
17	2010	Pfizer	Decentralized to centralized R&D	Acquisition led to another reorganization, with the R&D organization being unified under head of R&D at Wyeth (the acquired company)
18	2012	Baxter	Centralized to decentralized R&D	Split of entire company along therapeutic lines

* Information collected from company annual reports and 10-K/20-F/DEF 14A SEC filings as well as press releases and archived versions of company web pages accessed via archive.org.

investments. Furthermore, the making and managing of CVC investments in our sample's large pharmaceutical companies is typically led by managers in a separate company division specifically for this purpose (e.g., Pfizer Venture Investments, Novartis Venture Funds, and SR One, which is GlaxoSmithKline's CVC division). These divisions operate independently of the firm's R&D organization, and the CVC managers have no direct or indirect reporting relationships with managers in the R&D divisions. We directly verified this with our informants from firms responsible for approximately two-thirds of the investments in our sample. We also examined whether these firms' CVC activities were altered in conjunction with the changes to R&D structure, and we found no systematic changes in volume or type of investments or in the personnel in these divisions (we offer more detail on this after we discuss the main results).

Our empirical design examines how changes in incumbents' R&D structures influenced the startups that received CVC investment from these firms. As we draw on changes in structure over time, we have the significant advantage of being able to employ dyad-level fixed effects in all our estimates. Thus, our analyses account for any unobserved aspects of the incumbent firm–startup relationship that remain constant over time (e.g., inherent quality). These fixed effects also help to account for factors such as the investment objectives (strategic vs. financial, etc.), which are unlikely to change over time for a particular investment. Further, for each reorganization event, our effects are estimated based only on dyads formed prior to the reorganization occurring. Given our design, which is consistent with much existing research on alliances, our findings should be interpreted as local average treatment effects conditional on these relationships being formed between the firms (Gulati, 1999; Reuer and Devarakonda, 2016). We estimated all our models via OLS, unless noted otherwise.

Measures

Dependent variable. To characterize an entrepreneurial firm's output of realized inventions, we used the count of the number of new drugs belonging to it that entered phase 1 of clinical trials. To enter clinical trials in the U.S., a prototype drug must receive FDA Investigational New Drug (IND) approval, which can be challenging. Moving drug candidates from preclinical to phase 1 clinical trials represents a major milestone for a startup, as it represents the

first time the drug is tested on human subjects. Getting a drug candidate into clinical trials is a validation signal for the technology. This signal can be vitally important to startups because it can help them enhance their valuation, obtain additional funding, license the drug candidate for joint development, or undertake a liquidity event such as an initial public offering.

It should be noted that achieving the phase 1 milestone does not guarantee ultimate commercialization of a drug candidate. For this to occur, drug candidates must have cleared all three phases of clinical trials, and this typically takes many years after entering phase 1 (Petrova, 2014). Furthermore, often by the time the drug reaches the latter stage of trials (unlike at phase 1), the level of investment required means that startups typically share ownership of these candidates with other firms or have ceded decision rights altogether (Cunningham, Ederer, and Ma, 2021). To capture *New clinical drug candidates*, we used the log of one plus the number of new drugs that entered phase 1 clinical trials for the entrepreneurial firm in the three years after the focal year.

Independent variables. *R&D centralization.* This is a dichotomous variable that is set to zero if a firm has a decentralized R&D unit and one if it has a centralized R&D unit. We followed a four-step process to develop this variable, similar to the process used in other studies (Sytch, Wohlgezogen, and Zajac, 2018). First, using top management team (TMT) data available from company 10-K/20-F/DEF 14A SEC filings and annual reports, we identified the senior executives of each incumbent firm in our sample for each sample year. TMT data have been used extensively in the strategic management literature to develop high-level organizational structural measures (e.g., Guadalupe, Li, and Wulf, 2014; Girod and Whittington, 2015; Albert, 2018; Sytch, Wohlgezogen, and Zajac, 2018). This enabled us to develop a database of 6,967 executives and executive team roles for the sample of incumbent firms over the period 1995–2015.

Second, we coded all the roles of the managers in this database, using the categorization developed by Guadalupe, Li, and Wulf (2014). Further, we identified all the roles pertaining to R&D through careful review of the management roles in each organization. For diversified firms that operated beyond pharmaceuticals, we focused on R&D units that pertain to pharmaceuticals and excluded R&D units dedicated to areas such as consumer products. Using this approach, *R&D centralization* is set to zero if there are multiple R&D groups reporting to separate heads within the TMT covering different pharmaceutical domains or to leads of business units and is set to one if the firm has a single integrated pharmaceutical R&D group.

Third, we further validated the *R&D centralization* measure through careful review of organizational descriptions from companies' filings (e.g., CEO's letter to shareholders) and publicly available press releases. This also enabled us to identify 18 restructuring events at 10 sample incumbent firms, illustrated in Table 1. Using publicly available documents, we also examined the context of each restructuring event to identify the rationale for the structural changes and how those changes could impact the two mechanisms we outline in our theory development. Finally, we interviewed managers from all incumbent firms in our sample to validate the measure of centralization we employed.

The construct we seek to empirically capture with this measure relates to managers' scope of discretion in making resource distribution decisions; in the centralized case it is across the entire R&D organization, and in the decentralized case it is within the relevant R&D sub-unit. Thus, our definition of centralization is based fundamentally on where authority lies in the organization. A related but distinct construct is disaggregation, the degree to which an organization is separated into distinctive non-overlapping units in its task structure (Daft and Lewin, 1993; Podolny and Page, 1998). These two features of organizations, centralization and aggregation, are often correlated but not perfectly so. For instance, organizations may sometimes facilitate greater centralization, such as increasing managerial span of control, via disaggregation, by forming more sub-units to enable easier monitoring and coordination (e.g., Zenger and Hesterly, 1997). In the case of R&D in our empirical setting, decentralization tends to be strongly correlated with disaggregation as each disaggregated unit has significant freedom to make its own decisions independent of the other R&D units, without having to refer to a central authority. This is consistent with our proposed theoretical mechanisms, which are grounded in the distribution or concentration of authority, and these will be the focus of our hypothesis tests.

Therapeutic diversity incumbent. To evaluate the diversity of knowledge in the incumbent firm, we develop this measure of the diversification of the firm's drug development portfolio across therapeutic classes (e.g., Rothaermel and Deeds, 2004; Macher and Boerner, 2006; Macher and Boerner, 2012). The Pharmaprojects database classifies drugs into one or more of 18 classes based on the drug's therapeutic application. To create this measure, we estimated the sum of the squared proportions of drug candidates in each therapeutic class in the incumbent firm's overall clinical development portfolio. We then subtracted this Herfindahl measure from 1 to develop a measure that is higher when the diversity of a drug development portfolio is higher.

Therapeutic diversity startup. This is measured in a manner analogous to that of *Therapeutic diversity incumbent* but using the therapeutic classes of drug candidates in the startups' development portfolios at the preclinical stage. Hence, this measure captures the breadth of the application areas to which startups are attempting to direct their technologies, with a higher value indicating that a startup's preclinical portfolio is spread over a wider range of therapeutic areas.

