

Contracting Among Founders*

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Abstract

This paper develops a theory of contracting among founders of a new firm. It asks at what stage founders agree to commit to each other, how they structure optimal founder contracts, and how this affects team formation, ownership, incentives, and performance. The paper derives a trade-off between upfront contracting, which can result in teams with ineffective founders, versus delayed contracting, which can enable some founders to appropriate ideas and start their own firms. Delayed contracting becomes more attractive when there are significant doubts about the skills of founders. Contingent contracts with vesting of shares may be used to mitigate inefficiencies in the team formation process. Interestingly we show that outside investors cannot easily undo ex-post inefficient founder agreements. We also show that laws that provide protection to implied partnerships may have the unintended effect of encouraging more formal contracting.

Keywords: Entrepreneurship, partnership, founders, contracting, vesting, skill uncertainty, contract law.

JEL classification: D82, D86, K12, L26.

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1 Introduction

What determines a founder's ownership within a team? At what stage are founders selected and their stakes defined? And does it matter if there are several founders vying for each other's ownership stakes? At least in Hollywood the answer is 'Yes'! The main plot of 'The Social Network' revolves around a lawsuit by the Winklevoss twins. They claim to have been in a partnership with Mark Zuckerberg, who allegedly stole their idea when starting Facebook.

In this paper we examine how founder conflicts affect financial outcomes of start-up companies. We consider a model of the founding process, and ask at what stage it becomes optimal for founders to contract with each other, and what kind of contracts they write. We then examine how this affects team composition, ownership, incentives, and firm performance.

Standard reasoning holds that agents write (possibly incomplete) contracts ex-ante, before engaging in any joint activities. Company founders should thus agree on a contractual framework upfront: this allows them to establish ownership shares, and to draw up firms boundaries that provide some protection of the intellectual property (through trade secret laws), and possibly some protection against founder desertion (through non-compete clauses). In reality, however, there can be problems with 'tying the knot' too early. Consider the example of 'Zipcar', a pioneering US car sharing company: The two founders agreed to a fifty-fifty equity split at the start, prior to knowing much about each other. It soon became apparent that one partner was much more capable and committed than the other. The capable partner did not have the funds to buy out the ineffective partner. She was therefore stuck with the original agreement that gave her only half of the company, yet she was doing all the work (Hart, Roberts and Stevens, 2005).

The Zipcar example illustrates that there may be benefits of delaying the contracting until founders know more about each other. Vivek Khuller, the founder of Smartix, explains this further (Wasserman, 2009, p. 10):

"When you've worked with your co-founders before, it may make sense to divvy things up upfront because the trust is there and the information is there. But when the team doesn't know each other very well, where there are different domains, where you have little history of working together, it's best to delay it because things are still unknown and changing."

The palpable attraction of waiting before contracting is to avoid being obligated to an ineffective partner. However, the lack of contractual obligations can also lead to significant problems. One partner may be able to take advantage of the other, essentially stealing jointly-developed ideas and implementing them alone. This is what the Winklevoss twins claimed.

Our objective is to build a tractable model of the founding process that can explain how founder contracts affect ownership, incentives and firm performance. In our model there are two risk-neutral and wealth-constrained founders. They have a choice between contracting either at the beginning, when there is uncertainty about tasks and their respective skills, or at a later point in time, when the uncertainty is resolved. In the theory of the firm it is standard to assume that firm boundaries are determined ex-ante. In this paper we ask *when* it is optimal to make these decisions.

We assume that the entrepreneurial process involves the generation of new ideas that are appropriable. One of the main reasons for contracting early is to prevent opportunistic idea stealing. We assume that the establishment of a jointly-owned firm prevents founders from stealing each other's idea. However, ideas by themselves are worthless; they need to be commercialized. This requires that founders apply skilled effort to a set of tasks. We want a theory where founder teams are endogenous, so that the team composition is a reflection of underlying founder skills. For this we consider a value-creation process where there are two complementary tasks – production and marketing for example. Each task is essential, but it does not matter who performs it. Team formation is endogenous: depending on founder skills the two tasks can be performed either by a single founder, or by a team of two founders. Performing a task requires both effort and skill. We use a standard private effort model, where each founder can choose how much effort to provide, and how to allocate effort across the two tasks.

In order to capture the problem that founders have to start working together before knowing much about each other (as seen in the Zipcar and Smartix examples above), our model introduces ex-ante uncertainty about the founders' skills. Initially little is known about the details of the required tasks, so founders are unable to ascertain how good they are at performing them. For tractability we assume that skills are binary: a founder either can or cannot perform a specific task. Ex-ante the two founders have some probability of being good at their primary task (e.g., founder *A* at production and founder *B* at marketing), and some lower probability of being good at the other task (e.g., founder *A* at marketing and founder *B* at production). If a founder turns out to be good at both, we call him a *generalist*. If he is good at only one, we call him a *specialist*. If he is good at neither, we call him *ineffective* (relative to the required tasks).

As long as founders have ex-post symmetric skills, the timing of contracting turns out to be irrelevant. Differences arise when there are ex-post asymmetries. Consider upfront contracting. All is well if one partner turns out to be a generalist and the other a specialist. We call this a dream team, because both partners contribute valuable skills to the venture. The upfront contract prevents idea stealing and therefore preserves such a dream team. What if one partner is a generalist, and the other an ineffective partner? The generalist does all the work but the ineffective partner shares in the profits – just like in the Zipcar example. Depending on parameter

values, the ineffective partner may or may not voluntarily give up *some* ownership to enhance the generalist's incentives; but the ineffective partner would never give up *all* his ownership, which would be required for joint efficiency. Importantly, the wealth constraint prevents the generalist from buying out the ineffective partner. We call this a *dud team*.

With delayed contracting, the generalist will start a firm alone if the other partner is ineffective. Doing so is efficient in terms of maximizing joint utility. However, if one founder is a generalist and the other a specialist, then the generalist (but not the specialist!) can threaten to 'steal' the idea. Depending on the model parameters, the generalist either goes alone, or uses his threat to negotiate a larger ownership share. The outcome is inefficient in that the generalist's utility gains are always smaller than the specialist's losses.

The benefit of upfront contracting is the preservation of dream teams, but the cost is the preservation of dud teams. Delayed contracting has the opposite effect, allowing a generalist to leave an ineffective partner, but also allowing for idea stealing. The relative costs and benefits of upfront contracting depend on the uncertainty about the founders' task-specific skills. If founders are likely to have the required skills, upfront contracting is optimal as it helps to protect dream teams. However, if there is a significant probability that founders lack the required skills, then it is optimal to delay the contracting in order to avoid dud teams.

The trade-off between early and late contracting clearly depends on some contractual incompleteness. Specifically our model assumes that the realization of founders' task-specific skills is observable to the founders but not verifiable by third parties. Maskin and Tirole (1999) derive conditions for a general mechanism that effectively completes incomplete contracts. However, these conditions are not satisfied in our model, the main reason being that our binding wealth constraints limit the off-the-equilibrium-path penalties that are essential for the Maskin and Tirole mechanism to work.¹ The question remains whether there are other mechanisms that could address the contractual incompleteness. We focus on a mechanism that has both theoretical and empirical foundations. On the empirical side, Wasserman (2012) reports that founder teams sometimes agree to vesting agreements, where the allocation of founder shares is contingent on the achievement of pre-defined milestones. To theoretically model such contingent contracts, we build on the work of Aghion and Bolton (1992) where the true state of nature is not verifiable, but where there are imperfect signals that are correlated with the true state. This modeling approach allows us to capture the notion that milestones are imperfect measures of underlying founder skills. To see how signals can improve the contract efficiency, consider the case where one founder has a good signal and the other a bad signal. Suppose for simplicity that there is

¹The recent work of Aghion et al. (2012) also shows that mechanisms using subgame perfect implementation (including the Maskin and Tirole mechanism) are not robust to small perturbations in the common knowledge assumption.

‘full vesting’ where the founder with the bad signal loses all of his equity. If the signals are correct, they help to avoid the dud scenario. However, if they are incorrect, they may cause irreversible harm, most notably if they give a generalist the opportunity to get rid of a specialist. The better the signals, the more the initial contract makes use of vesting schedules, and the more founders prefer upfront contracting with contingent cash flow rights over delayed contracting.

Our model requires that founders are wealth-constrained. We contend that this is a realistic assumption for many start-ups. Moskowitz and Vissing-Jørgensen (2002), for example, report that on average 82% of the wealth of owner-managers is tied up within their companies. This average includes owners of long established firms, implying that start-up entrepreneurs hold even less or no wealth at all outside of their business. While typical founders may thus not have significant wealth outside of their company, the question remains whether they can use the assets within their companies to make transfer payments. We show that if a company has a secure asset with a guaranteed liquidation value, then it is possible to structure simple financial contracts that either partially or fully remedy the inefficiencies within teams. For example, a generalist may raise a secured loan against the firms assets and use the proceeds to buy out an ineffective partner. If the liquidation value is sufficiently large (small), then the generalist can buy back all (only some) of the equity, and thereby eliminate all (only some) of the inefficiencies in a dud team. The main issue for most start-ups is that at the beginning there have no or very few assets that would hold any liquidation value.

In the absence of founder personal wealth or inside liquidation value, we may ask if outside investors can relax the binding wealth constraint. The empirical work by Robb and Robinson (2013) documents how entrepreneurs raise outside financing. They show that most of outside funding comes in the form of secured debt that is backed by assets or personal guarantees. Typically this outside funding is used for investment, not for buying out ineffective partners. In our model we ask whether entrepreneurs (with no wealth and no collateralizable assets) can obtain unsecured outside financing for buying out partners? Interestingly we find that it is never optimal to raise outside funding by issuing a risky claim (either equity or risky debt) for the purpose of making transfer payments amongst founders. For example, if a generalist issues equity to fund a buyout of an ineffective partner, he has to dilute his ownership, which lowers his performance incentives. We show that the new inefficiencies from outside funding are at least as large as the old inefficiencies that the outside capital is meant to solve. More generally, investors in our model distinguish between funding productive investments versus buyouts. A willingness to invest in the firm does not imply a willingness to also finance a founder buyout.

