

Costs and Benefits of Learning through Alliances for Entrepreneurial Firms*

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Abstract

Due to resource constraints, startup innovators often struggle to build the complementary assets necessary to enable successful product commercialization. Entering an alliance with an incumbent firm is a primary avenue for a startup to access those assets, and also an important means by which it can acquire the commercialization skills. However, a learning alliance of this type may incur both inter-organizational governance and learning costs. Using data from biotechnology alliances, we examine how structuring the alliance to facilitate learning affects the hazard of drug approval in the short run. We find that when less-experienced firms do so, the product is less likely to be approved. However, firms that have engaged in learning alliances are more likely to successfully commercialize subsequent products than firms that licensed out their development rights completely. Overall the results suggest that the longer-term benefits of learning alliances compensate for the short-run costs.

Keywords: strategic alliances; learning; complementary assets; alliance structure; new ventures.

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1. Introduction

A central theme in the literature on the commercialization of innovation is that controlling complementary commercialization assets – as opposed to just technical excellence – can be an important determinant of value capture (Teece, 1986; Tripsas, 1997), especially for startup innovators. New ventures typically do not possess the necessary commercialization capabilities such as marketing competence and regulatory expertise in the early phases of their organizational development. At the same time, emerging enterprises are usually resource constrained, and so developing downstream commercialization skills may be difficult or not possible. An alternative strategy is to enter an alliance with a participant downstream in the value chain. However, to the extent that the requisite resources and capabilities are “tightly held” by the incumbent firms (i.e., they are not freely available on the market), the share of the value that a new venture will capture through such a relationship is limited (Teece, 1986). One way for an innovating firm to extricate itself from this situation is to enter a strategic alliance with a downstream participant but retain the rights to participate in the commercialization process (Wakeman, 2010). It often hopes that by participating in the commercialization process alongside an experienced product firm, it will get firsthand exposure to specialized knowledge and thereby acquire the commercialization skills for itself. This channel may be preferable to the others previously discussed as it provides a path to assembling the full value chain, with the end result of possibly loosening dependence on partners and/or gaining the ability to self-commercialize in the future.

These “learning alliances”, which allow the participants to enhance their internal skills and technologies (Hamel et al., 1989), can be particularly important for startup firms seeking to develop their commercialization capabilities. The literature has, however, highlighted the potential problems associated with unintended knowledge leakage to partners through such alliances (Hamel, 1991; Khanna et al., 1998). A second problem, albeit less studied, are the significant learning costs, particularly in an inter-organizational context. We unite these perspectives, explicitly examining the costs and benefits of learning alliances on product development outcomes. We concentrate on two types of costs that might impact product-level performance: learning costs of developing complementary assets and governance

costs associated with inter-organizational collaboration. In the former case, reconfiguring organizational routines to new processes may result in short-term setbacks in product development, while in the latter case trying to prevent unintended knowledge leakage to the partner may slow product development progress on the focal project and dis-incentivize the partner from investing optimal resources or effort in the project. Our empirical analyses examine firm-level product development outcomes by assessing how heterogeneous experience profiles in learning alliances among new ventures shape organizational actions and the outcomes of those actions with regard to product development. By contrast, to the limited extent that the prior literature has explicitly examined learning alliance costs, the studies have used ambiguous outcomes such as alliance dissolution, which can proxy for many different effects. For example, as Larsson et al. (1998: 287) point out, such measures may be misleading: "...high-performing alliances may be terminated early due to conflicting interests, changed priorities, quickly accomplishing their intended goals, or one of the partners [has] won the learning race."

The goal of the paper is therefore a simple, yet important, one: to theorize the source of (short run) costs and (longer term) benefits associated with learning alliances, and to empirically examine these issues. The prior literature on learning alliances has tended to evaluate the costs and benefits separately, and so an overall evaluation of this commercialization channel has been elusive. We empirically evaluate our predictions using a rich longitudinal dataset of biotechnology innovators. We build a database of biopharmaceutical innovators and their product development histories over time (most notably product approval by the U.S. Federal Drug Administration), and overlay information regarding commercialization mode (including learning alliances) for each product in the innovator's product portfolio. We find empirical support for the overall thesis that learning alliances are costly in the short run but yield long run benefits with regard to product development outcomes.

A strong theme in the literature is the argument that where firms start may not necessarily be where they would like to end up, whether it is in the context of new ventures or in the realm of more established firms developing dynamic capabilities to keep aligned with their business environment (Teece et al. 1997; Eisenhardt & Martin, 2000). Across these contexts, there has been little in the way of lifecycle

or “evolutionary” analyses assessing the costs and benefits of such commercialization capability development. We aim to address this gap in the context of learning alliances. The next section develops the theory on where costs and benefits will arise. We then turn our attention to the data and methodology, follow with results, and conclude with a discussion and interpretation of the results.

2. Literature and Hypotheses

2.1 Short run costs of learning alliances

Broadly speaking, there are two categories of costs associated with using learning alliances to develop downstream complementary assets for commercialization. The first category of costs stems from learning new skills. While this category entails costs beyond simple *learning costs* (such as opportunity, experimentation, and reconfiguration costs), we use this term as shorthand for the span of investments associated with developing new organizational skills. The second broad category derives from the inter-organizational nature of the exchange and the costs associated with governing the relationship. Similarly, while the issues extend beyond governance and into managing inter-organizational production and incentivizing behavior, we refer to these costs collectively as *governance costs* (other related costs include transaction and coordination costs). While we have grouped our discussion into learning and governance costs, the concepts likely interact: governance structures and challenges can impact learning (although we are unable to distinguish these effects in our empirical analyses). Nevertheless we believe the separate discussion is useful in furthering our conceptual understanding of the two types of costs.

Learning costs. Engaging in a new commercialization mode is likely to entail a range of costs. These include the direct costs associated with developing new organizational routines and capabilities, as well as the opportunity costs from not utilizing the organizational routines and capabilities the organization has developed to date. For example, switching from an arm’s-length technology licensing revenue model to one in which the firm seeks to compete directly in the product market involves both the costs associated with developing the various skills necessary to take the novel product to market (i.e.,

developing tightly-held complementary assets) and also the opportunity cost of foregone rents from the licensing relationships it has built to date.

There is a general notion in the strategy literature that acquiring or building valuable organizational resources and capabilities is a costly process (e.g., Barney, 1986; Dierickx & Cool, 1989; Winter, 2003), but to the best of our knowledge empirical evidence is extremely scarce or perhaps non-existent. The literature in dynamic capabilities on the costs of organizational reconfiguration appears similarly underdeveloped (Zott, 2003 is an exception). The premise of this literature is that firms will succeed if they are able to dynamically reconfigure their resources to match the opportunities afforded by the business environment (Teece et al., 1997; Eisenhardt & Martin, 2000). Finally, there is only limited discussion in the literature on learning alliances of the costs of inter-organizational learning. While the literature has recognized that focal firm-partner firm dyadic characteristics influence possible knowledge absorption and benefits (Lane & Lubatkin, 1998; Stuart, 2000), there is far less in the literature regarding inter-organizational learning costs. There is only a general notion that the evolution of learning alliances involves learning about the environment, task, process, skills, and about the partner – and for each element, there are periods of learning, reevaluation, and readjustment (Doz, 1996).