Insider CVC managers. To examine how effectively startups can navigate the complex decision-making environment of their incumbent partners, we focused on the senior managers in the CVC divisions of incumbent firms. We theorize that CVC managers with prior experience working in the incumbent firm in operational roles (i.e., insiders) will have developed stronger informal relationships and a better understanding of the decision processes in their firms that they can use to accelerate resource flows toward the startup. We obtained information on these managers' identities from the Greyhouse and Galante Venture Capital directories and from archived company web pages (archive.org). We then collected information on their career histories from linkedin.com and archive.org. We classified the CVC managers as insiders if they had at least three years of prior experience in the incumbent firm in non-CVC roles. Then, for each incumbent firm–year, we counted the number of insiders in the incumbent firm's CVC

divisions. We verified the robustness of our results to using other lengths of time (e.g., one year, five years) to classify CVC managers as insiders and to tighter restrictions on the nature of their prior experience in the incumbent firm (e.g., only R&D).

HQ colocation. We defined this variable to be equal to one if the startup's and the incumbent firm's headquarters are located in the same two-digit zip code, which roughly encompasses U.S. metropolitan areas; this definition has been extensively used in prior research to measure geographic colocation (Yue, Rao, and Ingram, 2013; Funk, 2014). We obtained information on the incumbent firms' headquarters from their annual reports and on those of startups from Venture Xpert.

The theoretical mechanism we focus on pertains to startups leveraging formal authority to help accelerate access to the incumbent firm's knowledge. In firms with centralized R&D, such authority generally lies in a firm's corporate headquarters rather than its R&D locations. The senior leadership of the R&D organization in these structures is typically based at the corporate headquarters (e.g., Pfizer in New York City, Eli Lilly in Indianapolis). We expect startups to find value in access to this authority because it alleviates impediments to knowledge access. In contrast, for firms with decentralized R&D, senior managers are generally located in the relevant R&D or subsidiary location (e.g., Roche at R&D sites in New Jersey, Arizona, and California). The incumbent firms in our sample all had several R&D sites located across many countries and, in most cases, multiple R&D sites within the U.S., with the firms' R&D expertise consequently spread out over those locations. We controlled for startups' colocation with the incumbent firms' R&D sites in all models. However, given the theoretical focus on hierarchical authority, we focused on HQ collocation to test our hypothesis.

Control variables. We controlled for a wide range of variables relating to the entrepreneurial and incumbent firms. Table 2 shows these variables along with a description of how they are measured and the rationale for their inclusion. We also included dyad fixed effects and year fixed effects in all our estimates.

RESULTS

Main Results

The summary statistics for the data that we used to test our hypotheses are shown in Table 3. In the raw data, the correlation between *R&D centralization* and *New clinical drug candidates* is positive and significant ($p = 0.00$). On average, startups progressed 0.13 drug candidates into phase 1 clinical trials when the incumbent had a centralized R&D unit and 0.07 drug candidates when the incumbent had a decentralized R&D unit (the difference is significant: $p = 0.00$, $t = 3.2$).

Figure 3 illustrates that the raw data are in line with all four hypotheses, as illustrated by the positive values of the difference in differences of *New clinical drug candidates* between incumbent firms with centralized and decentralized R&D units above and below the median values of each of the moderators. Centralization of R&D has the largest positive impact on *New clinical drug*

Table 2. List of Control Variables

Variable	Measurement	Reason for Inclusion
Business development TMT	Dummy variable set to 1 if the incumbent firm has a business development manager role within the top management team in the relevant year	Firms with centralized business development units may provide a higher level of support to startups than more ad-hoc arrangements through individual business units as has been observed for alliances and acquisitions. (Kale, Dyer, and Singh, 2002; Trichterborn, Zu Knyphausen-Aufseß, and Schweizer, 2016)
Corporate decentralization	Variable representing whether the incumbent firm is more functionally or more divisionally aligned. This variable is estimated using the composition of firms' TMTs (excluding CEO), dividing the number of business unit leads by the total size of the top management team. The greater the value of this variable, the more decentralized a firm. (Albert, 2018)	More divisionalized firms with multiple business units may present even greater barriers for startups trying to find the knowledge and resources that they require and could also be correlated with R&D centralization.
R&D size	We focus on the size of the incumbent's drug development portfolio. We operationalize this measure as the count of the number of drug candidates in an incumbent firm's development portfolio in 1000s (i.e., in preclinical development or phase 1 to 3 trials) as of the focal year.	The larger the size of an incumbent firm's drug development portfolio, the harder it may be for startups to locate the knowledge they require.
External portfolio	Proportion of drug candidates in the incumbent firms' portfolios that are externally sourced	External orientation could be related to both the way R&D is structured and the degree of attention the incumbent pays the startup.
Incumbent patent stock	Discounted cumulative number of patents filed by the focal firm (in thousands) (Arora, Belenzon, and Rios, 2014)	Firms with a larger stock of patents may choose not to invest as much effort into their relationships with entrepreneurial firms associated with CVC partnerships.
Slack	Current ratio, i.e., ratio of current assets to liabilities	Indicative of the slack resources the incumbent firm has on hand. Prior studies have indicated that greater slack may enable a firm to make technology-focused investments, which could impact their engagement with the startups in which they invest. (Greve, 2003)
R&D intensity	Annual spend on R&D by incumbent firms as a proportion of their annual revenues (Cohen and Levinthal, 1990)	Changes in this measure could be correlated to changes in organization design and to the knowledge the startup can access.

(continued)

Table 2. (continued)

Variable	Measurement	Reason for Inclusion
New CEO	Dummy set to 1 if a firm's CEO changes in any given year and 0 if not	This could precipitate a wide range of organizational changes that could influence structure and external knowledge sharing.
Performance (ROA)	Previous year's return on assets of the incumbent firm	Better-performing firms may be less reliant on CVC partners and may tend to structure R&D in specific ways.
Number of operating segments	Total number of operating segments that established firms report in their financial statements in their annual reporting documents (Albert, 2018)	The degree to which the firm is diversified can influence the variety of knowledge the startup can access, as well as how easily that knowledge can be accessed.
CVC managers with startup experience	The number of CVC investment managers in the incumbent firm in the focal year with prior experience working in an entrepreneurial firm	Having prior experience in an entrepreneurial environment may influence the type of feedback these individuals provide to the startup and the connections they are able to facilitate within the incumbent firm.
CVC managers with R&D experience	The number of CVC investment managers in the incumbent firm in the focal year with prior experience working in the R&D division of an incumbent firm (may be the focal incumbent firm or a different one)	Prior experience in R&D may influence these individuals' connections to the R&D personnel in the incumbent firm as well their understanding of R&D and where knowledge may be located. This could shape what startups get from these partnerships.
Number of CVC managers	Total number of CVC managers in incumbent firm	Access to more CVC managers, regardless of experience, may facilitate startups' breadth and rate of access to incumbents' knowledge.
Startup preclinical candidates	Number of preclinical drug candidates startup has in its portfolio	Startups with more preclinical drug candidates are more likely to progress more drug candidates into phase 1 trials.
Startup patent stock	Cumulative number of patents filed by the focal startup	This is likely to be related to the startup's own knowledge base as well as its attractiveness as a partner to the incumbent firm.
Therapeutic area overlap	Degree to which the two firms overlap in the therapeutic areas they focus on. Measured as the minimum complement distance between the firms based on the proportion of active drug candidates they have in each therapeutic area (Bar and Leiponen, 2012), subtracted from 1	A value of 0 indicates that the firms are targeting distinct therapeutic areas, whereas a value of 1 indicates perfect overlap in the therapeutic areas. This could be related to the amount of useful knowledge the startup could potentially access via the relationship as well as the incumbent firm employees' motivation to support the startup.