What does our model say about Mark Zuckerberg and the Winklevoss twins? The interesting issue here is that while Mark Zuckerberg never formally agreed to form a company, he was still sued for not respecting an ‘implied partnership’. In fact, courts regularly admit arguments about

‘implied partnership’, thereby muddying the distinction between the presence and absence of founder contracts. Presumably the courts want to protect naïve founders who are unaware about the need for contracting, but this can have ramifications for informed rational founders. We derive a result that is counter-intuitive at first: The more courts try to protect (naïve) founders who do not consider contracts, the more they push (sophisticated) founders into writing formal contracts upfront. Formally, we show that recognition of implied partnerships makes delayed contracting less attractive. This is because the ‘dud’ problem becomes relevant not only for upfront contracting, but also for delayed contracting. The model shows that some founders, who initially would have appreciated the flexibility of delayed contracting, are forced to switch to upfront contracting.

2 Related Literature

The analysis of founder contracts is novel, but our study naturally builds on a variety of prior literatures. First, our analysis draws on the theory of the firm literature. Closest is the work by Aghion and Tirole (1994), which examines how the allocation of property rights affects incentives for innovation. They also focus on early-stage innovative activities, and also emphasize the inefficiencies caused by wealth constraints. However, their paper differs in several important respects. First, they consider an inherently asymmetric set-up with a wealth-constrained innovator and an unconstrained innovation user; we consider a partnership between ex-ante symmetric and wealth-constrained partners. Their results are driven by specific investments, much in the spirit of Grossman and Hart (1986). Our results do not require any specific investments at all. They also impose incompleteness of contracts, whereas we examine an endogenous choice between upfront versus delayed contracting.²

A closely related paper is by Aghion and Bolton (1992), who also make use of ex-post wealth constraints. Their model has a different set-up (namely the financing of a company by outside investors), and also relies on private benefits as a source of ex-post inefficiencies. In our model, the ex-post inefficiencies are derived from a moral hazard problem in teams. In fact, our model embeds the standard team incentive problem (Holmström, 1982) into a multi-task environment (Holmström and Milgrom, 1991; Itoh, 1991).

The trade-off between upfront and delayed contracting is naturally related to the literature on contract incompleteness. There is a lively debate in the literature about the foundations for incomplete contracts. Our contribution is not about these foundations themselves; we impose some incompleteness by assuming that skills are observable but not verifiable. However, our

²A similar set of comments also applies to the comparison of our paper with Hart and Moore (1994).

analysis does provide new insights into the trade-off between having an incomplete contract versus having no contract at all.

Our model is related to the literature on idea appropriability, dating back to the seminal work of Arrow (1962). Anton and Yao (1994, 1995) show how inventors can limit the extent of users appropriating their inventions, using the threat of leaking information to the users' competitors. Gans and Stern (2000) show how the threat of appropriation can delay innovators' decisions to engage in cooperative development agreements. Gans, Hsu, and Stern (2002) provide related empirical evidence. Ueda (2004) argues that venture capitalists are in a better position to appropriate ideas than banks. Hellmann and Perotti (2011) compare how markets and firms differ in terms of the circulation of appropriable idea. A common element across all these papers is the question of how different parties can forge partnerships in an environment where ideas can easily be stolen. The typical assumption is that the other party can always steal the idea, but may not do so in equilibrium. In our model we derive the ability to steal ideas from a more fundamental skill constellation. As a consequence we endogenously derive under what circumstances stealing does or does not occur in equilibrium.

There is a literature on the economics of partnerships and teams. Much of this literature assumes a constant team size, and therefore ignores team formation issues. Interesting exceptions are Franco, Mitchell, and Vereshchagina (2011), who focus on how team incentive problems may affect how individuals are matched into teams; and Demougin and Fabel (2007), who examine optimal contracts for a match-maker that brings together a team composed of an inventor and a manager. Furthermore, Hellmann and Thiele (2013) consider a related model of vertical integration where the initial partners may want to switch to alternative partners ex-post.

The question of what skills are required for starting a new firm features prominently in the literature on the decision to become an entrepreneur. Lazear (2005) provides a theory and empirical evidence for the importance of generalist skills for starting new ventures - see also Åstebro, Chen, and Thompson (2011). One limitation of this literature is that it assumes that all entrepreneurs are solo founders, and therefore fails to recognize the trade-off between solo founders versus founding teams.

There is a relatively small literature on founding teams. In a broad cross-section of US start-ups, Ruef, Aldrich, and Carter (2003) find that 52% have founder teams. In a sample of high-technology start-ups, Wasserman (2012) finds that 84% have founder teams. Wuchty, Jones, and Uzzi (2007) argue that the increased specialization of scientists explains the dramatic rise of coauthor teams in scientific research. Åstebro and Serrano (2011) find that partnerships significantly outperform solo founders, even after controlling for selection effects. Finally, Hellmann and Wasserman (2012) provide evidence that equal splitting can be a sign of conflict avoidance, especially in asymmetric teams.

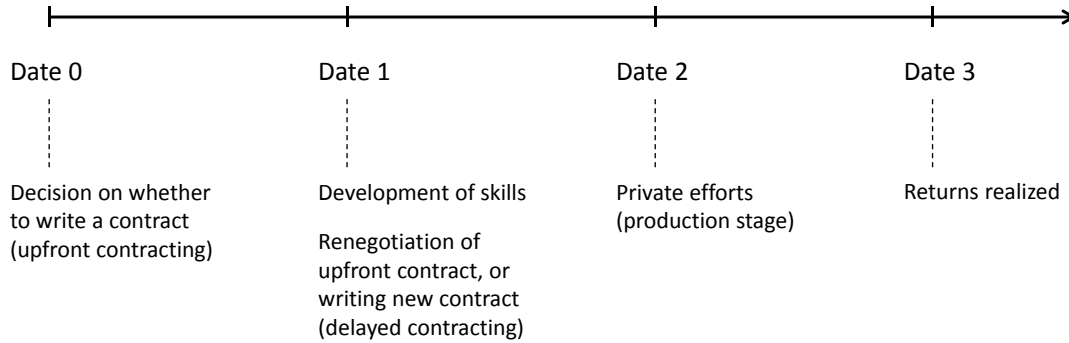


Figure 1: Timeline

The remainder of this paper is structured as follows: Section 3 introduces our model of the founder team formation. Section 4 examines the optimal timing and structure of founder contracts, and discusses their implications for the team composition, ownership structure, and performance of the venture. In Section 5 we allow for verifiable but imperfect signals about the founders’ skills, and derive the optimal contingent contract. In Section 6 we examine the role of outside investors. Section 7 considers several extensions to our model. Section 8 discusses some empirical predictions. Section 9 summarizes our key insights and concludes. All proofs are in the Appendix.

3 The Base Model

There are two economic actors A and B , called *founders*. Both founders are risk-neutral, wealth-constrained, and *ex-ante* symmetric (‘equal to start with’). Over time they may discover differences with respect to their individual skills (‘unequal later on’), which we elaborate on later. We assume zero discounting. In the base model we only focus on the founders and abstract from potential outside investors.³

The founders A and B have the opportunity to start a new venture. The founding process involves four main stages; see Figure 1. At date 0, the founders decide whether to write a contract among themselves, referred to as *upfront contracting*. The founders then explore their business opportunity at date 1, and learn whether they possess the skills required to pursue the opportunity. We call this the *development stage*. The skills can be observed by the two founders, but not by third parties. The founders then have to decide whether they want to pursue the venture jointly as a team, or they want to split in order to exploit the business idea individually. If the founders have already written a contract at date 0 (upfront contracting), they

³We analyze the role of outside investors in Section 6.

can renegotiate this contract. Otherwise, they can write a new contract, referred to as *delayed contracting*. At date 2, founders work for the venture by exerting private effort. We refer to this stage as the *production stage*. Finally, at date 3, the returns to the venture are realized and divided according to the relevant contract.

Central to our model is that a contract defines firm boundaries that require founders to pursue their business opportunity as a joint project, eliminating the option of pursuing it alone without the consent of the other founders. Thus, a contract allocates project-related intellectual property to a jointly-held company, where it is protected through trade secrets and non-competes. In the base model we therefore assume that with a founder contract, it is never possible to steal ideas from a cofounder.⁴ In Section 7.1 we relax this assumption and consider the possibility of founders suing each other, even if no formal contract was in place.⁵

In our model, entrepreneurial value creation starts with the creation (or refinement) of *ideas*. Specifically, the two founders jointly develop their business ideas at date 1. In the absence of an upfront contract, these ideas are appropriable by either founder. However, an upfront contract can prevent founders from stealing their jointly developed ideas.

The allocation of cash flow rights that results from an upfront or delayed founder contract matters because it affects the founders' incentives to create value. After the idea creation stage comes the stage where the founders implement their ideas, essentially launching a new commercial venture. This requires that founders apply their *skills* and *effort* to a set of *tasks*. We assume that the success of the new venture requires two critical *tasks*, that we label x and y . To perform these tasks effectively, founders need to possess the related skills, which we refer to as x -skills and y -skills. We do not think of these skills as absolute skills, but as skills pertaining to the ability to perform a specific task. For example, the tasks may be to develop and sell a new product. However, to be considered skillful at product development or sales, it would not be enough that a founder is an engineer or has prior sales experience; they would have to be able to develop or sell specifically the firm's new product. At date 0, there is uncertainty about the skills of each founder. However, at date 1 (development stage), each founder learns his own skills and those of his cofounder. A founder either has the skill to perform task $j = x, y$, or lacks this skill entirely. We denote the skill of founder $f = A, B$ for task j by $\phi_j^f \in \{0, 1\}$. The task-specific skills of a founder cannot be observed by third parties. In our example, this means

⁴In practice there may be a grey area where it is difficult to tell whether certain founder ideas or activities belong to the firm or to the individual. However, the key insight is that there is a big difference between having established a firm or not. If two individuals co-founded a company, and one of them subsequently tries to build another venture that is based on similar ideas, the other will have a strong legal case. However, without a founder contract, the legal case would be considerably weaker.