Learning and absorbing knowledge from outside the boundaries of the firm may require a firm to make internal investments in recognizing and valuing the external knowledge (Cohen & Levinthal, 1990). The organizational ability to integrate external knowledge reflects two basic organizational learning processes: learning by doing via direct experience, and learning from the experience of others (Levitt & March, 1988). The increasing complexity of codifying and organizing processes for learning in the inter-organizational setting (Larsson, 1998), as well as the existence of more potential blocking points and competition for knowledge, would seem to suggest that the cost of developing organizational routines escalates with the move from organizational to inter-organizational learning.

Incorporating knowledge from extramural sources is difficult even at the level of simple replication, and becomes especially challenging in contexts in which the desired output is novel. Scholars have noted that the seemingly simple act of transferring known knowledge “modules” or best practices is

notoriously difficult and costly (e.g., Szulanski, 1996), pointing to the complex organizational routines of creating, acquiring, storing, modifying, and transferring resources within and across organizational boundaries. Heterogeneous performance among franchisees of a given brand and the replication of automobile assembling operations across geographies are two notable examples of this.

Inter-organizational learning costs become more pronounced when the task extends beyond mere knowledge replication and into domains of new knowledge generation. First, such efforts likely involve considerable experimentation and recombination costs. Generating new organizational knowledge likely involves reconfiguring and recombining firms' capabilities (Kogut & Zander, 1992). However, reconfiguring knowledge is very challenging, as different parts of the organization tend to specialize in optimizing sub-processes for production. This leads to significant organizational challenges in the face of changes in the way components of innovation are assembled (Henderson & Clark, 1990). Furthermore, in novel contexts, understanding the relationship between cause and effect of experimentation and recombination involves time, resource, and managerial attention investments, with the possibility of inappropriately applying knowledge (Zollo & Winter, 2002) due to possible misperceptions in causal relationships. Moreover, these challenges are compounded in the inter-organizational learning context because the focal firm probably understands less about the knowledge modules sourced from outside their own boundaries, and there could be some adaptation or alteration of the knowledge modules when imported to the focal firm.

In unpacking inter-organizational learning costs, it is important to note that organizational inertia is a significant force, and that any change in strategic direction can be destabilizing (Hannan & Freeman, 1984). One important reason for this is that the tacit and codified knowledge stored in organizational memory contributes to firm know-how, and is reflected in policies and procedures. The prior literature has reported that there is a great deal of path dependence in organizational commercialization modes due to both governance capabilities and contemporaneous project selection which plays to the strength of those firm level governance capabilities (Aggarwal & Hsu, 2009). In addition, prior learning can decrease costs of experimentation or of imitation (Zott, 2003). This phenomenon reflects the learning curve (e.g.,

Lieberman, 1984; Argote, Beckman & Epple, 1990), which can also contribute to organizational inertia. Nevertheless, due to the differential abilities of firms in effectively integrating knowledge, firms that do so are potentially able to obtain sustained competitive advantage (Grant, 1996)

Governance costs. Governance costs arise in the context of inter-organizational relationships such as learning alliances because managers are unable to exercise control by fiat (as would be the case under vertical integration). The literature on learning alliances has discussed and analyzed several issues that might develop when control is not kept entirely in-house, including asymmetric learning among alliance partners and, relatedly, allocating resources and technology meant for one project (covered in the alliance) to another (not covered under the alliance). In addition, the literature on transaction costs more generally has highlighted the incentive problems associated with inter-organizational relationships, particularly when it is not possible to contract on all possible contingencies in advance.

Before we review and discuss these two types of governance situations below, it will be helpful first to discuss a higher-order organizational capability in alliance management. As firms engage in more alliances and confront the range of alliance management issues which may arise, these same organizations develop knowledge, both general and specific to a given alliance partner, as to both the type of conflicts which might arise and at least some conjectures regarding how such issues might be managed in the future.¹ Anand & Khanna (2000) find empirical support for the notion that firms' ability to anticipate issues and learn how to deal with contingencies improves with alliance experience. As to the contributing organizational processes behind these experience effects, Winter (2003) notes that organizational processes, which require investment, may be worthwhile (as compared to the alternative of "ad hoc problem solving") if managers and organizations expect to confront the challenge sufficiently frequently. A key set of processes enabling routine formation is codification, which allows organizations to transcend individual memory or employee and managerial turnover. Indeed, in the alliance context, knowledge

¹ While there is some debate in the literature regarding the comparative importance of general alliance experience versus partner-specific experience (e.g., Hoang & Rothermael, 2005; Gulati, Lavie & Singh, 2009), we are less concerned with their relative importance.

codification through managerial handbooks or dedicated alliance functions within organizations has been associated with superior performance (Zollo, Reuer & Singh, 2002). For most new ventures seeking learning alliances, however, such dedicated alliance functions and higher order organizational routines to govern alliances are unlikely to exist, and so the governance costs discussed below are likely to apply.

One of the main governance costs discussed in the learning alliance literature are those associated with avoiding a destructive “race to learn” between the parties (Hamel, 1991; Khanna et al., 1998; Baum et al. 2000). The main idea is that both learning opportunities and learning rates can differ among the parties to an alliance, which can lead to potentially destructive “racing to learn.” As a result, one of the key managerial challenges is how to balance learning from alliance partners with protecting unintended leakage of own knowledge (Kale, Singh & Perlmutter, 2000).

Interestingly, there does not appear to be any broad-based agreement in the literature as to what constitutes effective learning in alliances. For example, Hamel (1991) suggests that successful learning can take place even if the alliance fails more broadly; in contrast, Doz (1996) correlates failed alliance projects with inertial, non-learning situations.² Nevertheless, a key theme is the competitive aspect that exists within a broader cooperative alliance setting.

It is important to note that how pertinent these issues are depends on the extent to which learning is a rivalrous good, and therefore has a zero-sum quality, as is implicitly assumed in the literature on learning races. The notion behind knowledge spillovers and racing is value capture. If the spillover of a unit of knowledge to a non-originating firm introduces competition to exploit a given application afforded by that knowledge, then the zero-sum quality probably prevails and avoiding learning races is likely to be a concern. If instead, commercial potential can be unleashed in many different possible directions (e.g., Shane, 2000) without having an adverse effect on other uses, then the knowledge is non-rivalrous.

Another set of governance costs in learning alliances result from efforts to guard against unintended knowledge leakage. Knowledge can flow easily between alliance partners, whether intended

² For this reason, we examine subsequent innovator self-commercialization and product approvals as markers of learning in our empirics.

or not (Gomes-Casseres, Hagedoorn & Jaffe, 2006), and so knowledge appropriation can be a central concern even among alliance partners. The concern arises because learning alliances foster permeable organizational boundaries, which makes it difficult to demarcate and control the exact knowledge that flows across projects and firms. This problem is exacerbated when there are multiple product development efforts spanning a range of contracting entities.

Whether driven by preventing destructive learning races or guarding against unintended knowledge spillovers, the risk is that without appropriate alliance governance, an alliance may come unstable, or dissolve completely (Hamel, 1991; Inkpen & Beamish, 1997). This is because the more a partner learns (especially in an asymmetric fashion) or the greater the extent of knowledge leakage, the less necessary or desirable it becomes for the counterparty to continue the learning alliance.