(continued)

Table 2. (continued)

Variable	Measurement	Reason for Inclusion
Patent technological overlap	Degree to which the two firms overlap in the classes in which they file patents. Measured as the minimum complement distance between the firms based on the proportion of their patents in each technology class (Bar and Leiponen, 2012), subtracted from 1	Captures the degree of similarity in the firms' (incumbent and startup) technological focus, which could shape the type of engagement between them
R&D colocation	Binary variable equal to 1 if the startup is located in the same 2-digit zip code as one of the incumbent firm's R&D sites. The locations of incumbent firms' R&D sites were identified based on inventor locations on the firm's patents. All locations hosting at least 1% of the firm's inventors in a year were counted as an R&D site. We manually verified the presence of R&D sites at these locations via company filings, annual reports, and online sources for firms responsible for the majority of investments in the sample.	Startups collocated with R&D units may be better able to access the knowledge they require from the incumbent via their relationships with personnel located at these sites. Physical proximity to R&D may also be systematically correlated with the likelihood of investment under certain R&D structural configurations.

candidates when startups have above the median value of *Therapeutic diversity startup*.

Table 4 shows the results from our main regression analyses testing all four hypotheses. The results from Model 1 contain none of the interaction terms. Given the inclusion of dyad-level fixed effects in all models, the coefficient associated with *R&D centralization* gives us the estimate of the effect of a change in structure on the outcome variable. This model suggests that centralized R&D in the incumbent firm (compared to decentralized R&D) is associated with the entrepreneurial firm progressing more drug candidates into phase 1 clinical trials, as illustrated by the positive coefficient for *R&D centralization* ($p < 0.01$) in Model 1. The effect size is that 0.10 more of startups' drug candidates (0.30 standard deviations) move into phase 1 trials in the subsequent three years when the incumbent firms have centralized R&D units, compared to decentralized R&D units. We also observe that startups with more-diverse knowledge bases and incumbent firms with lower prior performance are associated with startups progressing more drug candidates into phase 1 clinical trials. Interestingly, we also observe that incumbent firms with fewer CVC managers with startup experience tend to be associated with the startup having more realized inventions. It appears that in relation to this outcome, CVC managers' experience in the incumbent firm counts for more than prior startup experience.

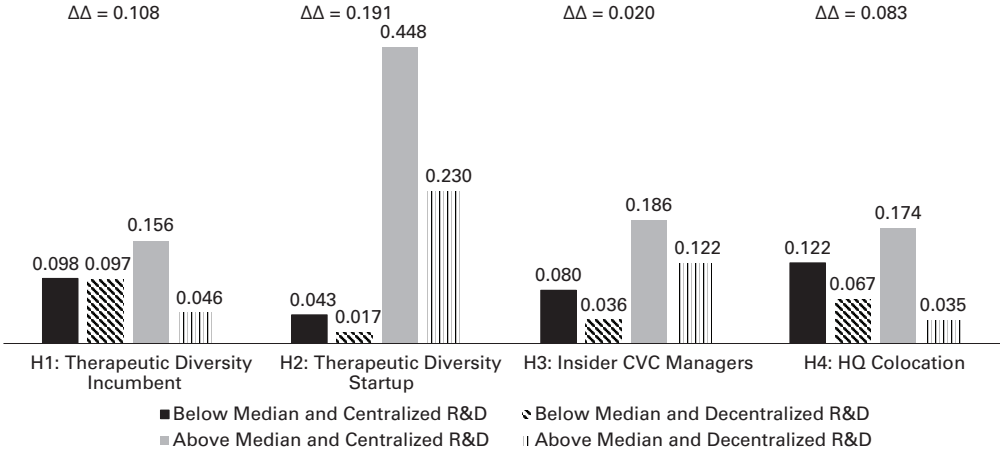
Focusing on our four hypotheses, Model 2 in Table 4 provides support for Hypothesis 1 in that *Therapeutic diversity incumbent* positively moderates the

Table 3. Summary Statistics*

Variable	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. New clinical drug candidates	0.118	0.329	1.00																							
2. R&D centralization	0.867	0.340	0.06	1.00																						
3. Therapeutic diversity incumbent	0.805	0.126	−0.07	−0.15	1.00																					
4. Therapeutic diversity startup	0.132	0.268	0.48	−0.01	−0.12	1.00																				
5. Insider CVC managers	2.263	1.678	0.10	0.04	0.24	−0.03	1.00																			
6. HQ colocation	0.091	0.288	0.03	−0.01	−0.14	0.01	−0.06	1.00																		
7. Business development TMT	0.252	0.434	−0.03	−0.11	−0.05	0.01	−0.28	0.10	1.00																	
8. Corporate decentralization	0.294	0.207	−0.01	−0.07	0.66	−0.05	0.17	−0.01	−0.00	1.00																
9. R&D size	0.142	0.073	−0.04	−0.26	0.65	−0.04	0.06	−0.04	0.13	0.62	1.00															
10. External portfolio	0.505	0.110	0.09	0.09	−0.26	−0.00	−0.06	0.13	0.01	−0.08	−0.29	1.00														
11. Incumbent patent stock	2.882	1.547	−0.02	0.03	0.61	−0.03	0.15	−0.13	−0.13	0.53	0.67	−0.21	1.00													
12. Slack	1.925	0.748	0.02	0.22	−0.46	0.09	−0.25	−0.01	−0.13	−0.49	−0.48	−0.03	−0.43	1.00												
13. R&D intensity	0.160	0.064	0.07	0.08	−0.53	0.11	−0.32	0.15	0.14	−0.34	−0.24	0.08	−0.26	0.19	1.00											
14. New CEO	0.114	0.317	−0.07	0.02	0.09	−0.03	−0.15	0.01	0.00	−0.03	0.12	−0.04	0.09	−0.00	−0.01	1.00										
15. Performance (ROA)	0.128	0.056	−0.02	0.06	0.14	−0.07	0.54	−0.07	−0.26	0.07	−0.10	−0.06	−0.17	−0.11	−0.51	−0.13	1.00									
16. Number of operating segments	2.543	1.091	−0.06	0.02	0.50	−0.04	0.05	−0.13	−0.07	0.42	0.24	−0.01	0.61	−0.38	−0.37	−0.01	−0.13	1.00								
17. CVC managers with startup experience	0.783	0.759	−0.02	0.13	−0.05	−0.02	0.53	−0.08	−0.16	−0.09	−0.11	−0.07	−0.12	−0.07	−0.09	−0.07	0.53	−0.03	1.00							
18. CVC managers with R&D experience	2.224	1.538	0.11	0.03	0.25	0.03	0.80	−0.03	−0.10	0.28	0.26	0.03	0.29	−0.29	−0.25	−0.05	0.39	0.12	0.44	1.00						
19. Number of CVC managers	6.049	2.474	−0.00	0.11	0.31	−0.09	0.68	−0.08	−0.23	0.28	0.04	0.07	0.30	−0.33	−0.30	−0.03	0.35	0.36	0.57	0.61	1.00					
20. Startup preclinical candidates	2.262	4.644	0.44	−0.02	−0.04	0.52	−0.04	−0.02	0.03	−0.00	0.01	−0.03	0.06	0.01	0.06	−0.02	−0.06	0.05	−0.03	0.03	−0.04	1.00				
21. Startup patent stock	0.012	0.049	−0.00	0.02	0.04	0.03	0.01	−0.04	0.01	0.00	−0.03	0.04	0.00	−0.01	−0.05	0.00	0.03	0.03	0.01	−0.00	0.04	0.03	1.00			
22. Therapeutic area overlap	0.128	0.193	0.37	−0.05	−0.02	0.67	−0.05	0.02	0.05	0.03	0.05	−0.05	0.07	0.04	0.12	−0.01	−0.10	0.02	−0.03	0.05	−0.08	0.69	0.00	1.00		
23. Patent tech. overlap	0.865	0.179	−0.17	0.03	0.09	−0.33	0.06	−0.02	−0.08	−0.03	−0.05	−0.00	−0.01	−0.06	−0.15	−0.01	0.10	0.08	0.06	−0.06	0.10	−0.35	−0.18	−0.34	1.00	
24. R&D colocation	0.346	0.476	0.01	0.08	−0.09	−0.00	−0.09	0.38	0.00	0.05	0.03	−0.16	0.14	−0.01	0.19	0.00	−0.19	0.06	−0.02	0.00	0.01	0.07	−0.08	0.05	−0.04	1.00