⁵Note that a contract among founders is typically written in conjunction with the incorporation of a company or partnership (Bagley and Dauchy, 2007). Therefore, we can also think of our model as a theory of the timing of incorporation.

Scope of Skills	Prob. Founder A	Prob. Founder B
Generalist	$\rho_1\rho_2$	$\rho_1\rho_2$
Specialist – task x	$\rho_1\bar{\rho}_2$	$\bar{\rho}_1\rho_2$
Specialist – task y	$\bar{\rho}_1\rho_2$	$\rho_1\bar{\rho}_2$
Ineffective	$\bar{\rho}_1\bar{\rho}_2$	$\bar{\rho}_1\bar{\rho}_2$

Table 1: Scope of Founder Skills

that at date 0 there is uncertainty whether the founders are good at developing or selling the new product. At date 1 the two founders learn their true skills, but outsiders still cannot verify these skills.

Most of the prior literature assumes that ideas can be stolen either always or never. In our model we derive the possibility of idea stealing from fundamentals, noting that only founders with generalists skills are in a position to implement an idea on their own. In order to model such differences between generalists and specialists, we introduce some uncertainty about the scope of a founder's skills. In our model each founder can not only be skillful at his main task, he can also be good at the other task. The engineer, for example, may turn out to be good not only at developing the specific product, but also at selling it. In the model, the two founders are symmetric ex-ante, but not identical. Let ρ_1 denote the probability that founder A develops the skill for task x , and ρ_2 the probability that he develops the skill for task y , where we define $\bar{\rho}_j \equiv (1 - \rho_j)$, $j = 1, 2$. We assume that $\rho_1 > \rho_2$, which captures the notion that founder A has a natural talent for task x (i.e., the engineer is more likely to be good at product development than sales). Accordingly, with probability $\rho_1\rho_2$, founder A will develop the relevant skills to perform both tasks x and y (i.e., $\phi_x^A = \phi_y^A = 1$). Founder A is then a *generalist* (indexed by g); see Table 1. Founder A could then pursue the business opportunity without a partner. With probability $\rho_1\bar{\rho}_2$, founder A will only develop the skill for task x (i.e., $\phi_x^A = 1$ and $\phi_y^A = 0$), and with probability $\bar{\rho}_1\rho_2$, only the skill for task y (i.e., $\phi_x^A = 0$ and $\phi_y^A = 1$). Founder A is then a *specialist* (indexed by s), and relies on a partner with complimentary skills. With probability $\bar{\rho}_1\bar{\rho}_2$, founder A will not develop any skills (i.e., $\phi_x^A = \phi_y^A = 0$). We call a founder without any skills *ineffective* (indexed by i) as he is unable to contribute to the new venture. The probabilities for developing the relevant skills are symmetric for founder B , who has a natural talent for task y . We denote the expected utility of a type j -founder by $U_{j,k}$ when his partner is of type k , with $j, k \in \{g, s, i\}$.

The productive inputs into the new venture are a combination of skills and *effort*. Let e_j^f denote the private effort of founder $f = A, B$ for task $j = x, y$. The total team effort for task j , denoted e_j , is

$$e_j = \phi_j^A e_j^A + \phi_j^B e_j^B, \quad (1)$$

where $\phi_j^f \in \{0, 1\}$. Implementing effort can only be worthwhile if a founder has the required skill. If both founders possess the skill, it is irrelevant who implements effort; all that matters is that skilled effort is applied. A founder's disutility of effort, denoted $c(e_x^f + e_y^f)$, is strictly convex in total effort $e_x^f + e_y^f$, with $c(0) = c'(0) = 0$ and $\lim_{e_x^f + e_y^f \rightarrow \infty} c(\cdot) = \infty$. This implies that only the total effort matters, not the specific allocation across the two tasks x and y .

To model the process of jointly exploiting the business opportunity, we assume that the new venture is either a success, generating a cash flow $\pi > 0$, or a failure, generating no cash flow at all.⁶ The venture will succeed with probability $\mu(e_x e_y)$, which is increasing and concave in its argument $e_x e_y$, with $\lim_{e_x e_y \rightarrow \infty} \mu(e_x e_y) < 1$. Thus, the venture cannot succeed unless both tasks x and y are performed, which in turn requires at least one founder to possess the corresponding skills.⁷

The payoff of the new venture – which is either $\pi > 0$ or zero – is verifiable, which in turn allows the founders to specify a division of surplus in a contract. Due to the binary structure of the venture's return, any contract can be expressed as an equity contract, which allocates cash flow rights to the two founders.⁸ We denote $\alpha_{j,k}$ as the equity allocated to a type j -founder when his partner is of type k , where $j, k \in \{g, s, i\}$. Accordingly, $\alpha_{k,j} = 1 - \alpha_{j,k}$. We will suppress the subscript of $\alpha_{j,k}$ for parsimony whenever we do not refer to a specific team constellation. To derive the equilibrium allocation of equity, we apply the symmetric Nash bargaining solution, assuming zero outside options for both founders. In addition to specifying the allocation of equity, a contract also assigns the intellectual property rights of the business idea to the venture. Thus, if one founder wants to leave the firm, he cannot implement the idea on his own.

Our base model in Section 4 assumes that skills are not verifiable by third parties, and that founders only use simple non-contingent contracts. Clearly, this assumes that contracts are incomplete. If skills were verifiable, the optimal contract would directly condition on the realization of founder skills, and our central trade-off would simply disappear. Empirically it is implausible to assume that a founder's task-specific skills are directly observable. However, there may be other verifiable events (such as the achievement of a milestone) that are correlated with the realization of founder skills. Our base model deliberately focuses on the case where founder contracts are not conditioned on anything. However, in Section 5.2 we consider a more complex environment where contracts can be made contingent on verifiable signals that are imperfectly correlated with the underlying skills. We then show how the optimal contract

⁶Note that π represents the total value obtained by the founders. This may be less than the total value of the company, namely if the company adds investors or other stakeholders at later stages of the venture.

⁷In our model the two skills are complements, but the task efforts, e_x and e_y , are substitutes.

⁸Note also that the binary payoff structure implies that budget breaking à la Holmström (1982) is not feasible in our model.

continuously changes from one extreme with no signals (incomplete contracts) to the other extreme with perfect signals (complete contracts).

To preserve analytical tractability, our model requires several simplifying assumptions. First, we limit our analysis to two required tasks, and teams of two partners. Allowing for more tasks or larger teams would create intractable state spaces.⁹ Second, skills are binary (i.e., $\phi_j^f \in \{0, 1\}$). This implies that a generalist is equally good at a given task as a specialist. On the one hand, one may argue that generalists are "jack of all trades, master at none", so that they are less efficient than specialists. On the other hand, one may think of generalists as "superstars" who enjoy absolute advantages at all tasks. It is easy to show that the basic trade-off between upfront and delayed contracting remains intact even if generalists and specialists have different skill levels. Unfortunately, however, this generalized model does not generate tractable comparative statics with respect to the skill differentials. Third, we assume that cash flows are binary, taking on either the value π or 0. This assumption is standard in financial contracting models, as it helps to avoid the complexities of analyzing general non-linear compensation structures. Note, however, that in Section 6.1 we consider a simple model extension that examines a non-linear compensation structure, where founders can get secured debt in addition to risky equity. Finally, we assume that at date 1 it is impossible to hire additional partners that have a missing skill. Allowing for late partner additions would considerably complicate the formal analysis. We conjecture that the main insights of our model continue to hold up as long as there are some frictions in the process of finding late partners, that give the generalist an advantage over a specialist in terms of stealing the idea. Frictions may include search costs, uncertainty about the quality of skills of late partners, not to mention the possibility that late partners themselves could steal the idea.¹⁰

4 The Optimal Timing for Contracting

4.1 Upfront Contracting

Suppose the founders write a contract at date 0 (upfront contracting). The only contractible outcome is whether the new venture generates a return π . The contracting space therefore only concerns the division of surplus as reflected by the equity stake α . Because the skills of the founders have not yet been developed, and their natural talents are symmetric, the Nash bargaining solution suggests that they split the equity equally when writing the contract upfront.

⁹Currently our model has 16 states. With three tasks and three founders, this would already increase to 512 states.

¹⁰Along those lines, Hellmann and Perotti (2011) provide a model where ideas can be stolen multiple times.

		FOUNDER B			
		Generalist	y-Specialist	x-Specialist	Ineffective
FOUNDER A					
Generalist		<i>Dream Team</i>	<i>Dream Team</i>	<i>Dream Team</i>	<i>Dud Team</i>
x-Specialist		<i>Dream Team</i>	<i>Dream Team</i>	<i>Give up</i>	<i>Give up</i>
y-Specialist		<i>Dream Team</i>	<i>Give up</i>	<i>Dream Team</i>	<i>Give up</i>
Ineffective		<i>Dud Team</i>	<i>Give up</i>	<i>Give up</i>	<i>Give up</i>

Table 2: Constellations under Upfront Contracting

Thus, $\alpha^* = 1/2$.¹¹ Given this, and assuming no renegotiation for now, the founders exert private effort at the production stage which determines the venture's prospect of success. Given the individual skills ϕ_x^f and ϕ_y^f , $f = A, B$, both founders simultaneously choose their effort levels e_x^f and e_y^f to maximize their expected utilities:

$$\max_{e_x^f, e_y^f} U^f = \frac{1}{2} \pi \mu(e_x e_y) - c(e_x^f + e_y^f), \quad f = A, B \quad (2)$$

where e_j is the total team effort for task $j = x, y$ as defined by (1). If founder f has the required skill to perform task j ($\phi_j^f = 1$), his optimal effort e_j^{f*} is characterized by the first-order condition

$$\frac{1}{2} \pi \mu'(e_x e_y) (\phi_j^A e_j^A + \phi_j^B e_j^B) = c'(e_x^f + e_y^f) \quad j \in \{x, y\}. \quad (3)$$

If founder f does not possess the necessary skill to perform task j , he chooses $e_j^{f*} = 0$. Clearly, the effort choice of a founder does not only depend on his own skills, but also on the skills – and hence the effort choice – of his partner in the Nash equilibrium. Table 2 summarizes all possible skill formations within the founding team that we discuss below.