The literature has also investigated governance mechanisms that can potentially reduce the transaction costs associated with curtailing unintended knowledge leakage and facilitate learning. Governance mechanisms may be more or less formal in nature. Formal governance mechanisms may include equity and other contractual alliance terms, which allocate certain legal rights to alliance parties. Mowery et al. (1996) find that equity-based governance structures are best for learning from alliance partners. This observation may arise because new entrants have incentives to give a stake in their success to their potential competitors in order to diffuse pro-competitive behavior on the part of the would-be competitors – a concept often referred to as “judo strategy” (Yoffie & Kwak, 2002). Outside of equity, other contractual control rights may be important in governing alliances. For example, Lerner & Malmendier (2010) focus on termination clauses with the partner obtaining broad intellectual property rights as a means of deterring innovator opportunism. Finally, Oxley & Sampson (2004) examine alliance scope as a means of curtailing unintended knowledge spillovers (allowing for other possibly disciplining avenues to enforce counterparty behavior).

Informal mechanisms often rely on trust and/or reputation. For example, relational capital (Dyer & Singh, 1998), which is related to the concept of trust (Gulati, 1995) but in the dyadic context of an alliance, may reduce contracting costs. Kale et al. (2000) suggest that firms possessing relational capital

(mutual trust) and taking an integrative approach to conflict resolution can achieve both learning and protection from expropriation. Indeed, trust can be particularly important in the context of joint production in circumstances in which the desired output is highly uncertain and novel (such as in research and development-based alliances). This is because it is difficult or impossible to pre-specify and allocate rights and responsibilities for the full range of possible outcomes in an alliance relationship, particularly joint development of innovation-oriented projects. As a result, trust can facilitate strategic flexibility, possibly allowing for re-contracting a relational (rather than formal) contract (Young-Ybarra & Wiersema, 1999). In the absence of such trust, transactions costs are raised (for example, the potential for hold-up such as the type Williamson (1975) describes), and the buy side of the market for technology learning alliances may shut down, leading to vertical integration (Pisano, 1990; Ring & Van de Ven, 1992). In addition to purely trust-based mechanisms but still on the side of informal governance mechanisms are firm-level reputational concerns. Individual transactions operate in the shadow of a firm's social network, and protecting its reputation within that wider network may discourage firms from acting opportunistically in a specific relationship. Robinson & Stuart (2006) show that reputation can substitute for more formal governance such as equity participation.³

Despite the various governance mechanisms discussed, inter-organizational project governance can be costly and imperfect, especially in the context of learning alliances. Consequently, guarding against unintended knowledge spillovers to alliance partners can hinder the hoped-for joint output of the alliance, and product development outcomes can suffer.

Finally, governance costs may interact with learning costs, resulting in incentive costs. Economic theory postulates that contracting parties have the strongest incentive to maximize their joint welfare

³ There is also work examining the relationship between trust and contractual mechanisms, which connects the informal and formal governance mechanisms. Some authors suggest they are substitutes (e.g., Ring & Van de Ven, 1992; Inkpen & Currall, 2004), arguing that high initial trust lowers control costs and more formal initial control is associated with slower development of trust in joint ventures. A number of other studies, on the other hand, conclude that prior relationships between parties are associated with more detailed contracts, with more enforcement mechanisms (Poppo & Zenger, 2002; Mayer & Argyres, 2004; Ryall & Sampson, 2009), suggesting that formal contracting and relational governance may be complements.

when there is complete information, all actions are observable, and it is possible to contract on all contingencies. Relaxing any of these conditions reduces the incentives of one or both parties to invest and/or exert effort in performing their contractual obligations (see Salanie, 1997, for a summary). Moreover, if one party has multiple objectives or “tasks”, it is likely to divert effort to the task which is easier to measure and/or is more highly rewarded, leading to weaker effort incentives for the other (Holmstrom & Milgrom, 1991). These incentive problems are likely to be severe in learning alliances where learning is only one of several objectives, and firms asymmetrically benefit from learning, as is the case in technology commercialization alliances. If the optimal balance or level of activities that facilitates learning differs from that which maximizes the outcomes of other objective(s), then the firm seeking to learn may divert resources and/or bias its effort in a way that impacts the ability to achieve the other objective(s). If the counterparty in the learning alliance does benefit from learning over the long term, then the issue is achieving the right balance of incentives (Gibbons, 2005). However, if the counterparty does not directly benefit from the learning, then the risk of diversion reduces its incentives to invest resources and/or effort into the project, which in turn impairs achievement of the primary objective.

In summary, learning and/or governance costs are likely to have negative consequences for the performance of a learning alliance, at least in the short-run. While we have discussed governance and learning costs separately, they are also likely to interact in theory. For example, guarding against possible learning race behavior may impact the costs of learning via incentive costs. Therefore we propose:

- **Hypothesis 1:** *Firms without downstream commercialization experience who engage in learning alliances will incur short-run product development performance costs.*

2.2 Longer run benefits of learning alliances

A good deal of the literature on alliances and learning alliances has concentrated on their benefits, so as a result, we will be brief in reviewing this literature before proposing our main predictions regarding the longer run benefits of learning alliances. Our main point of differentiation from this literature is to consider how the benefits associated with learning alliances evolve across the firm’s lifespan.

A central tenet of the resource-based view of the firm as applied to cooperative commercialization is that dealing with resource-rich partners will enhance alliance performance. A set of empirical studies lends support to the proposition that “firms grow by being connected to benefit-rich networks” (Powell et al., 1996: 139). For example, Stuart et al. (1999) find that partnering with prominent partners improves the likelihood of an initial public offering for new ventures, and the effect of partner affiliation is strongest the more uncertain and unknown is own quality, as is the case with new ventures. Other studies find that large and innovative alliance partners (Stuart, 2000) and partners with diverse resources (Baum et al., 2000) are associated with high own-firm performance. These and other studies in this research stream suggest that the strong-partner effect can result from positive signaling to the outside world about venture quality and/or the flow of tangible resources to the enterprise.⁴

The benefits of organizational absorptive capacity, which are built-up through research and development investments and assembling a diversity of expertise within the organization, include enhanced technical knowledge (Cohen & Levinthal, 1990). Extending absorptive capacity to the dyadic level, Lane & Lubatkin (1998) find that similarity in partners’ basic knowledge and organizational structure can aid inter-organizational learning. Mowery, Oxley & Silverman (1996) find, in the context of established firms, that absorptive capacity augments knowledge inflows and also that alliances facilitate parties’ abilities of exploring new strategic directions after alliances are struck.

The literature has also discussed self-perpetuating dynamics associated with the learning alliances process. Firms with greater alliance experience get more positive responses from the stock market when they next form or announce alliances (Anand & Khanna, 2000). This is a likely reason why cooperative ties tend to beget further cooperative ties (Walker, Kogut & Shan, 1997). The boundary condition to this behavior at a given alliance-dyad level would seem to be when the learning potential is exhausted and/or when the costs of accessing the partner’s knowledge exceed the benefits.

⁴ To single out a few illustrations of these themes in the literature: Cooperative ties are correlated with patenting output (Shan et al., 1994), and cooperative ties are associated with product innovativeness (Kotabe & Swan, 1995).