* N = 2428.

Figure 3. Examination of Differences in *New clinical drug candidates**



* Examination of firms with centralized and decentralized R&D units, above and below the median values of the four hypothesis moderators using raw data. ΔΔ represents the difference in differences between firms with centralized and decentralized R&D units, above and below the median value of the moderator, i.e., $[(Cent_{above} - Cent_{below}) - (Decent_{above} - Decent_{below})]$.

R&D centralization–New clinical drug candidates relationship. Figure 4a shows this relationship graphically. Similarly, *Therapeutic diversity startup* (Model 3, Figure 4b), *Insider CVC managers* (Model 4, Figure 4c), and *HQ colocation* (Model 5, Figure 4d) positively moderate this relationship, providing support for Hypotheses 2, 3, and 4. The fully saturated Model 6 provides support for all four hypotheses at the 95 percent confidence level or above.

Figure 5 illustrates the effect sizes associated with each of these hypotheses (Model 6 in Table 4). Interestingly, for all four hypotheses, bottom decile values of the moderators are associated with higher values of realized inventions (*New clinical drug candidates*) for firms with decentralized R&D units, compared to those with centralized R&D units, i.e., decentralized structures may be more beneficial to startups under these conditions. With respect to our theoretical arguments, this means that under these conditions, the benefits of greater rate of knowledge access for more-decentralized structures outweigh the costs of reduced breadth of access. This suggests that when incumbent firms have R&D units with less knowledge diversity or startups have less need for diverse knowledge, the startups do not suffer significantly from the reduced interconnectedness associated with decentralized R&D. Further, in the absence of mechanisms such as insider CVC managers and colocation with the incumbent firm's HQ to help startups mitigate knowledge flow constrictions associated with centralized structures, startups may benefit less from partner centralization. Under these conditions, the more streamlined decision processes associated with decentralized structures and greater rate of knowledge access are more valuable for startups.

The largest moderator impact is associated with increasing *Therapeutic diversity incumbent* from the lowest decile (0.63) to the highest decile (0.88), which translates to an increase in the difference in *New clinical drug candidates* between firms with centralized and decentralized R&D units of 0.645 (or 0.906

Table 4. Effect of Incumbent R&D Structure Change on New Drugs into Development*

DV = New clinical drug candidates	1	2	3	4	5	6
R&D centralization	0.099••	−1.450•	0.052••	0.052+	0.093••	−2.230••
	(0.027)	(0.679)	(0.014)	(0.025)	(0.025)	(0.613)
H1. R&D centralization × Therapeutic diversity incumbent		1.799•				2.580••
		(0.783)				(0.698)
H2. R&D centralization × Therapeutic diversity startup			0.347•			0.401••
			(0.130)			(0.115)
H3. R&D centralization × Insider CVC managers				0.026+		0.025•
				(0.012)		(0.010)
H4. R&D centralization × HQ colocation					0.051••	0.058••
					(0.015)	(0.015)
Therapeutic diversity incumbent	−0.202	−1.922•	−0.226	−0.217	−0.199	−2.707••
	(0.179)	(0.861)	(0.178)	(0.182)	(0.178)	(0.809)
Therapeutic diversity startup	0.373••	0.372••	0.068	0.373••	0.372••	0.019
	(0.068)	(0.069)	(0.142)	(0.068)	(0.069)	(0.128)
Insider CVC managers	0.019	0.012	0.018	−0.003	0.018	−0.013
	(0.013)	(0.014)	(0.013)	(0.017)	(0.013)	(0.016)
Business development TMT	−0.026	−0.033	−0.024	−0.029	−0.027	−0.037
	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)	(0.032)
Corporate decentralization	0.020	0.019	0.021	0.017	0.020	0.018
	(0.049)	(0.047)	(0.052)	(0.049)	(0.049)	(0.049)
R&D size	0.121	0.014	0.188	0.134	0.126	0.063
	(0.208)	(0.212)	(0.210)	(0.221)	(0.206)	(0.216)
External portfolio	−0.145	−0.147	−0.145	−0.141	−0.148	−0.147
	(0.117)	(0.120)	(0.112)	(0.122)	(0.117)	(0.117)
Incumbent patent stock	−0.044	−0.043	−0.040	−0.044	−0.044	−0.038
	(0.029)	(0.028)	(0.027)	(0.030)	(0.029)	(0.025)
Slack	0.004	0.009	0.002	0.003	0.004	0.008
	(0.009)	(0.010)	(0.010)	(0.009)	(0.009)	(0.009)
R&D intensity	−0.052	−0.087	−0.043	−0.066	−0.054	−0.106
	(0.091)	(0.100)	(0.088)	(0.095)	(0.091)	(0.097)
New CEO	0.012	0.017	0.006	0.015	0.012	0.014
	(0.015)	(0.014)	(0.015)	(0.014)	(0.015)	(0.012)
Performance (ROA)	−0.478••	−0.534••	−0.459•	−0.493••	−0.480••	−0.553••
	(0.160)	(0.174)	(0.162)	(0.165)	(0.160)	(0.174)
Number of operating segments	0.012	0.010	0.009	0.015	0.012	0.010
	(0.015)	(0.014)	(0.017)	(0.013)	(0.015)	(0.013)
CVC managers with startup experience	−0.042•	−0.037+	−0.039+	−0.046•	−0.042•	−0.036+
	(0.020)	(0.019)	(0.020)	(0.019)	(0.019)	(0.018)
CVC managers with R&D experience	−0.004	−0.006	−0.004	−0.002	−0.004	−0.005
	(0.013)	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)
Number of CVC managers	0.004	0.002	0.005	0.005	0.004	0.003
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Startup preclinical candidates	−0.009	−0.009	−0.011	−0.009	−0.009	−0.011
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Startup patent stock	−0.111	−0.110	−0.089	−0.116	−0.107	−0.085
	(0.136)	(0.136)	(0.124)	(0.142)	(0.136)	(0.128)
Therapeutic area overlap	−0.255	−0.252	−0.246	−0.257	−0.258	−0.245
	(0.236)	(0.235)	(0.240)	(0.234)	(0.234)	(0.237)
Patent tech. distance	−0.077	−0.077	−0.085	−0.080	−0.077	−0.087
	(0.056)	(0.058)	(0.059)	(0.055)	(0.056)	(0.060)

(continued)

Table 4. (continued)

DV = New clinical drug candidates	1	2	3	4	5	6
R&D colocation	0.003 (0.021)	0.005 (0.021)	0.003 (0.021)	0.003 (0.021)	0.003 (0.021)	0.006 (0.021)
Startup–incumbent dyad fixed effects	Y	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y
N	2428	2428	2428	2428	2428	2428
R^2	0.177	0.180	0.190	0.178	0.178	0.199

+ $p < .10$; • $p < .05$; •• $p < .01$.
* Standard errors values in parentheses: errors clustered at incumbent firm level. The coefficient of the interaction term (H3) in Model 4 has a p value of .053.

drug candidates). The smallest impact is for *HQ colocation*: moving from firms whose HQs are not colocated with the startup to those whose HQs are colocated, we observe an increase in the difference in *New clinical drug candidates* between firms with centralized and decentralized R&D units of 0.058 (or 0.060 drug candidates).