If the founding team lacks at least one of the two required skills, then they have to abandon the idea of developing the new venture. The expected utility for each founder is then $U^f = 0$, $f = A, B$.

If both founders are specialists, and their respective skills are complementary to each other (i.e., one founder has x -skills while the other has y -skills), team production is the only possible

¹¹In Section 5.2 we formally show that randomizing the allocation of equity is not optimal (see Proposition 2 (i)).

constellation. The optimal effort choice e_j^{f*} of founder f , who has the required skill for task $j \in \{x, y\}$, is then characterized by (3) with $\phi_j^f = 1$ and $\phi_l^f = 0$, $l \in \{x, y\}$, $l \neq j$. Thus, each founder focuses on only one of the two tasks, where the respective effort levels are symmetric (because $\alpha^* = 1/2$). We call this specific team formation a *dream team* as it constitutes the most efficient outcome, and denote the corresponding expected utility for each founder U^{dream} . We obtain the same outcome in case one partner is a generalist and the other a specialist.

If both partners turn out to be generalists, they can either stay together and work as a team (with a dream team as the equilibrium outcome), or agree to split up in order to pursue the business idea individually. For parsimony we focus on the case where two generalists always prefer to stay together.¹² As will become clear, however, the optimal choice between upfront and delayed contracting does not depend on whether two generalists stay together. The efforts of the two generalists are then symmetric (because $\alpha^* = 1/2$).

The last possible constellation is where one partner is a generalist and the other is ineffective. The generalist then needs to provide all the productive efforts in this partnership to generate a positive return from the business idea. His optimal effort level e_j^{f*} for task $j = x, y$ is characterized by (3) with $\phi_j^f = 1$ and $\phi_k^f = 0$, $k \in \{A, B\}$, $k \neq f$. We call this team formation a *dud team* as the generalist is forced to share equity with an unproductive partner. We define U_g^{dud} as the expected utility of a generalist in a dud team, and U_i^{dud} as the expected utility of the ineffective partner.

We also consider whether the partners can benefit from renegotiating the initial equity allocation $\alpha^* = 1/2$ after learning their own skills and that of their cofounders. Changing the equity allocation cannot lead to a Pareto improvement whenever both partners have either symmetric skills. The contract with $\alpha^* = 1/2$ is then renegotiation-proof. It is easy to show that the same applies to partnerships consisting of a generalist and a specialist.¹³ The more interesting case occurs when one partner is a generalist and the other ineffective (dud team). Although the generalist would prefer to pursue the business idea alone, he cannot buy out the ineffective partner because of the binding wealth constraint, nor can he exclude him because of the contract written at date 0. However, the ineffective partner could be better off giving up some of his equity in order to improve effort incentives for the generalist who is the only productive party. We denote $\hat{\alpha}_{i.g}$ as the equity share which maximizes the expected utility of an ineffective founder when his partner is a generalist. Thus, the contract with $\alpha^* = 1/2$ is renegotiation-proof whenever

¹²Technically we assume that half of the monopoly profit π is still greater than the duopoly profit π^D . This assumption reduces the number of possible outcomes and simplifies our exposition.

¹³If the specialist gave up some of his equity, he would exert less effort for his task. Because the disutility $c(e^f)$ is convex in total effort e^f , the generalist will not raise his own effort to the extent to completely compensate for his partner's lower input. As a result, any equity allocation which deviates from $\alpha^* = 1/2$ cannot lead to a Pareto improvement.

$\hat{\alpha}_{i.g} \geq 1/2$ (as the generalist's preferred equity share $\hat{\alpha}_{g.i} = 1$). To keep our base model as concise as possible, we focus in our base model on the case where $\hat{\alpha}_{i.g} \geq 1/2$. However, we show in the Appendix that the basic trade-off between upfront and delayed contracting remains intact when $\hat{\alpha}_{i.g} > 1/2$.

Using the expected utility levels for the various team formations (see Table 2), we can characterize the overall expected utility, denoted EU_u^f , of founder $f = A, B$ under upfront contracting:

$$EU_u^f = [(\rho_1\rho_2)^2 + (2\rho_1\rho_2)(\rho_1\bar{\rho}_2 + \rho_2\bar{\rho}_1) + (\rho_1\bar{\rho}_2)^2 + (\bar{\rho}_1\rho_2)^2] U^{dream} + \rho_1\rho_2\bar{\rho}_1\bar{\rho}_2 U_J^{dud},$$

where $U_J^{dud} = U_g^{dud} + U_i^{dud}$ is the joint utility of a dud team.

Note that for a given type combination (e.g., a generalist and an ineffective founder), each founder could be either type with equal probability. Hence, the expected utility functions are inherently symmetric. This symmetry also implies that the socially efficient allocation is the allocation that maximizes the symmetric expected utility of each individual founder.

The drawback of upfront contracting is that it can result in a dud team: A generalist may be forced to share equity with an unproductive partner. Delaying the formal contracting until after the development of critical skills resolves this inefficiency as it allows founders to exclude unproductive partners. However, as we will show in the next section, delayed contracting comes with its own problems.

4.2 Delayed Contracting

We now consider the benefits and costs of delaying the formal contracting until after the founders' respective skills have been developed. Delayed contracting therefore allows the founders to account for observed skills when writing a formal contract. The possible constellations under delayed contracting are summarized by Table 3.

The key difference to upfront contracting is that a generalist can now pursue the business idea alone. Delaying the formal contracting therefore prevents a dud team whenever the partner of a generalist turns out to be ineffective. While eliminating the risk of sharing equity with an unproductive partner is an argument for delayed contracting, it introduces a new problem whenever one partner is a generalist and the other a specialist.

The following two scenarios are conceivable. First, in the absence of a founder contract, the generalist may leave a specialist, which is inefficient from the perspective of joint value

		FOUNDER B			
		Generalist	y-Specialist	x-Specialist	Ineffective
FOUNDER A	Generalist	<i>Dream Team</i>	<i>Idea stealing</i>	<i>Idea stealing</i>	<i>A-Solo</i>
	x-Specialist	<i>Idea stealing</i>	<i>Dream Team</i>	<i>Give up</i>	<i>Give up</i>
	y-Specialist	<i>Idea stealing</i>	<i>Give up</i>	<i>Dream Team</i>	<i>Give up</i>
	Ineffective	<i>B-Solo</i>	<i>Give up</i>	<i>Give up</i>	<i>Give up</i>

Table 3: Constellations under Delayed Contracting

maximization.¹⁴ We can think of this scenario as a classic case of one founder stealing the project or business idea from the other. In the second scenario, the generalist could simply threaten the specialist to leave the partnership and start his own venture (in which case the specialist's payoff is zero) in order to obtain more equity.¹⁵

We now characterize the founders' expected utility levels for those constellations that are different to those under upfront contracting. Suppose one founder is a generalist and the other is ineffective. The generalist is then better off pursuing the business opportunity alone; his expected utility is then denoted U^{solo} . The expected utility of the ineffective founder is zero.

Now consider the constellation where one founder is a generalist and the other a specialist. The generalist can then either steal the idea and start a solo venture, or offer the specialist to stay in exchange for more equity. Let $\hat{\alpha}_{g,s}$ denote the equity share which maximizes the generalist's expected utility when his partner is a specialist. The generalist prefers to start a solo venture if $\hat{\alpha}_{g,s} = 1$. Otherwise, team production still prevails, but the equilibrium equity allocation will be asymmetric. For our base model we consider the case where $\hat{\alpha}_{g,s} = 1$, so that the generalist will always steal the idea to start his own venture. The generalist's expected utility is then U^{solo} , while the specialist gets a zero utility. We show in the Appendix that the main trade-off between upfront and delayed contracting remains intact when $\hat{\alpha}_{g,s} < 1$.

Using the expected utility levels for the various constellations as summarized by Table 3, we can characterize the overall expected utility, denoted EU_d^f , of founder $f = A, B$ under delayed contracting:

$$EU_d^f = [\rho_1 \rho_2 \bar{\rho}_1 \bar{\rho}_2 + \rho_1^2 \rho_2 \bar{\rho}_2 + \rho_1 \rho_2^2 \bar{\rho}_1] U^{solo} + [(\rho_1 \rho_2)^2 + \rho_1^2 \bar{\rho}_2^2 + \rho_2^2 \bar{\rho}_1^2] U^{dream}.$$

¹⁴This is because the expected payoff from the venture is concave in effort, while a founder's disutility is convex in total effort (i.e., keeping the total effort constant, the specific effort allocation across the two tasks does not affect a founder's disutility of effort).

¹⁵Note that side-transfers are not feasible due to the founders' limited wealth. Thus, the socially efficient outcome cannot be achieved as the generalist is unable to compensate the specialist for his loss of utility.

4.3 Upfront vs. Delayed Contracting

We can now contrast the main implications of upfront and delayed contracting on (i) the potential team compositions, (ii) the ownership structure; and (iii), the performance of the venture. This comparison will be useful for discussing the optimal timing for the founders to sign a formal contract, which will be the main focus of this section.

The most efficient outcome is when two skilled partners stay together as a team, and split the equity of the venture in half. This maximizes total team effort, and hence the expected performance of the venture. This is the equilibrium outcome whenever the two founders are both generalists, or both specialists. The issues arise in asymmetric teams where one founder is a generalist. In a generalist/specialist team, only the protection of an upfront contract guarantees the most efficient outcome. Delayed contracting, on the other hand, results in the generalist going alone (holding all of the equity). While such opportunistic behavior is optimal from a selfish perspective, it results in a lower expected performance of the venture. We contrast this with the case where one founder is a generalist and the other ineffective (dud team). Without a contract, the generalist would always leave the ineffective partner, which is efficient from a selfish as well as social perspective. The expected performance of the solo venture is below that of a dream team, but still above the performance when sharing equity with an unproductive partner.