The issue of how the benefits from a learning alliance evolve over a firm's lifespan has received much less attention, however. Rothaermel & Deeds (2004) provides one of the few illustrations of alliance lifecycle effects, finding that exploration alliances lead to products in development, which lead to exploitation alliances, and in turn to products on the market. Learning alliances enable a firm to build its base of resources and capabilities, which in turn provides a foundation to establish a stronger competitive advantage (e.g., Barney, 1986). We therefore expect that with experience accumulated through learning alliances (especially as compared to other, more passive commercialization modes such as technology licensing), firms will ultimately reap benefits over the long run. In summary, we propose:

- **Hypothesis 2:** *Firms with more experience in learning alliances will receive long-run product development performance benefits.*

3. Data, Variables, and Empirical Strategy

To empirically examine these predictions, we investigate the relationship between the structure of the commercialization arrangement and the firm's commercialization success over the short and long terms. We start by motivating our empirical context and describing our data, then turn to a discussion of our variables and our empirical method. The typical biotechnology innovator starts with a strong research base (often built from the founders' experience in university labs), yet does not have expertise in commercializing products or the downstream complementary assets (such as a manufacturing plant or sales force) necessary to bring the innovation to market. Furthermore, lengthy and uncertain drug development means that a start-up firm is rarely able to finance commercialization completely from its own resources or even with only the help of venture capital finance. This combination of factors makes cooperative commercialization attractive. Nevertheless, biotechnology firms report often that they are not able to capture a proportional share of the value from an innovation purely through licensing (Wakeman, 2007), and so there is a strong motivation to integrate downstream if and when it becomes possible. Hence the industry provides an ideal setting to observe and measure both the short-term costs and the longer run benefits of commercialization capability development through learning alliances.

3.1 Data sources and construction

We build our primary dataset using a set of databases compiled by Deloitte Recap (“Recap”): RecapRx, rDNA, and Valuation Analyzer. RecapRx contains a clinical development history for each indication of all products developed by the 146 largest biotechnology firms since their inception. rDNA contains detailed information on all publicly announced alliances since the industry’s inception, obtained from a combination of press releases and public filings. Valuation Analyzer contains the effective royalty rates that the innovating firm stands to earn post-commercialization for the subset of alliance contracts for which the uncensored version is published. In addition we use information from IMS Lifecycle’s R&D Focus database, the NBER patent dataset (Hall et al., 2001), and the Derwent Innovations Index.

Using the information on related licensing and M&A activity from RecapRx and rDNA, we determined which firm (or firms) owned the U.S. rights to sell the product for a specific indication for each month of the product’s lifespan. If the rights were transferred, we recorded the nature of the transfer (i.e., whether the owner was acquired, the product was sold outright, or the product rights were licensed).⁵ If the transfer involved technology licensing, we collected information on the deal terms from rDNA and Valuation Analyzer, including whether the biotechnology firm retained the rights to participate in the development and/or marketing of the product and the effective royalty rate (when available). Furthermore, we collected information on the clinical development history and the disease field to which the product relates (from RecapRx), the discovery date and the primary (or “priority”) patents covering the underlying product (from IMS Lifecycle’s R&D Focus database), and the citations to the priority patent (from the Derwent Innovations Index). Finally, we collected information on the characteristics of each firm, including the number of patents assigned to the firm (from the NBER patent file), the number

⁵ Our unit of analysis is a “product-indication-instance” – an instance is when a biotechnology firm holds rights to market a given product for a specific indication. For simplicity we use the term “product” throughout.

of prior alliances (from rDNA), the number of products in its pipeline (from R&D Focus), and its total sales in the prior quarter (from Compustat).⁶

3.2 Variables

Dependent variable. Our primary dependent variable is an indicator for whether the underlying alliance product successfully completed clinical trials and received FDA approval. Since the majority of a biotechnology firm's payoff from commercialization depends on regulatory approval of the underlying product (whether the product is developed alone or in an alliance), we believe that product approval is a useful measure of commercialization performance.⁷

Since an innovating firm arguably seeks to maximize the payoff from commercialization, rather than simply the probability of commercialization, as a robustness check we repeat our analyses using the effective royalty rate that the firm ultimately receives instead. The effective royalty rate depends on whether the product is approved for sale and – if the product is licensed – the terms of the contract. In the empirical model, we set the dependent variable equal to 100 if the product is approved *and* the biotech firm owns exclusive rights to the product, equal to the effective royalty rate (from the Valuation Analyzer database) if the product is approved *and* the product is licensed to another firm, and zero otherwise.⁸

Explanatory variables. Our primary explanatory variables capture (1) the extent of the originating firm's involvement in the development and commercialization process, and (2) the amount and nature of the originating firm's clinical development experience. In addition, we control for a number of other

⁶ All alliances in our dataset relate to an identifiable biopharmaceutical product. This stands in contrast to most previous analyses on alliance data, which contain a mixture of both technology- and product-related alliances. These different alliance types have different structures, and including both in the same analysis introduces unobserved heterogeneity. We can be more confident that the parties to our dataset of alliances were negotiating over similar issues. Moreover, we can also observe the outcome of the clinical development process, which gives us a clear measure of alliance performance.

⁷ There are several stages of drug development prior to involvement with the FDA (discovery, identification of lead molecule, preclinical trials) and after such involvement (small sample human safety, efficacy, and large scale clinical trials corresponding to Phase 1, 2, and 3 studies, respectively). Thereafter, when sufficient clinical data has been collected, the developer can apply to the FDA for approval (which allows the drug to be offered for sale).

⁸ The licensor's payoff from successful commercialization may come from simple royalties (i.e., a proportion of net sales), tiered royalties, a transfer price, profit split, manufacturing cost reimbursement, or some combination of the above. The "effective royalty rate" is a measure developed by Deloitte Recap to make these alternative payment schemes comparable. For more details see Edwards & Brundt (2008).

variables that are likely to be correlated with product approval, including the commercialization capabilities of the originating (biotechnology) firm, the commercialization capabilities of the developing firm,⁹ and the quality of the underlying product.

The main explanatory variables in our first analysis of the short-term payoff from the choice of commercialization arrangement distinguish between straight licensing, co-development, and self-commercialization arrangements. From the product's licensing history, we create an indicator of whether the innovating firm retains exclusive control over the product or licenses the product rights to a contracting partner. In addition, if the originating firm licenses out the product rights, we code whether the innovating firm retains the rights to participate in development of the alliance product (also known as co-development rights) using the alliance summary on rDNA.¹⁰

A co-development arrangement entitles the innovating firm to participate in the design and conduct of the clinical trials, and gives it a significant influence – if not an equal say – over whether the alliance product advances to subsequent stages of the development process.¹¹ Typically the innovating firm incurs a share of costs from development and takes a cut of the profit.

Prior interview research reveals that biotechnology firms commonly see a co-development arrangement as a way to acquire knowledge about the commercialization process that they can then apply to commercializing subsequent innovations (Wakeman, 2007). This arrangement enables the

⁹ The developer is the originating firm if the product is developed internally (i.e., self-commercialization) and the licensee if the product is licensed.

¹⁰ We also record if the originating firm sold the product outright or was acquired by another firm. We treat an asset sale as equivalent to a completed out-licensing arrangement.