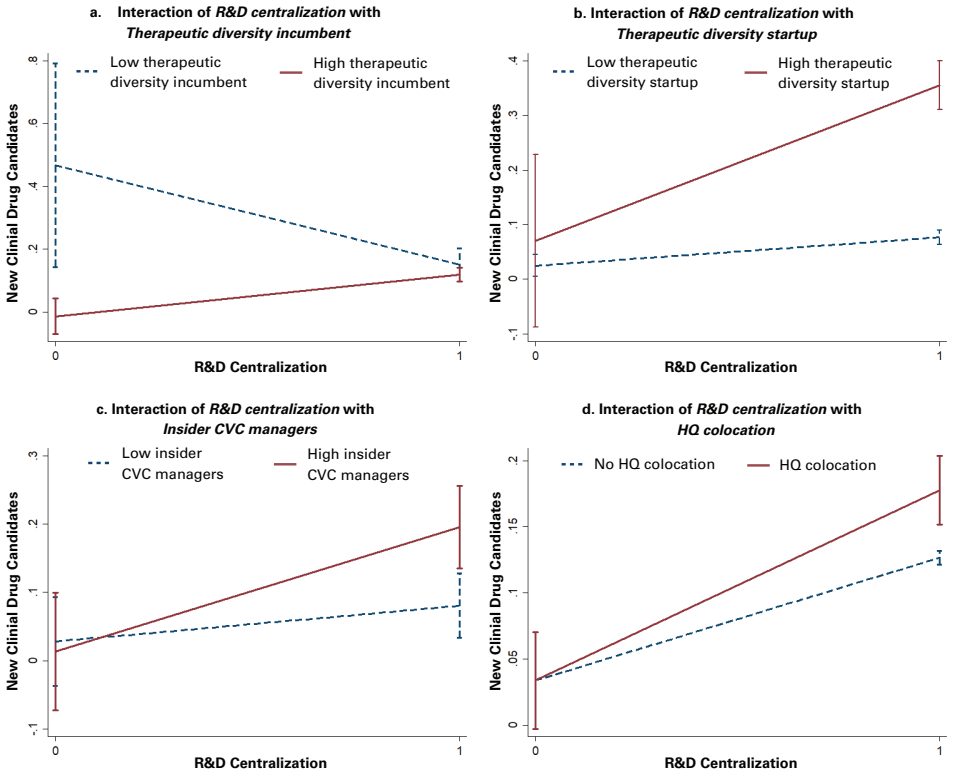
We undertook 18 additional tests to examine the robustness of our findings to employing alternative approaches to measure each of our dependent and independent variables, and these alternative estimation methods include the use of non-linear models and the use of split samples rather than interaction terms and subsample analyses. A detailed description of each of these tests and tables showing results are provided in Online Appendix B.

Additional Analyses

Examining alternative explanations. We also conducted multiple analyses to examine alternative explanations for our results to those outlined in our theoretical development. Table 5 summarizes each test, listing the alternative explanation we considered, the test we carried out, and the findings. We examined alternative explanations based on how CVC activity was managed, R&D personnel's attitude toward CVC startups, systematic differences in the quality of the drugs that startups moved into trials when incumbents had centralized vs. decentralized R&D, the role of competition between the incumbent and the startup, the impact of R&D structure on startups' likelihood of exit via IPO or acquisition, alliance formation between the two firms post investment, concurrent (but unrelated) occurrence of R&D centralization and the advancement of inventions, and heterogeneity between dyads that experienced structural changes and those that did not. Detailed descriptions of each test are provided in Online Appendix C.

Supplemental analyses of mechanisms. We undertook two further analyses to probe the mechanisms through which an incumbent firm's R&D structure may have influenced startups' realized inventions. First, we probed the timing of our effects to examine the interplay between informal and formal

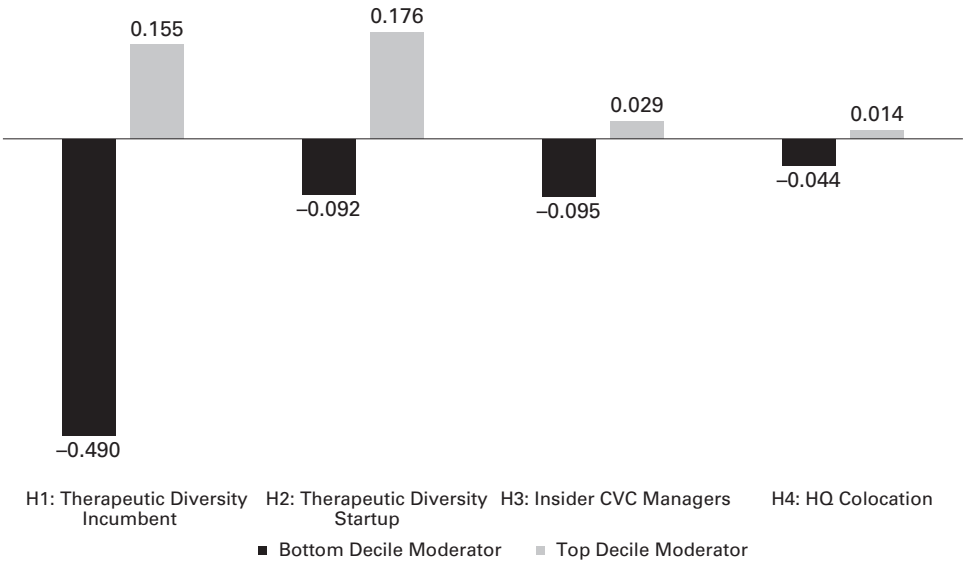
Figure 4. Graphical Examination of Interaction Effects for Hypotheses 1–4



structure. As highlighted, we view formal structure as enacted in part via the informal norms and networks that persist within the organization (McEvily, Soda, and Tortoriello, 2014). Research shows that an organization's informal structure, such as the network of ties between managers, can be sticky and that a change in informal structures can lag a change in formal structures (Nickerson and Zenger, 2002; Gulati and Puranam, 2009). In our context, for instance, even if there is a switch from decentralized to centralized R&D, it will take time for the connectedness benefits of R&D centralization to emerge, as initially the new centralized R&D unit may be still quite siloed along the lines of the former R&D decentralized units. The processes and norms that characterize decision making are also unlikely to be altered immediately.