The optimal contracting decision depends on the trade-off between preserving dream teams with upfront contracting, versus weeding out unproductive partners with delayed contracting. The next proposition provides a condition for founders to prefer upfront versus delaying contracting. For this we define

$$\Theta = \frac{U^{solo} - U_J^{dud}}{2U^{dream} - U^{solo}}$$

Proposition 1

(i) Founders prefer delayed contracting if (ρ_1, ρ_2) are such that

$$f(\rho_1, \rho_2) \equiv \frac{\rho_1}{1 - \rho_1} + \frac{\rho_2}{1 - \rho_2} \leq \Theta$$

Otherwise they prefer upfront contracting. Delayed contracting is optimal for a larger set of (ρ_1, ρ_2) when Θ increases.

(ii) Define $\hat{\rho}_1(\rho_2)$ such that $f(\hat{\rho}_1, \rho_2) = \Theta$. Then $\hat{\rho}_1(\rho_2)$ is decreasing in ρ_2 . Moreover, the maximum value of ρ_1 for which delayed contracting can be optimal is $\frac{\Theta}{1+\Theta}$, and for ρ_2 the maximum value is $\frac{\Theta}{2+\Theta}$.

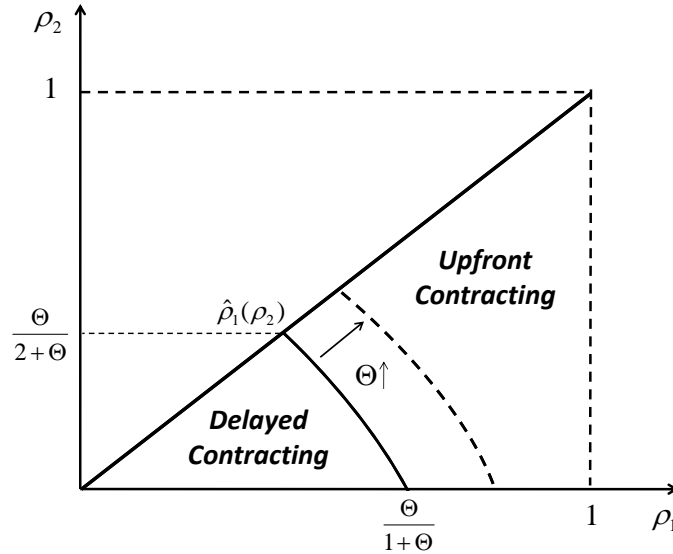


Figure 2: Optimal Timing for Simple Contracts

Figure 2 illustrates the insights from Proposition 1. Notice that only the equilibria below the 45-degree line are relevant as we imposed the requirement $\rho_1 > \rho_2$. Consider first the corners of the triangle which represents the set of all potential equilibria. At $(0, 0)$, neither partner possesses the critical skills, so the founders are forced to give up on the venture. At $(1, 0)$, each founder has his natural talent skill (i.e., founder A has the x -skill, and founder B has the y -skill); team production is thus the only possible constellation. Finally, at $(1, 1)$, both founders are generalists. For all of these extreme cases, it does not matter whether founders choose upfront or delayed contracting, because neither a dud team nor idea stealing would arise in equilibrium. For the remainder of the discussion, we focus on the more interesting cases where $\rho_1, \rho_2 \in (0, 1)$.

We can infer from Figure 2 (and more formally from Proposition 1) that the founders prefer to write a contract upfront whenever they are sufficiently likely to possess the critical skills for the venture. The intuition is as follows: For higher values of (ρ_1, ρ_2) , both partners are concerned about the fact that a specialist is vulnerable to potential idea stealing whenever his partner turns out to be a generalist. To prevent this from happening, the founders prefer to write a formal contract upfront at date 0. On the other hand, if both founders are unlikely to develop any skills, it is optimal for them to delay the formal contracting. Each founder knows that he and his partner will likely be ineffective, and will thus likely be forced to abandon the venture. However, if one founder actually turns out to be a generalist, he faces a high risk of sharing equity with an unproductive partner when contracting upfront. To avoid this

inefficiency, founders prefer to wait with the formal contracting until after they have observed their own skills and that of their partners.

The optimal timing for writing a formal founder contract is determined by the trade-off between the dud team problem (upfront contracting) and the idea stealing problem (delayed contracting). This trade-off is determined by the parameter Θ as defined in Proposition 1, where the numerator reflects the inefficiency costs of the dud team, and the denominator the inefficiency costs of idea stealing. Clearly, Θ increases when the dud team problem becomes relatively more severe, which results in a higher threshold $\hat{\rho}_1(\rho_2)$; see Proposition 1. Founders then delay the formal contracting more often. In contrast, founders contract more often upfront when the idea stealing problem becomes relatively more severe.

5 Contingent Cash Flow Rights

So far we have considered a simple contracting environment where verifiable information about the founders' respective skills are not available. We now extend our model by introducing verifiable but imperfect signals which are correlated with the actual quality of a founder. We think of these signals as objective performance measures, e.g., whether founders hit milestones such as developing a prototype or making a first sale by a certain date. However, these milestones are only imperfect signals of the true underlying skills of a founder. For example, a bad salesman may be lucky to make his first sale, or a good salesman may be unlucky to miss his first sale. Making contracts contingent on these signals, even if they are imperfect, will enable founders to readjust the equity allocation ex-post, in order to better reflect their actual contributions to the venture. We are particularly interested in (i) how the optimal allocation of cash flow rights depends on these signals; and (ii), how the availability and precision of signals affects the founders choice between upfront vs. delayed contracting.

One approach of modeling contingent cash flow rights is to use a mechanism design approach where players can play subgame perfect implementation games along the lines of Maskin and Tirole (1999). We note that these revelation mechanisms rely on the existence of sufficiently large punishments – see Aghion and Holden (2011) for a discussion. Such punishment are not possible in our model because of risk-neutrality and the founders' wealth constraints. Moreover, implementation games are typically not robust to small perturbations of the common knowledge assumption, as shown by Aghion et al. (2012).

We use an alternative approach of modeling contingent contracts that is akin to Aghion and Bolton (1992). Specifically we assume that there exist some verifiable signals that are imperfectly correlated with the underlying states of nature. The parties can make the contract

contingent on these verifiable signals. However, contingent cash flow rights remain imperfect because the signals do not perfectly match the underlying state. These contingent cash flow rights closely resemble the contractual structures used by founder teams that make use of founder vesting schedules. Wasserman (2012, chapter 6) describes how founders use milestones and vesting schedules to dynamically adjust founder equity stakes over time. In a related vein, Kaplan and Strömberg (2004) also note that contingent allocations of cash flow rights are common in venture capital contracts.

5.1 Signals, Milestones and Vesting

We begin by defining the structure of signals and contingent cash flow rights. Suppose that after the development stage, there exists an independent and verifiable signal $\Gamma_f \in \{\Gamma_f^+, \Gamma_f^-\}$ for founder $f = A, B$ that is an imperfect indicator of the presence or absence of skills (which are still only observable by the founders themselves). If founder f has at least one task-specific skill ($\phi_x^f + \phi_y^f > 0$), then with probability $\eta \geq 1/2$ the signal is positive ($\Gamma_f = \Gamma_f^+$); and with probability $1 - \eta$, the signal is negative ($\Gamma_f = \Gamma_f^-$). Likewise, if founder f is ineffective ($\phi_x^f + \phi_y^f = 0$), then with probability η the signal is negative ($\Gamma_f = \Gamma_f^-$); and with probability $1 - \eta$, the signal is positive ($\Gamma_f = \Gamma_f^+$). Thus, the signals may expose unproductive partners, but they do not reveal the specific skills of founders.¹⁶ For $\eta = 1/2$, the signals are uninformative; and for $\eta = 1$, the signals are always correct. We denote the set of the signals for both founders $\Gamma = \{\Gamma_A, \Gamma_B\}$. A natural interpretation of the signals is that they represent the achievement of milestones. If $\Gamma_f = \Gamma_f^+$, then founder $f = A, B$ has reached his individual milestone (e.g. developed a working prototype, acquired first customer, etc.). Our model recognizes that achieving such a milestone is only an imperfect indicator of the actual skills of a founder.

The signals can be used to improve the efficiency of upfront contracting. For instance, if only one founder, say founder A , obtains a positive signal ($\Gamma_A = \Gamma_A^+$), then the contract may specify a new allocation of equity, that we denote by $\alpha^*(\Gamma_A^+, \Gamma_B^-) \geq 1/2$. Any asymmetric equity allocation can then be interpreted as *performance-based vesting*. Initially, when writing a contract at date 0, each founder gets the same amount of shares. However, some (or all) shares are subject to vesting: They are withheld until founders have reached their respective milestones (i.e., $\Gamma_f = \Gamma_f^+, f \in \{A, B\}$).¹⁷

¹⁶We focus on one very intuitive signal structure, but clearly there could be other signal structures too. For instance, a signal could identify a generalist, but not distinguish between specialists and unproductive partners. Or a signal could identify the presence of only one of the two skills. While a model with such alternative signal structures would generate different threshold values, the basic principle of using the signal to write a contingent contract remains valid for any informative signal.

¹⁷To see this more formally, let λ_f^u be the number of shares given upfront to founder f , and let λ_f^m be the number of shares given upon achievement of the milestone. With symmetric founders we have $\lambda_A^j = \lambda_B^j \equiv \lambda^j, j = u, m$.

Finally we denote the updated skill probabilities for a founder by ρ_1^+ and ρ_2^+ in case his signal is positive ($\Gamma_f = \Gamma_f^+$), and by ρ_1^- and ρ_2^- in case his signal is negative ($\Gamma_f = \Gamma_f^-$). These updated skill probabilities are derived in the Appendix (see Proof of Proposition 2).

5.2 Optimal Contingent Cash Flow Rights

We first identify the structure of the optimal contingent contract, assuming that the founders choose to contract upfront. This is an important stepping stone for our analysis in Section 5.3, which examines the optimal contracting choice of the founders, including the decision to contract upfront or later.

We start by deriving the optimal contingent contract for the more interesting case where one founder has a positive signal while his partner has a negative signal ($\Gamma = \{\Gamma^+, \Gamma^-\}$). As explained earlier, we can interpret any asymmetric equity allocation $\alpha^*(\Gamma^+, \Gamma^-) \neq 1/2$ as performance-based vesting, where only the founder with the positive signal receives his vested shares. However, depending on the founders' respective skills, the stipulated equity allocation $\alpha^*(\Gamma^+, \Gamma^-)$ may not be Pareto-efficient. We therefore allow for renegotiation, using Nash bargaining.