¹¹ It is useful to contrast co-development arrangements to several other arrangements for commercializing biotechnology innovations. In a straight product license, the biotechnology firm licenses all development, marketing, and distribution rights to the pharmaceutical firm. In such licensing arrangement, the originating firm delegates all rights to its alliance partner and typically is compensated just through milestone payment and a royalty on net sales. Alternatively, the parties may agree to split geographic territories, partitioning rights to develop, market, and/or sell the same drug in separate (exclusive) territories. A co-development arrangement should also be distinguished from a co-promotion arrangement in which the biotechnology innovator licenses the marketing rights to the pharmaceutical partner, but has the biotechnology firm participating in the marketing and distribution process alongside the partner (i.e. the two parties together develop a joint marketing strategy and sales force, sell under the same brand name, and pool – and ultimately split – revenues). These two forms of agreement are not mutually exclusive, and an innovating firm that retains co-development rights can also retain co-promotion rights, but they are not necessarily coincidental.

biotechnology firm to “piggy back” on the expertise of its alliance partner or to “leverage the alliance partner’s expertise internally” to learn the skills necessary to develop the next drug. This interview evidence is consistent with the results in Anand & Khanna (2000), which found that the learning potential of straight licensing arrangements is limited. Hence we believe these arrangements are a good indicator of whether the biotechnology firm seeks to acquire downstream commercialization knowledge through the alliance. In addition, by giving the firm a role in the decision-making process, these arrangements better enable the firm to monitor the partner’s activity and make sure that their product gets favorable treatment. Finally, since co-development typically includes a profit-split, many biotechnology firms believe that the arrangement gives them a larger share of the pie than they would earn through the royalty-based payments that usually are associated with a straight licensing arrangement (Wakeman, 2007).

Nevertheless, such terms can influence payoffs to alliance parties and can therefore affect their incentives (Parkhe, 1993). As discussed above, such deal terms may have a short-run incentive cost. If the partner allows the startup firm to share in the profits (e.g., revenue sharing based on product sales) the partner’s benefits will be reduced. There may also be a number of indirect costs associated with limiting the partner’s control over the commercialization process and instituting governance mechanisms to mitigate the risk of unintended knowledge spillovers (per our discussion of governance costs). Facilitating downstream startup complementary assets development may also, over the longer term, create competition for the alliance partner.

The primary explanatory variables for our second analysis seek to capture how the choice of commercialization mode affects longer-term outcomes. We create measures of commercialization experience by counting the number of months in which the innovating firm was alternatively (a) the sole developer of a product; (b) a partner in a co-development arrangement; or (c) the licensor in a straight licensing arrangement. To make the comparison of (b) to (c), we create two additional variables to run in the regression: (1) the aggregate of (b) and (c); and (2) the difference between (b) and (c).

Control variables. We control for the commercialization capabilities of both the innovating firm and its contracting partner, as both will likely have a direct effect on whether the product is successfully

commercialized. The innovating firm's own capabilities are also likely to impact its ability to attract and realize benefits from stronger partners. This can happen in two ways. First, an innovating firm's own characteristics shape its bargaining power (vis-à-vis the alliance partner). For instance, Nicholson et al. (2005) find that inexperienced biotechnology firms face discounted deal terms when forming their first alliance, but afterwards these firms realize higher valuations from venture capitalists and the public-equity markets (controlling for product characteristics). More generally, the party that controls scarce resources enjoys stronger bargaining power and therefore higher value appropriation in the context of strategic alliances (Lavie, 2007). Beyond bargaining power, venture quality can also shape the benefits it accrues from partners. For example, a firm's resources affect the rate at which it is able to absorb commercial and technical knowledge from its partners (Mowery et al., 1996). Furthermore, firms may differ in their ability to manage and lead partners (Anand et al., 2000), including partner-specific alliance experience (Reuer et al., 2002). Inexperienced firms will thus lag in both bargaining power and alliance management skills, and so will be less successful at attracting and realizing value from their partners. Our instrumental-variable approach (discussed below) attempts to deal with the endogeneity between the quality of both the originating firm and the underlying product, and the selection of partner and deal terms.

To measure each firm's commercialization capabilities, we construct two different proxies and then use principal components analysis to construct a composite measure. Our first proxy of commercialization capabilities is the firm's total sales in the prior quarter normalized by the highest total sales among all firms in the industry. We gathered quarterly data on firm sales for all firms in the pharmaceutical industry (i.e., firms with primary NAICS codes of 325411, 325412, 325413, or 325414) from Compustat, then ranked all firms by sales in each quarter, and finally normalized each firm's sales by the highest total sales across all firms in that quarter.¹² Our second proxy is the normalized count of products in the firm's portfolio (including those in its clinical development pipeline). To create this

¹² The purpose of the normalization is to facilitate comparison across different time periods, since average firm sales in more recent years is likely to be higher than average firm sales in the early years of the biotechnology industry. As an alternative measure to check result robustness, we used the logged value of the raw total sales (while controlling for the month in which the alliance was signed).

measure we count products at any stage of development with which the firm was (or had been) associated with at the time of the alliance,¹³ then rank all firms by the number of products in their portfolio in that month and normalize the firm's count by the highest among all firms in that quarter.

We also control for the quality of the underlying product. We use dummies for stage of product development at the time the product was transferred – pre-clinical, phases 1, phase 2, phase 3, and new drug application filed (corresponding to 3%, 52%, 29%, 13%, and 3% of our observations, respectively). In addition, we include the log of the number of forward citations to the priority patent covering the product as a measure of the underlying product quality.¹⁴

We also control for other aspects of the deal that may influence commercialization success. In particular, we include indicators of whether the originating firm retained co-promotion rights, whether the developer took an equity stake in the biotechnology firm (i.e., whether it is an “equity-based alliance”), and whether the parties had a prior alliance together. Co-promotion is similar to co-development in that the innovating firm retains the right to participate in the marketing & distribution process with the opportunity to learn from its partner. Although it is unlikely to have a direct effect on whether a product gets approved, it may have a similar negative incentive effect on the partner's willingness to effort. We coded the information on equity participation using the alliance summary from rDNA. Since co-promotion rights are often indication-specific, we coded this from the details of the alliance announced in press releases and/or the alliance contract. We constructed the indicator of whether the parties had done a prior alliance from the two parties' alliance history from rDNA. The equity and alliance history variables capture two alternative alliance governance mechanisms emphasized by the prior literature: vertical control in the case of equity and the reputational effects and alliance management associated with

¹³ It is not possible to get accurate and comprehensive data on which firm had which rights to each product at each point in time, so instead we count any product with which the firm was associated (i.e., was either the originator or a licensee in any territory) at any time during the product's lifespan. This approach will overestimate the size of the pipeline but we do not have any reason to believe it will distort the measure in any way that would bias our results.

¹⁴ Hall et al. (2005) validate the number of forward citations as a good proxy for a patent's economic value. Since we were unable to identify the priority patent for a number of products, several values of this variable are missing. To avoid having to drop these observations, we set the value of the missing variables equal to the mean and include a dummy variable that indicates the missing value in the regression.

bilateral alliance history. Table 1 presents summary statistics for the key dependent and explanatory variables used in the analysis, as well as pairwise correlations between those variables.

3.3 Empirical strategy

We structure the empirical analysis in two stages. In the first stage, we examine the short-term payoff to the alternative commercialization arrangements. To do so, we separate out those firms that do not have any active clinical-development experience (i.e., have never taken a product into phase 2 trials, either alone or in a co-development arrangement with another firm) and compare this to the results from the entire sample. For each case we examine the relationship between the structure of the commercialization arrangement and the performance of that product.