To examine the temporal variation in the magnitude of the effects pertaining to startups' realized inventions, we created dummy variables to indicate the first two years following the change in structure and another dummy variable to indicate the subsequent two years (i.e., third and fourth) following the change. We then interacted the R&D centralization indicator with each of these. The interaction effects in each case should tell us the extent to which the treatment effect we observe is altered for the period in question. The results are shown in Table 6. We observe that the baseline positive effect is substantially depressed in the initial two years following centralization of

Figure 5. Variation in the Difference in *New clinical drug candidates* Between Firms with Centralized and Decentralized R&D Units*



* Examination of how the difference varies between top decile and bottom decile values of the four hypothesis moderators using regression Model 6 in Table 4.

R&D and depressed to a much smaller extent in the subsequent two years. This finding is precisely in line with what we would expect given that our mechanisms are closely related to the informal structures within the organization, which will lag the change in formal structures. Network formation in centralized structures takes time, meaning the breadth-related benefits are unlikely to be realized immediately. It is also plausible that the downsides of centralized structures relating to organizational complexity and overlapping decision authority may be especially pronounced in the years immediately following a structural change. Over time, as managers settle into the new structure, they develop an understanding of how to make decisions in more efficient ways, thereby increasing the rate of knowledge access.

Second, we examined the impact of an incumbent firm's R&D structure on a startup's patenting output. This study focused on a specific innovation-related outcome that is of proven importance to startups in these relationships: advancing drug candidates into the first phase of clinical trials. However, patenting is another commonly used measure of innovation outcomes. These two outcome variables, patenting and advancing drugs into clinical development, relate to two distinct phases of the innovation process (Garud, Tuertscher, and Van de Ven, 2013). Patents characterize the earliest stage of invention and are primarily driven by deep scientific knowledge in a relatively narrow domain, whereas the advancement of drug candidates requires bringing together expertise on a wider range of areas such as formulation, toxicology, and regulatory norms, as well as a degree of scientific expertise (Iansiti and West, 1997; Kapoor and Klueter, 2015).

Table 5. Summary of Tests of Alternative Explanations*

#	Alternative Explanation	Test	Finding	Table
1	Incumbent firms' approach to managing CVC changes in conjunction with R&D structure change	Compare various indicators of CVC activity and personnel in the 5 years before versus after R&D structural change via t-tests	No statistically significant difference observed pre vs post R&D structure change	C1
2	R&D personnel more inclined to engage with external partners (such as CVC startups) when R&D is centralized	Compare number of externally focused TMT roles in incumbent firms (corporate development, business development, alliance, M&A) with centralized vs decentralized structures via t-tests	No statistically significant differences observed ($p > 0.6$ in all cases)	N/A
3	Startups partnered with incumbents having decentralized R&D move higher-quality drugs into trial (though fewer in number) compared to centralized R&D	Change dependent variable to only count number of drugs into trial that are eventually commercialized	Positive but insignificant effect of R&D centralization on outcome; we would expect to see negative relationship if alternative explanation was true	C2
		t-test in full sample of startup drugs to compare whether likelihood of eventual commercialization is different depending on whether incumbent has centralized or decentralized R&D at the time the drug enters clinical trials	7% drugs entering trials when incumbent has centralized R&D are commercialized, 4% for decentralized. Difference not statistically significant. No evidence that drugs entering trials when incumbent R&D is decentralized are more likely to be commercialized	N/A
4	Decentralized R&D generates higher competition between incumbent and startup	Examine whether the baseline effect of R&D centralization on *New clinical drug candidates* varies with the level of therapeutic area overlap, the extent to which the startup and incumbent are targeting similar therapeutic areas, which is a proxy for the level of competitive forces at play between the two firms	Therapeutic area overlap has no significant interaction effect with *R&D centralization*. Also, it has no significant direct effect on the outcome. Little evidence that competitive forces are instrumental in driving the observed results.	C3–Models 1,2
		New DV, *Incumbent conversion PC1*, proportion of drug candidates that an incumbent firm progresses from preclinical to phase 1. Examine whether *Startup progress*, one-year lagged number of drug candidates startup progresses to Phase 1, has an impact on this outcome	No significant effect observed, no evidence of negative competitive spillover effect of *Startup progress* on incumbent firm	C3–Model 3
5a	Decentralized R&D structure associated with faster exit for startups	Event history analyses examining impact of incumbent R&D structure on startup's hazard of exit via acquisition or IPO	Incumbent R&D structure does not show any significant relationship on exit in aggregate or on IPO or acquisition individually. Main findings are robust to the exclusion of startups that exit	C4

(continued)

Table 5. (continued)

#	Alternative Explanation	Test	Finding	Table
5b	Alliance formation between incumbent and startup (which aids startups to advance drugs) more likely when incumbents have centralized R&D	New DV, binary characterization of whether the startup and incumbent form an alliance in focal period	*R&D centralization* has no significant impact on alliance formation	C5
6	Incumbent firms more likely to centralize over time, and startups advance more drugs into trial over time	(a) Included dyad-specific time counter variable, (b) lagged DV as control, (c) Arellano-Bond dynamic panel estimator, (d) Arellano-Bover/Blundell-Bond dynamic panel estimator	*R&D centralization* shows positive and significant effect on outcome across all specifications	C6
7	Heterogeneity in characteristics between dyads in which incumbent R&D structure changes and those in which it does not	Matching, both coarsened exact and propensity score, to restrict comparisons to dyads matching on observable characteristics and dropping all unmatched dyads	All four hypotheses continue to be supported	C7

* Descriptions of each of the above tests and tables showing the results can be found in Online Appendix C.

Table 6. Temporal Variation in Size of *R&D centralization* Effect After Structure Change*

DV	New Clinical Drug Candidates
R&D centralization	0.131••
	(0.036)
R&D centralization × First 2y post change	-0.106•
	(0.040)
R&D centralization × Next 2y post change	-0.037
	(0.057)
First 2y post change	0.015
	(0.035)
Next 2y post change	0.022
	(0.045)
Controls	Y
Year fixed effects	Y
Dyad fixed Effects	Y
N	2428
R^2	0.138

+ $p < .10$; • $p < .05$; •• $p < .01$.
* Standard errors in parentheses. Errors clustered at incumbent firm level.

To examine the impact of the structural changes on patenting, we repeated each of our analyses, using a logged count of the number of patents produced in the three years following the focal year by the startup (plus one) as our outcome variable, *New patents* (Table 7). From Model 1, we do not observe a significant direct relationship between a change in the R&D structure and a

Table 7. Effect of Incumbent R&D Structure Change on Startup Patenting*

DV = New patents	1	2	3	4	5	6
R&D centralization	−0.063	0.508	−0.106••	−0.194••	−0.055	−0.144
	(0.041)	(1.311)	(0.032)	(0.067)	(0.050)	(1.501)
H1. R&D centralization × Therapeutic diversity incumbent		−0.663				−0.112
		(1.519)				(1.735)
H2. R&D centralization × Therapeutic diversity startup			0.316			0.321
			(0.188)			(0.194)
H3. R&D centralization × Insider CVC managers				0.073•		0.078•
				(0.027)		(0.030)
H4. R&D centralization × HQ colocation					−0.062	−0.053
					(0.216)	(0.223)
Controls	Y	Y	Y	Y	Y	Y
Startup–incumbent dyad fixed effects	Y	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y
N	2428	2428	2428	2428	2428	2428
R^2	0.152	0.152	0.154	0.153	0.152	0.156

+ $p < .10$; • $p < .05$; •• $p < .01$.
* Standard errors in parentheses. Errors clustered at incumbent firm level.

startup's patenting outcomes. Table 7 also shows estimates of our interactions of interest. In three of the four cases, we do not find these to bear a statistically significant relationship with the outcome, either. The exception is the case of CVC managers who are insiders, which has a positive relationship with the startup's patenting when the incumbent firm has a centralized R&D structure.