The key advantage of including a vesting clause in the founder agreement is the mitigation of the dud team problem: If the signal about an ineffective partner's skills is indeed negative ($\Gamma_f = \Gamma_f^-$), then the generalist obtains more equity, which is efficient from a joint perspective. However, including a vesting clause in the contract can also impair the efficiency of dream teams. For instance, performance-based vesting could result in a generalist obtaining the majority of equity, which is individually optimal but inefficient from a joint perspective. The trade-off between these two effects depends to a large extent on the quality of signals, i.e., the ability of signals to distinguish dream teams from dud teams.

The next proposition specifies the optimal contingent contract for asymmetric signals.

Proposition 2 *Suppose the signals are asymmetric. Then, there exists a threshold signal precision $\bar{\eta} < 1$ such that the optimal vesting schedule $\alpha^*(\eta)$ at date 0 is as follows:*

(i) If $\eta = 1/2$, no shares are vested: $\alpha^(1/2) = 1/2$.*

If both founders achieved their milestones, they each obtain the equity share $\alpha = (\lambda^u + \lambda^m)/(2\lambda^u + 2\lambda^m) = 1/2$; if they both failed to achieve their milestones, they each obtain the equity share $\alpha = \lambda^u/(2\lambda^u) = 1/2$. The vested shares, $2\lambda^m$, remain the property of the venture, and are therefore proportionally owned by both partners. However, if, for example, founder *A* achieved his milestone but founder *B* did not, then $\alpha = (\lambda^u + \lambda^m)/(2\lambda^u + \lambda^m) = \alpha^*(\Gamma^+, \Gamma^-)$. For $\lambda^u > \lambda^m = 0$ we obtain $\alpha^*(\Gamma^+, \Gamma^-) = 1/2$; and for $\lambda^m > \lambda^u = 0$ we obtain $\alpha^*(\Gamma^+, \Gamma^-) = 1$. Moreover, we can obtain any intermediate value $\alpha^*(\Gamma^+, \Gamma^-) \in (1/2, 1)$ by setting the ratio of vested shares, λ^m/λ^u , to $\lambda^m/\lambda^u = (1 - \alpha^*)/(2\alpha^* - 1)$. This shows that our model of allocating equity based on the outcomes of the two signals naturally corresponds to contracts that include a vesting clause based on performance milestones.

(ii) If $1/2 < \eta \leq \bar{\eta}$, some shares are vested: $\alpha^*(\eta) \in (1/2, 1)$, where $\alpha^*(\eta)$ is increasing in η .

(iii) If $\eta > \bar{\eta}$, all shares are vested: $\alpha^*(\eta) = 1$.

The precision of the signals – as reflected by η – is a critical factor for the founders' vesting decision. Whenever the signals do not contain any information ($\eta = 1/2$), the founders prefer to use a simple contract. Using uninformative signals would do more harm than good, namely by compromising the efficiency of dream teams. On the other hand, if the signals about the founders' skills contain some information ($\eta > 1/2$), vesting part of the shares at date 0 is optimal; and more shares are vested the more informative the signals. The optimal vesting schedule then trades-off the benefit of improving the efficiency of dud teams and the cost of asymmetric equity allocations in teams where both founders are skilled.

Proposition 2 provides another interesting insight: If the signals are sufficiently precise ($\eta > \bar{\eta}$), all shares are vested at date 0. The founder with the positive signal is then entitled to the entire equity of the venture.¹⁸ Both founders, however, can always overturn Pareto-inefficient equity allocations; for example, a specialist would never want to keep the entire equity when his partner has the complementary skill.

In the Appendix we also derive the optimal contingent contract for two symmetric signals. The main insight is that if both signals are negative, then it is optimal to keep (break up) the firm whenever the updated beliefs (ρ_1^-, ρ_2^-) are sufficiently high (low).

5.3 Contingent Upfront vs. Delayed Contracting

We have shown in the previous section that verifiable signals about skills allow founders to write more sophisticated contracts by including a vesting clause in the founder agreement. Accounting for such contingent upfront contracts, it remains to identify the optimal contracting time for both founders.

Proposition 3 *Suppose $\eta > 1/2$.*

(i) *There exists a threshold $\hat{\rho}_1^s(\rho_2, \eta)$ such that founders only delay the contracting if $\rho_1 < \hat{\rho}_1^s(\rho_2, \eta)$. Otherwise, they always contract upfront, using performance-based vesting.*

(ii) *The threshold $\hat{\rho}_1^s(\rho_2, \eta)$ is decreasing in η , with $\hat{\rho}_1^s(\rho_2, 1/2) = \hat{\rho}_1(\rho_2)$.*

¹⁸This result may seem extreme, so it is interesting to note that such contracts do exist. Wasserman (2011) reports the case of Ockham Technologies, where the founder vesting schedule includes the possibility that founders lose all of their shares if certain conditions apply.

Whenever both founders are sufficiently likely to develop some skills ($\rho_1 \geq \hat{\rho}_1^s(\rho_2, \eta)$), they contract upfront at date 0. Provided signals are informative ($\eta > 1/2$), they include a vesting clause in the contract. The optimal vesting schedule then balances the benefit of curbing the dud team problem, and the cost of inducing an asymmetric equity allocation in dream teams. On the other hand, delayed contracting remains the optimal choice whenever both founders are sufficiently unlikely to possess any skills ($\rho_1 < \hat{\rho}_1^s(\rho_2, \eta)$). Delayed contracting then eliminates the risk of sharing equity with an unproductive partner.

The precision of the signals – as reflected by η – also affects the founders’ contracting choice. More informative signals make detrimental asymmetric equity allocations in dream teams less likely, and at the same time, improve the efficiency of equity allocations in dud teams. This in turn makes upfront contracting with performance-based vesting more attractive to founders that are likely to possess some skills. More informative signals therefore lead to more contingent cash flow rights at date 0. Formally this means $d\hat{\rho}_1^s(\rho_2, \eta)/d\eta < 0$.

If the signals about skills are perfectly precise ($\eta = 1$), founders always contract upfront (i.e., $\lim_{\eta \rightarrow 1} \hat{\rho}_1^s(\rho_2, \eta) = 0$). Moreover, we know from Proposition 2 that full vesting is then optimal ($\alpha^*(1) = 1$). This is intuitive as perfectly precise signals fully separate productive from unproductive partners. Full vesting then ensures that a generalist in a dud team receives the entire equity of the venture. The only potential downside of upfront contracting, namely the dud team problem, is then completely eliminated, while delayed contracting is still afflicted with the idea stealing problem. It is therefore always optimal to contract upfront with full vesting whenever available signals about the founders’ skills are perfectly precise.

6 The Role of Outside Investors

Our model clearly depends on a binding wealth constraint. If founders held sufficient personal wealth *outside* the business, then they could resolve all inefficiencies. Under upfront contracting, a generalist could *buy out* an inefficient partner to obtain all of the founder equity. Under delayed contracting, a specialist could “*buy in*” himself with a generalist, in order to prevent inefficient idea stealing. While theoretically elegant, these solutions are of limited practical relevance, given that founders typically do not have enough personal wealth to buy out their partners, or buy their way back into the firm.

In this section we consider the role of outside investors under two alternative scenarios. We first consider a model with assets that hold some liquidation value, and derive a role for secured debt. We then ask whether beyond such secured lending, investors are also willing to finance founder buy-outs or buy-ins with unsecured risky securities.

6.1 Secured Funding

If founders have no outside wealth, an interesting question is whether and how they can use any wealth *inside* the firm to make transfers payments (relating to buy-outs or buy-ins). To examine this we add a positive liquidation value to our base model. We first show how this relaxes the founders' binding wealth constraints, and then explain how founders can use simple financial securities to structure optimal contracts.

Let π_H be the return of a successful venture, and $\pi_L > 0$ be the return in case of a failure, with $\pi_H > \pi_L > 0$. The payoff π_L represents the liquidation value of the firm. We define $\pi \equiv \pi_H - \pi_L$ as the incremental return in case the venture succeeds. With a positive liquidation value it is natural to talk about downside returns π_L that are perfectly safe, and additional upside returns π that are uncertain. The optimal security design for the founders consists of some allocation of the cash flows π_H and π_L . W.l.o.g. we can describe the optimal security structure as a combination of secured debt for allocating the downside returns π_L , and risky equity for allocating the additional cash flows π on the upside. We denote A 's secured debt claim by d_A , and B 's debt claim by d_B satisfying $d_A + d_B = \pi_L$. A 's expected utility becomes

$$EU^A = \mu(e_x e_y) [d_A + \alpha\pi] + (1 - \mu(e_x e_y))d_A - c(e_x^A + e_y^A).$$

Founder B 's expected utility is symmetric. We immediately note that EU^A is linear in d_A , and EU^B is linear in $d_B (= \pi_L - d_A)$. It follows that the liquidation value π_L acts as transferable utility.

One minor complication concerns the appropriability of the liquidation value. If the liquidation value is directly tied to implementing the idea, then a generalist who appropriates the idea also captures the entire liquidation value. However, if the liquidation value is tied to some other assets that are owned by the respective founders, then a generalist can only appropriate the idea and his portion of the assets, but not his partner's portion. We allow for a flexible model specification where $\delta \in [0, 1]$ measures the degree of appropriability. For $\delta = 0$ none of the liquidation value is appropriable, for $\delta = 1$ all of it is appropriable.

The following proposition explains how founders optimally allocate the cash flow rights in the presence of a positive liquidation value.

Proposition 4

- (i) *Under upfront contracting, the optimal ex-ante contract is always symmetric. Ex-post a generalist (A) and an ineffective partner always renegotiate the financial structure. There exists a threshold $\hat{\pi}_L > 0$, such that the renegotiated contract entails*

- $\alpha^* = 1$ and $d_B^* > d_A^* \geq 0$ for $\pi_L \geq \widehat{\pi}_L$
- $1/2 < \alpha^* < 1$ and $d_B^* = \pi_L > d_A^* = 0$ for $\pi_L < \widehat{\pi}_L$.