In the second stage we focus on firms that have some prior experience with product commercialization, either as an active partner in a co-development relationship or as the licensor in a straight licensing arrangement, but have not yet successfully commercialized a product (either alone or in a co-development arrangement) at the time of observation. This subsample contains those firms that are most likely to have faced a decision whether to retain co-development rights in the past, but have not yet become fully integrated firms. We exclude firms that have successfully commercialized a product because once firms have done so, they have by definition acquired the expertise and capabilities necessary to commercialize subsequent products (and their prior co-development experience is likely to be less relevant in determining their ability to do so).

This objective in this stage of the analysis is to analyze the long-term payoff to the choice of commercialization arrangements in the first stage. To examine whether the nature of their prior cooperative experience impacts product commercialization success we include two variables in the model: (1) the aggregate experience in cooperative arrangement (i.e., the sum of experience as a co-development partner and as a licensor) and (2) the difference between these two types of experience (i.e., experience as a co-development partner minus experiences as a licensor). The coefficient on the second

variable should reflect whether the *type* of prior experience has any relationship to subsequent commercialization performance.

We estimate both stages of the analysis using a Cox proportional hazard rate model. The Cox model compares the actual development profile for a given product to the profile for the average product at the same point in the product's lifespan, and examines how differences in the explanatory variables affect the instantaneous hazard of approval. The instantaneous hazard of approval in turn influences both the overall (or cumulative) likelihood of approval and the time to market. The hazard-rate model is especially appropriate in this context because all pharmaceutical firms seek to maximize both the overall likelihood of approval and the time to market. This model also accounts for right censoring of the products development profile, which is useful because the average time from invention to approval is at least 10 years and can range up to 20 years.

We also address two possible confounds to the analysis. The first possible confound is that the ability to negotiate a co-development arrangement is positively correlated with the quality of the originating firm and the underlying product. There is also likely to be a trade-off between negotiating a co-development arrangement and doing a deal with a stronger partner. To identify the effect of commercialization arrangement, we use an instrumental variables (IV) approach, where the IV is the logged value of the ratio of upfront payments to the average upfront payments in the same year and therapeutic area (the denominator normalizes the payment by cohort). While upfront payments are correlated with the underlying quality of the product, and thereby the likelihood of negotiating co-development rights, such payments are likely uncorrelated with alliance product performance. This is because upfront payments do not affect the innovating firm's ability to perform its alliance obligations, as R&D payments (typically based on number of researchers) finance development costs. Furthermore, upfront payments are sunk at the time an alliance is struck and are unlikely to impact ongoing effort required for successful product development.

Since there is no straightforward way to estimate a Cox hazard-rate model with an instrumental variable, we instead approximate the hazard-rate model using a probit model and include the underlying

hazard (extracted from the hazard-rate model) as a covariate. The dependent variable in the first stage is an indicator of whether the firm retained co-development rights and the dependent variable in the second stage is an indicator of whether the product is approved (as in the Cox model). We estimate the IV model using both an IV probit model (Newey, 1987) and a bivariate probit model.

The second possible confound is that the originating firm's outside option to commercialize the product alone (or to advance it to a later stage of development without partnering) may affect the cases in which the biotechnology firm retains co-development rights. If stronger innovating firms do not partner, or delay their partnering activities, then an empirical design that does not take into account the decision whether to partner may understate the effect of retaining co-development rights on performance as we will only observe performance when weaker firms retain co-development rights.

To address this concern we re-estimate the effect of retaining co-development rights on performance using the Heckman correction for selection into licensing.¹⁵ In the first stage the dependent variable is an indicator of whether a biotechnology firm entered into an alliance in a given month and we include the likelihood of raising external finance (in the VC and IPO markets) as an additional independent variable. The likelihood of raising external finance will be negatively correlated with the likelihood an innovator does an alliance deal in a given time period (Lerner et al., 2003), but is unlikely to be strongly correlated with the probability of product approval since that event is shaped more by scientific merit and drug efficacy.

4. Empirical Results

Table 2 presents the results of the regressions of whether a product is approved, assuming that the commercialization mode and the developer's capabilities are determined exogenously. Specifications (2-1) through (2-4) in Panel A show the Cox proportional hazard-rate regressions while specifications (2-5)

¹⁵ The two-stage procedure for accounting for selection was proposed by Heckman (1979) and adjusted for limited dependent variables by Van de Ven & Van Praag (1981).

through (2-8) in Panel B show the bivariate probit regressions with an instrumental variable.¹⁶ The regressions in the odd columns are on all products developed in a cooperative commercialization arrangement (i.e., licensing) while those in the even columns include just those products developed by firms that at the time of entering the alliance did not have any active commercialization experience at or above phase 2. The first two regressions in each panel contain just the indicator of a co-development arrangement while the second two include the full set of controls.

The results from Panel A suggest that there is no significant relationship between retaining co-development rights and the hazard of product approval. However, since these results do not adjust for the fact that retaining co-development rights is likely endogenous to the unobserved quality of the underlying product and/or originating firm, it is difficult to draw conclusions from these regressions.

In Panel B we use the relative size of the upfront payments as an instrument to control for unobserved quality. As discussed above, we believe that this is a valid instrument because firms with high quality products are more likely to retain co-development rights and to negotiate higher upfront payments, but since upfront payments do not fund the development of the product and are not conditioned on effort, they are unlikely to affect incentives to develop the product. The results show that while in general there is a strong positive relationship between retaining co-development rights and product approval, for those firms without commercialization experience, the relationship is negative, particularly when we control for other factors. In economic terms, the positive coefficient on retaining co-development in (2-7) corresponds to a positive marginal effect of retaining co-development on approval of around 12% per product-indication, while the negative coefficient in (2-8) corresponds to a negative marginal effect of around 7% per product-indication.¹⁷ We also observe that firms that engage in cooperative arrangements

¹⁶ In a separate analysis we have also estimated this analysis using an IV probit model. Both estimation procedures produce qualitatively similar results and so we only report the bivariate probit results here.

¹⁷ The analysis reported in Panel B of Table 2 is estimated using a bivariate probit model, which allows for a binary endogenous variable but assumes that the errors have a joint normal distribution. We also estimated the same specification using a linear IV probit model (Newey, 1987), which allows for more flexible error distribution but assumes that the endogenous variable is continuous. The results are qualitatively similar.

with partners with stronger commercialization capabilities experience a worse outcome, suggesting that doing a deal with a stronger partner does not made up for other factors that are lost in the process.

In separate analyses not reported here we find that these main effects persist when we account for the decision to engage in a cooperative commercialization arrangement in the first place and when we use the deal payoff as the dependent variable. In particular, in a two-stage, Heckman analysis of product approval where the first stage uses the hazard of obtaining external finance to adjust for selection into licensing, retaining co-development rights is not significantly related with product approval. Meanwhile, in a series of regressions on deal payoffs using both ordinary least squares and tobit models (in the latter the dependent variable is constrained to lie between 0 and 100%), there is a negative relationship between retaining co-development rights and deal payoff for firms with no active commercialization experience, and a positive relationship between co-development experience and deal payoff.