Overall, incumbents' R&D structures appear to have a weaker impact on the patenting of startups. At the point of investment, startups typically have their foundational IP in place, and the focus of these partnerships for both sides is less on invention and more on advancing technology into a commercial application. Furthermore, the mechanisms we outline here relating to the formal organizational structure of the incumbent firm are less likely to be salient in shaping the knowledge exchanges supporting the early stages of technology formation.

DISCUSSION

Summary of Results

For partnerships to enable innovation, firms need to access resources such as knowledge and expertise embedded within their partner organizations. Research has demonstrated that such resource flows can be impeded by frictions and has highlighted the importance of understanding the origins of these frictions (Ghosh and Rosenkopf, 2014). We investigated an important source of such frictions in the knowledge flows associated with partnerships that originate in the partners' organizational structures: the level of discretion managers in the partner organization have over resource orchestration decisions (Dattée et al., 2022). While a range of structural choices can impact this, we focus primarily on centralization, the extent to which decisions are made closer to the head, or center, of the organization (Pfeffer and Lammerding, 1981; Garicano, 2000). We highlight a critical tension related to the centralization of a partner's organizational structure. Centralized structures promote connectedness within the partner organization,

thereby enabling access to a greater breadth of a partner's knowledge (Hounshell and Smith, 1989; Karim and Kaul, 2015). Yet, such centralized structures are also characterized by more-complex decision processes, which can constrict the rate of access to the partner's knowledge (Burton, Obel, and DeSanctis, 2011).

We developed hypotheses allowing us to probe this tension by identifying factors that would theoretically shift the balance and make partner centralization more valuable, via their impact on the breadth and rate of knowledge access. We grounded these hypotheses in entrepreneurial firms' innovation-focused relationships with incumbents arising from corporate venture capital investment. We find that access to greater breadth of the incumbent's knowledge base facilitated by centralized structures is more valuable when the incumbent has greater diversity of knowledge available and when the startup's innovation efforts require a wider variety of expertise. The constricted rate of knowledge flows arising from centralized structures can, in turn, be alleviated by incumbent firm managers with prior experience in operational roles working with startups, using their informal intra-firm networks to help push knowledge to startups, or startups being colocated with the headquarters (HQ) of the incumbent firm, which enables them to leverage the formal authority of senior executives to pull knowledge toward themselves.

Contributions

This study helps bridge the literatures on organizational structure and interorganizational partnerships, which enables us to make several contributions. First, we illustrate an important tradeoff that managers face regarding their external partnerships, which has important implications for questions relating to partner choice in interorganizational relationships. Existing theories have principally focused on the complementarity of the partner's resources as well as on their formal and informal incentives to share resources. However, these assessments are typically made at the organizational level with an assumption of alignment between these macro-level factors and the firm's internal structure. For instance, resource-based perspectives, when applied to the study of interfirm partnerships, generally assume that the locus of the partnership coincides with the locus of any relevant resources within the firm (March, 1962; Barney and Felin, 2013). Our findings suggest that a partner's internal structure should be a consideration as well. Structure can generate heterogeneity in the degree and in the rate at which different resources in the partner organization are accessible. Hence, considering how effectively the partner's structure maps to the objectives of the partnership is important. For instance, if the partnership seeks to explore a new technological domain in which a wide range of resources would be valuable to the endeavor, our results suggest that all else equal, seeking a partner with a more centralized structure would be beneficial. This study paves the way for future research to further consider the implications of organizational structure from a partnership perspective, which our findings suggest may be a productive avenue for scholars of interorganizational collaboration.

Second, this study also speaks to the organization design literature by highlighting important mechanisms through which organization design can shape firms' innovation outcomes by impacting knowledge flows. Our theory

illustrates how managers can adjust the formal structure of their organizations to systematically shape the informal processes and networks in organizations, which, in turn, shape interfirm knowledge flows (Powell et al., 2005; McEvily, Soda, and Tortoriello, 2014; Sytch, Wohlgezogen, and Zajac, 2018). The findings also highlight that firms may optimize access to a greater breadth of their organizations' knowledge bases or the rate at which this knowledge can be accessed, but there is an inherent tradeoff between the two (e.g., Puranam, 2018). The design of the partnering organizations is therefore likely to be a key link between a partnership's objectives and its actual performance.

Third, research on interorganizational networks has historically focused on tie structure. This study adds to the emerging body of work on node characteristics by highlighting the systematic impact of the internal structure of nodes on friction in the knowledge flows occurring within networks (e.g., Barden and Mitchell, 2007; Kleinbaum and Stuart, 2014; Lumineau and Oliveira, 2018). Contrast one network primarily made up of centralized nodes to another made of decentralized ones. Our findings indicate that the knowledge circulating in these networks will be substantially different. While one network (centralized nodes) will feature a greater variety of knowledge, the other (decentralized nodes) is likely to feature more-timely flows of focused knowledge. Being embedded in one versus the other is therefore likely to have materially different implications. We hope that future research will delve further into this question to consider how the distribution of the nodes' structural characteristics in interorganizational networks relates to the types of resource flows that arise within them.

Fourth, in terms of the innovation literature, parametrizing knowledge flows in terms of breadth and rate of access and considering them simultaneously allowed us to describe an important tradeoff related to partner structure. Existing research on how partnerships impact innovation typically theorizes about knowledge flow as a unidimensional construct. Our findings suggest that to understand the value creation that can arise from interfirm collaboration, managers need to explicitly consider both questions: what are the available pathways to access the relevant knowledge and resources (i.e., how many pipes can knowledge flow through), and how easily can the knowledge and resources be obtained from the relevant holder (i.e., how constricted is the flow through these pipes)? Unpacking these dimensions of knowledge flow can provide greater insight into how structure can shape firms' innovation outcomes both when such innovation efforts are conducted in isolation and when they are conducted in partnership with other firms. For example, different types of innovation may require different flow characteristics, as some rely on timely knowledge flows and others on access to diverse knowledge.

Finally, our findings also contribute to the growing literature on the impact of CVC on startup performance. Recent scholarship suggests that startups' outcomes are contingent on effective access to the incumbent's resources, which depends on navigating the complex organizations within which resources are embedded (Pahnke, Katila, and Eisenhardt, 2015; Alvarez-Garrido and Dushnitsky, 2016; Balachandran, 2018, 2023). We add to this research by examining how startups' access to resources relates to the organizational structures of incumbent firms and by identifying conditions under which different types of structures are most valuable. For entrepreneurs, these findings suggest that undertaking a practical assessment of the structure of their

corporate investors and the associated difficulties in locating and accessing the resources they require in a timely manner could help them to avoid unproductive partnerships.