(ii) Under delayed contracting the optimal ex-ante contract is always symmetric if the partners have symmetric skills. With a generalist (A) and a specialist (B), there exists a threshold $\widehat{\pi}_L$, such that the optimal contract entails

- $\alpha^* = 1$ and $d_A^* = \pi_L > d_B^* = 0$ for $\delta = 1$
- $\alpha^* \in (1/2, 1)$ and $d_A^* = \pi_L > d_B^* = 0$, for $\pi_L < \widehat{\pi}_L$ and $\delta < 1$
- $\alpha^* = 1/2$ and $\pi_L \geq d_A^* > 0$, $d_B^* \geq 0$ for $\pi_L \geq \widehat{\pi}_L$ and $\delta < 1$

Because our partners are ex-ante symmetric, the optimal upfront contract is always symmetric.¹⁹ However, at the ex-post stage (date 1) founders may renegotiate towards an asymmetric financial structure. Consider upfront contracting. At date 1, a generalist would like to offer an ineffective partner some debt in exchange for equity. This is because equity increases the generalist's effort incentives, thereby reducing the inefficiencies of the dud team. If there is a lot of liquidation value ($\pi_L > \widehat{\pi}_L$), the generalist buys out all the equity ($\alpha^* = 1$), and the dud problem is fully solved. For a lower liquidation value (i.e., $\pi_L < \widehat{\pi}_L$), the generalist gives up the entire liquidation value ($d_A^* = 0$) to buy as much as equity as possible. Since $\alpha^* < 1$, the dud problem is not fully resolved.

Under delayed contracting we find again that all symmetric constellations have symmetric security structures. The interesting case concerns a generalist/specialist team.²⁰ If the entire liquidation value is appropriable, the generalist simply retains all of the value on the upside and on the downside. However, if not all of it is appropriable, the specialist can trade his claim on the downside against some upside equity. For a high liquidation value (i.e., $\pi_L \geq \widehat{\pi}_L$), the specialist buys back exactly half of the equity ($\alpha^* = 1/2$). In this case the joint surplus is maximized and the idea stealing problem is fully eliminated. For a lower liquidation value (i.e., $\pi_L < \widehat{\pi}_L$), the specialist buys back as much equity as possible. However, his debt claim is insufficient to get half of the equity, so that $\alpha^* > 1/2$. In this case the inefficiency is not fully resolved.²¹

¹⁹If we use the above security structure with debt and equity, the optimal debt claims are given by $d_A^* = d_B^* = \pi_L/2$ and the equity is split 50-50. An equivalent security structure is to simply give each founder a symmetric 50% equity claim over the entire firm value.

²⁰Here we focus on the case where the generalist wants to steal the idea ($\widehat{\alpha}_{g.s} = 1$). In the Appendix we show that very similar results obtain for the case where idea stealing is only threatened ($\widehat{\alpha}_{g.s} < 1$).

²¹Note that $\widehat{\pi}_L$ is an increasing function of δ , since for higher values of δ the specialist has a lower downside claim to trade with.

Our discussion so far assumes that the secured debt claims d_A and d_B are held by the founder themselves. However, an equivalent arrangement would be that the secured debt claim is held by an outside investor (e.g., a bank). In the case of a buy-out, for example, this might allow an ineffective founder to completely sever all ties with the company, receiving cash in return to handing over the secured debt claim.

6.2 Unsecured Funding

The discussion above shows that if the firm has assets with liquidation value, these can be used for transfer payments through the use of secured debt instruments. This assumes that the firm has assets with a liquidation value π_L , and that no other investor has a prior claim on that liquidation value. In practice, start-ups are rarely born with assets that have a significant liquidation value. Moreover, the assets that they acquire over time are typically purchased with secured debt, so that they cannot be used for the transfer payments described in Proposition 4. We now ask whether beyond any secured lending, founders can raise funding for transfer payments by issuing risky securities. Obviously start-ups typically already raise unsecured funding for investment purposes. Therefore the question is whether they can also raise additional unsecured funding for structuring buy-outs or buy-ins.

To address this, we consider a model extension where the founders require capital in order to launch the venture. To simplify the exposition we return to the base model with $\pi_L = 0$, although nothing depends on this simplification. In the absence of a safe asset, founders can only issue risky claims to outside investors. Throughout we assume that outside investors are passive (i.e., they do not impact returns), and that financial markets are perfectly competitive.²²

The main question is whether it is optimal for founders to raise more capital than required for launching the venture. Let I be the total amount of funding raised, K the amount of capital needed to launch the venture, and $T(= K - I)$ the amount of additional capital raised, which could be used by the founders to mitigate, or even to eliminate, the dud problem (early contracting) or the idea stealing problem (delayed contracting).

We immediately state the main result of this section.

Proposition 5 *It is optimal for the founders to only raise the minimal amount $I = K$ from outside investors.*

²²Allowing for active investors who can add value to the venture would generate a distinct and separate reason for outside investors to acquire equity in the company. However, analyzing the role of active investors is beyond the scope of this paper. Hellmann (2006) provides a detailed analysis of optimal contracts for active value-adding investors.

At first glance the insight from Proposition 5 is surprising as one might have expected that raising external capital in excess of K helps founders to resolve the inefficiencies imposed by their binding wealth constraints. The key intuition why outside investors cannot ameliorate this problem is that they have to take a risky position on the cash flows of the company. This creates an incentive distortion that is at least as harmful as the inefficiency that founders try to address. Raising more than the required amount K is therefore never optimal.

To see why, note that founders could be seeking additional outside funding T at two distinct points in time: ex-ante (date 0) or ex-post (date 1). Consider first the case of ex-ante fundraising under upfront contracting. Suppose the two founders raise an additional amount $T > 0$ from an outside investor at date 0. In our simple binary specification there are only two states (π and 0), so investors' claims on the cash flows π can be equally interpreted as equity or risky debt- for simplicity we refer to it as equity. We denote the equity share that founders need to offer investors in order to raise capital I by $\gamma(I)$. In a competitive market $\gamma(I)$ satisfies

$$[\chi_1 \mu^{dream}(e_x(\gamma)e_y(\gamma)) + \chi_2 \mu^{dud}(e_x(\gamma)e_y(\gamma))] \gamma \pi = I,$$

where $\chi_1 = (\rho_1 \rho_2)^2 + (2\rho_1 \rho_2)(\rho_1 \bar{\rho}_2 + \rho_2 \bar{\rho}_1) + (\rho_1 \bar{\rho}_2)^2 + (\bar{\rho}_1 \rho_2)^2$ and $\chi_2 = \rho_1 \rho_2 \bar{\rho}_1 \bar{\rho}_2$ are the probabilities of a dream team and a dud team, respectively, and where μ^{dream} (μ^{dud}) denotes the equilibrium success probability in case of a dream (dud) team. Symmetry implies that each founder gets $T/2$ of the additional funds, as well as an equity share $(1 - \gamma)/2$. The expected utility of a founder under upfront contracting is then given by

$$EU_u^f(\gamma(I), T) = \chi_1 U^{dream}(\gamma(I), T) + \chi_2 U_J^{dud}(\gamma(I), T). \quad (4)$$

We note from (4) that raising the extra amount T affects not only dud teams (U_J^{dud}), but also dream teams (U^{dream}). The joint surplus of dream teams is maximized when each productive founder gets exactly half of the venture's equity. Giving up the additionally required equity share $\gamma(K + T) - \gamma(K)$ for an investor in exchange for the excess capital T further weakens the founders' effort incentives, and thus further compromises their joint payoff. Dream teams are therefore better off just raising the required amount K .²³

Next we ask whether the dud team problem can be mitigated by raising additional capital $T > 0$. Each founder now has an equity stake of $(1 - \gamma(K + T))/2$ instead of $(1 - \gamma(K))/2$. This weakens the generalist's effort incentives, but the generalist can now use his part of the additional funding, namely $T/2$, to buy equity from the ineffective partner. In the Appendix we

²³In fact, the founders of a dream team would want to use the excess capital to buy back shares from the outside investor, thus effectively reversing the additional fundraising of T .

show that the best the generalist can do – namely if he can make a take-it or leave-it offer that leaves the ineffective partner indifferent between accepting and refusing – is to bring his equity stake from $(1 - \gamma(K + T))/2$ back to $(1 - \gamma(K))/2$. In other words, the best the generalist can hope for by raising $T > 0$ brings him back to what he would have already gotten with $T = 0$. Therefore, raising additional outside capital cannot increase the generalist’s equilibrium equity share. Overall we find that there are no gains for dud teams to raising more than the required amount K from outside investors.

For delayed contracting, we ask if a specialist can use external capital to retain a generalist. The problem is again that raising additional outside capital ($T > 0$) requires giving up even more equity to outside investors. In the Appendix we show that for any allocation where the investor holds the equity $\gamma(K + T)$, there is a better allocation where the founders use whatever additional capital was raised to buy back equity, up to the point where investor are back to holding the minimum equity $\gamma(K)$. Overall we conclude that the provision of outside funding does not help to solve the fundamental problem of binding wealth constraints.²⁴

7 Model Extensions

7.1 Implied Partnerships

Courts sometimes assume the existence of a partnership among founders, even when no formal contract was signed. In the introduction we already mentioned the example of Mark Zuckerberg and the Winklevoss twins. The courts’ reasoning for assuming implied partnerships is largely based on protecting naïve founders who may not understand the need for formal contracting, and may be taken advantage of by savvier cofounders. The extent to which founders are naïve or savvy is an empirical question not to be settled here. What we examine here is how the protection of implied partnerships affects the contracting decisions of ‘non-naïve’ founders that satisfy the standard economic assumption of being rational and understanding the game that is being played.