Table 3 analyzes the relationship between firms' prior commercialization experience and subsequent commercialization activity outcomes. The sample in this analysis is originating firms that have some cooperative commercialization experience (at or above phase 2) but have not yet successfully commercialized a product (either alone or in a co-development arrangement). The dependent variable is an indicator of whether the product was approved in a given month, and the results are estimated using a Cox proportional hazard-rate model where analysis time is product age.

The results suggest that prior self-commercialization experience is unrelated to the hazard of product approval, and in general prior cooperative commercialization experience may have a negative effect on the hazard of approval. However, if that experience is in a co-development arrangement rather than as a licensor then the product is significantly more likely to be approved.¹⁸ The positive coefficient on the difference between co-development and licensor experience corresponds to hazard ratio of 1.71,

¹⁸ The reason for including the total cooperative experience and co-development experience variables in the regression is that with this specification, interpreting the marginal effect of switching from licensor to co-development experience from the coefficient on the co-development experience variable is straightforward, as the cooperative experience variable is not affected.

which means that an additional year of co-development experience corresponds to a 71% increase in the hazard of product approval.

5. Discussion & Conclusion

This paper analyzes the costs and benefits of learning alliances from the perspective of the innovating startup seeking to develop its commercialization capabilities. We hypothesize that firms engaging in learning alliances to develop downstream commercialization capabilities incur a combination of learning and governance costs, and impose incentive costs on their partners, leading to negative consequences for product development outcomes in the short term. However, over the firm's lifespan the experience accumulated from these learning alliances will ultimately reap benefits of greater success in subsequent commercialization attempts. We test these predictions on a dataset of product commercialization in the biotechnology industry, measuring the costs and benefits of the learning alliance by whether the underlying product is successfully commercialized. We find evidence of small but significant short-term costs, as well as substantial long-term benefits from engaging in learning alliances. In numerical terms, our results suggest that on average, retaining co-development rights reduces the likelihood of successful product commercialization by 7% for a firm without prior commercialization experience. However, the resulting experience translates into an increase in the likelihood of commercialization of 71% in subsequent products per year of experience relative to firms without any such experience.

We believe our results have three main implications for the literature on learning alliances. First, it is often difficult for emerging enterprises to vertically integrate into downstream commercialization activities due to resource and capability constraints, and even without such constraints, such entry might spur retaliation by incumbents (Yoffie & Kwak, 2002). The learning-alliance channel of business development is therefore an important one, particularly for startup firms. By contrast, established firms typically have a wider range of choices in developing their downstream skills, including merger and acquisition or vertical integration. Learning alliances require engaging the counterparty, of course, and so

controlling for product quality as well as addressing the potential endogeneity of alliance structure (and the decision by the innovating firm to partner in the first place) with firm quality are important elements of our empirical design and analysis.

Furthermore, given the special importance of learning alliances for new ventures, we emphasize a conceptually distinct domain relative to the prior literature. Perhaps the most influential line of literature on alliances for new ventures is by Stuart et al. (1999) and Stuart (2000). In these papers, the emphasis is on the heterogeneous value of counterparty alliance partners (depending on their technological and commercial prominence) and the signaling value prominent alliance partners and equity holders can have on focal venture quality. As a complement to that perspective, our emphasis is on both the costs and benefits of learning-by-doing and product co-development with the alliance partner (while taking into account the line of research followed by Stuart et al. by both controlling for counterparty quality and by endogenizing the startup's ability to strike an alliance with a prominent partner, as previously discussed). We therefore give more nuance relative to the prior literature on the temporal effects associated with the resource exchange in learning alliances.

Doing so gives rise to a second main implication of the study for the learning alliance literature. The majority of literature on learning alliances and alliances more generally for emerging companies concern the benefits of such alliances for own-firm or alliance success (e.g., Powell et al., 1996; Stuart et al., 1999, 2000; Baum et al., 2000). One puzzle then is why *all* startups do not engage in learning alliances. We highlight the costs any strategy designed to strengthen a firm's resources and capabilities and quantify those costs in a tangible and direct way. While these costs can arise from learning and/or governance mechanisms, by putting together the costs and benefits of learning alliances for a common set of companies, we help understand the average effects associated with this channel of developing downstream complementary assets.

Our results on short-run learning and governance costs associated with a given commercialization mode is consistent with the findings of Aggarwal & Hsu (2009) that firm path dependencies in cooperative commercialization modes result from governance capabilities and appropriation

environments. However, we extend that paper and others examining new capabilities more generally by quantifying investments and payoffs to the set of organizational processes necessary in developing new skills. To the long run benefits part of the analysis once new capability investments have been made, we move beyond the prior empirical literature that has used alliance longevity/failure as measures of success (Hamel, 1991; Doz, 1996) and instead look at success in commercializing the underlying product. This has two benefits: first it is a more direct measure of success, being something that the partners seek to maximize; secondly it makes it possible to move beyond the static context of one alliance to study more dynamic benefits that evolve over time.

This last benefit underscores a final implication of our research for the literature: it is useful to consider both static and dynamic perspectives of business development. The literature on organizational reconfiguration (e.g., Teece et al., 1997; Eisenhardt & Martin, 2000) has been influential, but empirical analysis of this perspective has lagged significantly. Our study contributes to a dynamic perspective on resource acquisition that is particularly salient for new ventures as such entities typically face severe resource constraints which make learning alliances an attractive organizational form for their business development. Our results are also applicable to the dynamic capabilities literature within strategic management, which is concerned with questions of how firms change their strategies over time, and the consequences of such change. Most of that literature is theoretical and focuses on the benefits associated with dynamically aligning strategy with the business environment (see Zott, 2003 for an exception). In contrast, we empirically examine the inter-temporal investment and payoff patterns on the path to developing commercialization capabilities, which should also inform more established firms seeking to undergo strategic change.

To deepen our understanding of learning alliances for new ventures, we discuss a few potential avenues for future work. First, there could be important heterogeneity in the learning and governance costs faced by (and incentive costs imposed by) startup innovators. A deeper understanding of such heterogeneity is consistent with the central tenets of the resource-based view of the firm in the strategy literature. It will also be interesting to study a broader set of mechanisms beyond a formal contractual

channel in facilitating learning alliances. Gibbons & Henderson (forthcoming), for example, discuss the importance of heterogeneous managerial practices, which are rooted in relational (implicit or informal) contracts as being important sources of within-industry differences in competitive performance. While they mainly consider the case of intra-organizational relational contracts, their arguments also extend to the inter-organizational domain, as would be the case with learning alliances. Finally, it would be valuable to study how the contractual arrangements we study compare to other contractual and non-contractual means by which entrepreneurs can develop downstream complementary assets. Overall, this study deepens our understanding of the dynamics of learning alliances by quantifying the short-term costs of learning alliances, and also shows that such collaborations alter subsequent firm commercialization mode choices and benefits future product commercialization success with a net positive effect.