Generalizability and Boundary Conditions

We consider the generalizability of our findings along three dimensions: other facets of organizational structure, other forms of partnership, and other industries. Our theory and empirical analyses focus on how partner centralization shapes the balance between localized autonomy and unified control within the organization. A range of other facets of organizational structure can impact managers' level of discretion. We expect the basic tension we theorize relating to managerial autonomy to manifest in relation to these other structural elements as well. For example, we consider this in relation to formalization: the use of ''codified rules, policies, and procedures to shape behavior, guide actions, and govern social positions and role relationships between individuals'' in organizations (Child, 1973; Gibson, Dunlop, and Cordery, 2019: 1022). Formalization is associated with standardized policies and processes as well as a common language within the organization that helps to ensure that different parts of the organization move in concert (Mintzberg, 1980; Adler and Borys, 1996; Lin and Germain, 2003). However, a high level of formalization can also limit flexibility and restrict the potential for emergent processes to address issues that arise locally within the organization (Juillerat, 2010). Hence, the level of formalization in a partner organization could theoretically be the source of a tension analogous to the one we outline in this study for centralization. A highly formalized partner organization, with its uniformity of processes and greater degree of integration, may ease access to a wider swath of the partner's resources. However, the limited discretion available locally within these structures may impede responsiveness and thus limit the rate of access (Baum and Wally, 2003; Eisenhardt, Furr, and Bingham, 2010). While we expect the specific theoretical mechanisms we outline in this study to apply to the facets of organizational structure that impact autonomy, the broader approach we describe here could also be extended to consider how innovation within partnerships may be shaped by other elements of partner structure that we know to impact knowledge mobilization, such as the flatness of a partner's hierarchy (e.g., Lee, 2022).

Our hypotheses and empirical findings focus on partnerships arising from corporate venture capital, which is the predominant form of cooperative engagement between established and entrepreneurial firms (Dushnitsky, 2012). However, this form also has several unique features that distinguish it from some other forms of alliances and interfirm partnerships, raising the important question of whether and when our findings generalize to other forms of partnership. In broad terms, the salience of the theoretical tension we outline will depend on the extent to which ongoing resource mobilization challenges in partnering organizations influence the partnership's outcomes. We outline three boundary conditions that are likely to shape the relevance of these resource mobilization challenges and, in turn, the salience of the mechanisms we describe in this article. First is how precisely the resource commitments of each side are defined ex ante. The distinction here is between partnerships in which the resource commitments from each side are precisely articulated when the

partnership begins and those in which these commitments are left more open-ended. This is a characteristic of our setting: while there is an understanding on both sides that the investor will employ its resources to support the startup, the precise nature of that resource access is not defined ex ante. This may also be true of a range of other partnership types, especially exploratory ones (Lavie and Rosenkopf, 2006).

Second, the size of the partnering organizations is a relevant boundary condition. If the partnering organizations are both small, the organizational structure's role in shaping resource mobilization for partnerships is likely to be more limited. In this case, internal bureaucratic hurdles to resource mobilization for the partnership (that arise from the organizational structure) are likely to have less of an impact on outcomes. Similarly, the internal connectivity-related benefits of a centralized structure are also less relevant, as resources will be easier to find in smaller organizations. Hence, the mechanisms we describe are likely to become relevant only if at least one of the organizations involved in the partnership is relatively complex. A related concern is that the partnerships we focus on empirically involve one large and one small firm. We view the existence of resource mobilization issues only on one side in our setting as an aid to discerning the mechanisms underlying the observed effects, and we broadly expect these mechanisms relating to knowledge search and access to continue to operate even if, for instance, both firms are large. The findings from Sytch, Wohlgezogen, and Zajac (2018) offered some support for this view, showing that large firms' propensity to form complex partnerships and the outcomes of those partnerships vary systematically with formal organizational structure.

Third, the nature of managerial incentives is likely to differ in CVC partnerships compared to other forms of interorganizational partnership. In CVC partnerships, R&D managers are typically not directly incentivized to work with CVC-invested startups, which may not be the case in other forms of partnership, such as R&D alliances. It is well established in the strategic management literature that an organization's design can shape managerial incentives (Zenger and Hesterly, 1997) and that localized autonomy is generally associated with higher-powered incentives (Jensen and Meckling, 1992). This is consistent with our expectation that decentralized structures would facilitate an enhanced rate of access to the partner's knowledge, as the structure facilitates the creation of localized incentives to promote sharing. Hence, we expect the central tradeoff relating to how a partner's structure may shape a focal firm's breadth and rate of knowledge access to apply even when the incentive structures diverge from those in the CVC context. However, the specific role of our theorized contingencies may vary when direct incentives to share knowledge play a more prominent role in determining access. Relatedly, CVC managers are rarely members of a company's top management team (Strebulaev and Wang, 2021). Hence, they typically do not have the unilateral authority to precipitate resource access for startups. But if the boundary spanners in other types of partnerships do have this level of authority, they may be able to override some of the frictions that we describe here.

Finally, the U.S. pharmaceutical industry is distinct in that relationships between incumbents and startups are common, and the innovation process has some distinct features such as the involvement of regulatory authorities and the well-defined stages of product development. In industries in which the translation of an idea into a final offering is relatively straightforward, such as

basic phone apps, this study's findings may be less likely to apply directly. However, the basic theoretical mechanisms we outline are likely to be relevant to other high-technology areas in which firms face knowledge-related challenges associated with applying technology (Iansiti and West, 1997). Analogs of this from other industries include turning a machine-learning routine into a fraud detection tool in banking (Wei et al., 2013) or a digital signal processing chip into a hearing aid device (Edwards, 2007). Even in industries such as consumer products, firms create a huge volume of patents, but there are significant challenges to translating an idea into a viable product (e.g., Cardinal et al., 2011). In these situations, partnerships are common, and the mechanisms we describe relating to knowledge mobilization are likely to be salient (Gans and Stern, 2003).

This study has several limitations that could serve as avenues for future studies. We do not directly capture knowledge flows between and within organizations but infer their occurrence based on changes in firms' knowledge-related outcomes. Our empirical specification focuses on changes in R&D structure within entrepreneurial-established firm dyads, and we rule out various alternative explanations for our findings. However, we cannot make strong causal claims regarding the relationship between the established firm's R&D structure and entrepreneurial firms' innovation outcomes given these structural changes are not randomly assigned. It is challenging to identify natural experiments in which an exogenous shock leads to established firms changing their structures because this is a critical managerial decision. We have therefore tried to adopt a preponderance-of-evidence approach to discern the mechanisms underlying the relationships we observe (e.g., Feldman, Gartenberg, and Wulf, 2018). Further, our empirical characterization of organizational structure is binary, in line with prior research in this domain (Argyres, Rios, and Silverman, 2020). This limits our ability to capture nuanced distinctions between structures by means of which organizations may attempt to adopt features enabling ambidexterity (Raisch and Birkinshaw, 2008). Finally, our empirical design focuses on isolating the startup's access to the incumbent's R&D organization, as it is the principal repository of the knowledge that startups require. We cannot rule out the possibility of startups engaging with other parts of the incumbent firm, although it is unlikely. We control empirically for other incumbent structural characteristics beyond R&D, but to the extent that R&D structural changes correlate to broader events in the organization, they may also shape startups' access to other parts of the firm that impact their outcomes in ways we do not capture.

Despite these and other limitations, this article helps to advance our understanding of how a partner's organizational structure can shape a firm's innovative productivity. Firms not only must find partners with the requisite complementary expertise but also must navigate the organizational challenges associated with locating and accessing resources they need within their partners in order to use these partnerships successfully. We demonstrate the critical role played by the partner's organizational structure in this respect.

Authors' Note

This article has been updated to remove an erroneous footnote in Figure 4 and to correct the Figure 5 footnote to say ''Table 4.'' Table 5 has also been updated to correct a minor typographical error.

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