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Table 1
Descriptive Statistics and Pairwise Correlation Matrix of Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) <i>Product approval (d)</i>	1.00													
(2) <i>Deal payoff</i>	0.96	1.00												
(3) <i>Originator retains co-development rights (d)</i>	0.01	0.15	1.00											
(4) <i>Comm. experience as sole developer (product years)</i>	0.01	0.09	0.07	1.00										
(5) <i>Comm. experience in cooperative arrangement (product years)</i>	-0.01	0.04	0.02	0.61	1.00									
(6) <i>Comm. experience as co-development partner (product years)</i>	0.01	0.12	0.06	0.61	0.87	1.00								
(7) <i>Innovator comm. capabilities (composite variable)</i>	0.11	0.15	0.03	0.45	0.15	0.17	1.00							
(8) <i>Partner comm. capabilities (composite variable)</i>	-0.03	0.01	0.17	-0.09	-0.09	-0.10	-0.06	1.00						
(9) <i>Citations to priority patent (log)</i>	0.03	0.06	-0.01	0.13	0.10	0.18	0.12	0.06	1.00					
(10) <i>Originator retains co-promotion rights (d)</i>	0.05	0.14	0.38	0.05	0.01	0.05	0.09	0.23	0.16	1.00				
(11) <i>Developer acquires minority equity stake (d)</i>	-0.02	-0.05	0.11	-0.12	-0.10	-0.06	-0.08	0.22	-0.10	-0.03	1.00			
(12) <i>Prior alliance between two parties (d)</i>	0.02	0.12	0.10	0.03	0.02	-0.02	0.09	0.11	0.12	0.20	-0.11	1.00		
(13) <i>Deal upfront payments vs. year & stage mean</i>	0.06	0.09	0.12	0.01	-0.01	-0.03	0.12	0.17	0.11	0.19	-0.13	0.19	1	
(14) <i>Hazard of raising external finance</i>	0.15	0.01	-0.12	-0.18	-0.15	-0.10	0.17	-0.04	0.01	-0.01	0.19	-0.01	-0.09	1
<i>Observations</i>	710	211	710	710	710	710	710	710	710	710	710	710	422	612
<i>Mean</i>	0.06	2.57	0.36	6.46	2.39	1.28	0.00	2.20	3.37	0.25	0.39	0.12	0.50	0.05
<i>Standard Deviation</i>	0.24	7.51	0.48	15.88	6.20	4.36	0.53	3.36	1.01	0.43	0.49	0.32	1.74	0.01
<i>Minimum</i>	0	0	0	0	0	0	-0.30	-0.30	0	0	0	0	-1.00	0.02
<i>Maximum</i>	1	30	1	163	60	56	5.32	14.77	6.39	1	1	1	18.37	0.07

This table presents the summary statistics and pairwise correlations for the variables used in the analysis. Missing observations for the citations to the priority patent (†) were imputed by replacing with the mean value and including an indicator that the variable is missing.

Table 2: Short-Term Effect of Commercialization Arrangement on Product Approval

<i>Dependent variable:</i>	<i>Panel A</i>				<i>Panel B</i>			
	<i>Cox proportional hazard-rate model</i>				<i>Bivariate probit model with instrumental variable</i>			
	<i>Product approved in month (d)</i>				<i>Product approved in month (d)</i>			
	(2-1)	(2-2)	(2-3)	(2-4)	(2-5)	(2-6)	(2-7)	(2-8)
	all	no clinical experience	all	no clinical experience	all	no clinical experience	all	no clinical experience
<i>Firm retains co-development rights (d)</i>	0.386 (0.358)	-0.463 (0.788)	0.357 (0.459)	0.128 (0.851)	2.122*** (0.148)	-2.214* (1.192)	1.886*** (0.212)	-1.489** (0.638)
<i>Innovator commercialization capabilities (composite variable)</i>			0.379** (0.173)	0.649 (0.519)			0.090 (0.210)	0.423 (0.416)
<i>Partner commercialization capabilities (composite variable)</i>			-0.016 (0.050)	0.065 (0.180)			-0.069** (0.034)	-0.723** (0.322)
<i>Citations to priority patent (log)† and dummies for product stage at transfer</i>	No	No	Yes	Yes	No	No	Yes	Yes
<i>Dummies for co-promotion rights, equity stake, and prior alliance</i>	No	No	Yes	Yes	No	No	Yes	Yes
<i># monthly observations</i>	37,445	15,781	37,445	15,781	419	125	419	125
<i># product-indication-instances</i>	707	260	707	260	419	125	419	125
<i># products</i>	359	160	359	160	214	82	214	82

This table presents the results of regressions of product approval on the choice of commercialization arrangement. The sample in the odd columns contains all product indications that were outlicensed; the sample in the even columns contains all product indications belonging to firms that had no commercialization experience (i.e., had neither attempted to commercialize a product alone or as a partner in a co-development arrangement). Results in Panel A are estimated using a Cox proportional hazard-rate model where analysis time is product age. Regressions in Panel B are estimated using a bivariate probit model with the baseline hazard of approval included as control variable to approximate the specification of a Cox hazard-rate model. The indicator for retaining co-development rights is instrumented with the relative size of the upfront payments (relative to mean upfront payments in the same year and disease field). Missing observations for the citations to the priority patent (†) were imputed by replacing with the mean value, and an indicator is included that the variable is missing. Robust standard errors, clustered by product, are in parentheses; *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.

Table 3: Longer Term Effect of Commercialization Mode on Product Approval

<i>Dependent variable:</i>	<i>Cox proportional hazard-rate model</i>			
	<i>Product approved in month (d)</i>			
	(3-1)	(3-2)	(3-3)	(3-4)
<i>Commercialization experience as sole developer (product years)</i>	-0.044* (0.026)	-0.034 (0.027)	-0.010 (0.032)	-0.010 (0.032)
<i>Commercialization experience as partner in any cooperative arrangement (product years)</i>	-0.279** (0.140)	-0.311** (0.130)	-0.490** (0.219)	-0.527*** (0.192)
<i>Commercialization experience as partner in co-development arrangement (product years)</i>	0.282* (0.150)	0.332** (0.139)	0.512** (0.228)	0.536*** (0.208)
<i>Innovator commercialization capabilities (composite variable)</i>		0.435 (0.296)	0.499 (0.374)	0.519 (0.376)
<i>Partner commercialization capabilities (composite variable)</i>		0.104** (0.043)	0.037 (0.057)	0.030 (0.057)
<i>Product rights licensed (d)</i>				0.328 (0.816)
<i>Citations to priority patent (log)† and dummies for product stage at transfer</i>	No	No	Yes	Yes
<i>Dummies for co-development rights, co-promotion rights, equity stake, and prior alliance</i>	No	No	Yes	Yes
<i># monthly observations</i>	79,119	79,119	79,119	79,119
<i># product-indication-instances</i>	1384	1384	1384	1384
<i># products</i>	692	692	692	692

This table presents results of regressions of product approval on prior commercialization experience of the originating firm. The sample contains all product indications belonging to firms that had products in later stage clinical development but no self-commercialization experience. The dependent variable is an indicator of whether a product was approved in a given month. The results are estimated using a Cox proportional hazard-rate model where analysis time is product age. The commercialization experience variables capture experience in self-commercialization, experience in a cooperative arrangement (as co-development partner and as licensor), and experience in a cooperative arrangement. In this regression, the co-development experience variable captures the marginal effect of switching from a straight licensing to a co-development arrangement. Missing observations for the citations to the priority patent (†) were imputed by replacing with the mean value and including an indicator that the variable is missing. Robust standard errors, clustered by product, are in parentheses; *, **, and *** indicate statistical significance at 10%, 5%, and 1% levels, respectively.