To formally model this we return to our base model, but now allow for the possibility of lawsuits concerning implied partnerships. Consider delayed contracting, and suppose that a founder with generalist skills pursues the business opportunity alone, but subsequently gets sued by his former partner, who is either a specialist or ineffective. We assume that lawsuits for implied partnerships take place after the production stage, are costless, and succeed with

²⁴In the appendix we also show that for any given level of investment I , investors cannot change the equity allocation amongst founders to improve joint efficiency.

probability $\lambda \in (0, 1)$.²⁵ If the lawsuit is successful, the court grants the former partner an equity share $\theta \in (0, 1)$. The expected equity share for the solo founder is therefore given by

$$\lambda(1 - \theta) + (1 - \lambda)1 = 1 - \lambda\theta.$$

For parsimony, we define $\Lambda \equiv \lambda\theta$. We can think of Λ as the shadow equity value for an ineffective founder that could sue his former partner.

The next proposition points out how potential lawsuits affect the founders' contracting decision.

Proposition 6 *The higher Λ , the greater the range where upfront contracting is optimal (i.e., $d\hat{\rho}_1(\rho_2, \Lambda)/d\Lambda < 0$, with $\hat{\rho}_1(\rho_2, 0) = \hat{\rho}_1(\rho_2)$).*

This proposition suggests that the legal protection of implied partnerships can lead to unintended effects that seem opposite to the original intent. In our model such protection encourages founders to contract upfront. This is because the dud team problem is no longer unique to upfront contracting, but also affects delayed contracting. Rational founders may want to delay contracting, yet implied partnership protection makes this option less attractive. Thus, when founders are rational and forward looking, enforcing implied partnerships pushes founders into early contracting, and may reduce the founders utilities.²⁶

7.2 Specific Investments

In our base model we treat the development of skills as exogenous. An interesting question is how the contracting decision would affect founders' incentives to invest in task-specific skills. One intuitive conjecture may be that contracts provide commitment, giving the founders better protection from idea stealing, and thus encouraging specific investments. Below we show the opposite: lack of contractual commitment may actually generate stronger incentives for skill development, since founders realize that developing task-specific skills is necessary to be included in the team.

Consider the base model without verifiable signals, We now endogenize the probability ρ_1^f for founder $f = A, B$ to develop his main skill. For tractability we keep ρ_2 constant. We assume

²⁵Allowing for positive costs will not change the qualitative nature of our results.

²⁶One theoretical solution to this problem is that founders write a contract about the non-existence of a partnership. Consider a pair of founders who would have liked to delay the contracting if there were no lawsuits, but now prefer upfront contracting in the presence of lawsuits. Conceivably they could write an explicit 'non-partnership' agreement, stating that they have no contractual commitments, and that they indemnify each other from possible lawsuits. In practice, however, it is unclear whether courts would be willing to enforce such 'non-partnership' agreements. In a world with asymmetric information, founders may also hesitate to grant such indemnifications.

that $\rho_1^f = \rho_0 + \psi s^f$, where $\rho_0 (\geq \rho_2)$ is a constant minimum probability of being skillful, and s^f is private effort leading to a further development of the main skill. The parameter $\psi \in [0, \psi^{\max}]$ reflects the productivity of effort, where ψ^{\max} ensures that $\rho_1^f \leq 1$. The skill development cost $c(s^f)$ is increasing and convex in s^f , with $c(0) = c'(0) = 0$.

Let z_u^f denote the marginal effort incentives for founder $f = A, B$ to invest in his main skill under upfront contracting, and z_d^f his marginal incentives under delayed contracting, with $\Delta z^A \equiv z_u^f - z_d^f$. In the Appendix we show that delayed contracting provides founder A with stronger incentives to develop his main skills if $\Delta z^A > 0$ where

$$\begin{aligned} \Delta z^A = & \rho_2 [\rho_1^B \rho_2 (U^{dream} - U_s^{steal}) + \rho_1^B \bar{\rho}_2 (U_g^{steal} - U^{dream})] \\ & \rho_2 [\bar{\rho}_1^B \rho_2 (U_g^{steal} - U^{dream}) + \bar{\rho}_1^B \bar{\rho}_2 (U^{solo} - U_g^{dw})] \\ & + \bar{\rho}_2 [\rho_1^B \rho_2 (U_s^{steal} - (U^{dream} - U_i^{dw}))]. \end{aligned}$$

The case for founder B is symmetric.

From Δz^A it becomes clear that there are five different incentive effects. The first four effects are all positive, suggesting that incentives are stronger under delayed contracting. They all pertain to the case where founder A has the secondary skill (as reflected by ρ_2). The four effects only differ in the skills that founder B has. For the first effect, B is a generalist ($\rho_1^B \rho_2$). Under upfront contracting there are no incentives to acquire further skills, but under delayed contracting possessing both skills guarantees A to be part of a dream team (U^{dream}) rather than B being in a position to steal the business idea (leaving A with U_s^{steal}). For the second and third effect B is a specialist, so A 's incentive under delayed contracting is to become a generalist who can steal the idea ($U_g^{steal} - U^{dream}$). For the fourth effect, B is ineffective. Becoming a generalist under delayed contracting gives A the chance to own the entire venture (U^{solo}), rather than having to share it with a deadweight partner (U_g^{dw}). The fifth effect is in general ambiguous, and always negative when idea stealing is realized so that $U_s^{steal} = 0$. This effect pertains to the case where A does not have the secondary skill (as reflected by $\bar{\rho}_2$), and B is a generalist. In this case delayed contracting may lead to lower incentives than upfront contracting. This is because the benefit of acquiring skills under delayed contracting are now small (and zero when idea stealing occurs, i.e., $U_s^{steal} = 0$), given that B is a generalist who can steal the idea. By contrast, the benefit of acquiring skills under upfront contracting is moving from being an ineffective partner (U_i^{dw}) to being a fully contributing member of a dream team (U^{dream}).

Intuitively, the first four effects dominate the fifth for a wide range of parameters. However, there is a small range of parameters where the fifth effect can dominate. In the Appendix we state Lemma 1 that contains the formal conditions for this to be true.

We can now state the key result for this section:

Proposition 7 *Under the conditions of Lemma 1, delayed contracting provides greater incentives to invest in specific skills.*

So far we considered the base model without the verifiable signals. Allowing for verifiable signals as in Section 5 may affect the results. It is easy to see that for η sufficiently close to $1/2$, the basic intuition of Proposition 7 continues to hold. However, for sufficiently precise signals and ρ_1 being sufficiently high and ρ_2 being sufficiently low ($\rho_1 \geq \hat{\rho}_1$ and $\rho_2 < \hat{\rho}_2$), incentives to invest in specific skills are greater under upfront contracting.²⁷ The key intuition is that precise signals help to identify ineffective founders. This solves the incentive problem of upfront contracting, so that an ineffective founder can no longer free-ride alongside a generalist partner. Founders therefore have good incentives to invest in skills, even under upfront contracting.

One may also ask whether upfront or delayed contracting provides different incentives for idea generation. Suppose that founders can determine the (concave) probability $\theta(e_\theta^A, e_\theta^B)$ of a successful idea development by exerting effort e_θ^f , $f = A, B$, at the convex private cost $c(e_\theta^f)$. Under upfront contracting, founder $f = A, B$ chooses development effort e_θ^f to maximize $\theta(e_\theta^A, e_\theta^B)EU_u^f - c(e_\theta^f)$, where EU_u^f is the founder's expected utility under upfront contracting given a fully developed idea; see Section 4.1. Likewise, founder $f = A, B$ chooses development effort e_θ^f under delayed contracting to maximize $\theta(e_\theta^A, e_\theta^B)EU_d^f - c(e_\theta^f)$, where EU_d^f is his expected utility under delayed contracting in case the idea is fully developed; see Section 4.2. We can immediately see that upfront contracting provides greater incentives to develop the idea whenever $EU_u^f > EU_d^f$. It is then also optimal for the founders to contract upfront instead of delaying the formal contracting (see Proposition 1). Thus, the founders' optimal contracting decision also maximizes incentives for developing the business idea for their venture.

8 Empirical Implications

Our theory of contracting among founders generates a number of interesting empirical predictions. First, the timing of contracting should depend on how likely critical skills are present in the founder team, with a lower likelihood predicting greater delays. Empirically this can be measured both in terms of market characteristics (e.g., required tasks are more predictable in established than in new markets), and in terms of team characteristics (e.g., founders with a common prior history should find it easier to assess their respective skills). One empirical

²⁷Formally, the condition $\Omega > 0$ from Lemma 1 (see Appendix) is always violated for sufficiently precise signals, as $U_i^{dw} \rightarrow 0$ as $\eta \rightarrow 1$.

challenge is to observe the partners that were excluded from the venture (especially if courts are sympathetic to the implied partnership argument). Interestingly, the empirical prediction that upfront contracting is associated with likely skilled founders remains true even if we only observe a subset of the teams that delayed contracting.

Our model makes some predictions about the expected success of new ventures. Founder teams that delay contracting should have a higher performance than teams that contract upfront, because the latter include outright failures (critical skills are not present), and teams with ineffective partners. Conditional on skills, however, upfront-contract teams either have the same expected performance as delayed-contract teams (generalist/generalist and specialist/specialist combinations), or they have a higher expected performance (for a generalist/specialist constellation, upfront contracting is efficient, whereas the generalist gets an inefficiently large ownership share with delayed contracting).²⁸

Our model also makes interesting predictions about the use of founder vesting clauses. Vesting naturally depends on how well milestones reflect the presence of critical skills. Our model predicts that more accurate signals do not only lead to more founder shares being subject to vesting, but also result in more upfront contracting. Vesting based on more accurate signals should also have a positive effect on the expected performance of a venture as it leads to equity allocations that better reflect the relative importance of individual founders (generalist/ineffective case).

Finally, our model makes some interesting predictions concerning financial transactions among founders, such as buy-ins and buy-outs. Specifically it predicts that such transactions can be readily made by restructuring founder debt claims, or by issuing secured debt claims to outside investors. However, the model predicts that such transactions would not be financed with the issuance of risky equity claims to outside investors.

9 Conclusion

In this paper we examine contractual choices concerning the formation of founder teams. We develop a model where partners face uncertainty about critical skills that are specific to their business opportunity, and consider whether committing upfront or waiting for the resolution of the uncertainty is optimal. Upfront contracting prevents inefficient idea stealing, but may also lead to teams with unproductive partners. The model shows that delayed contracting is optimal whenever founders are sufficiently likely to lack the critical skills. We also show that contingent contracts with a vesting of shares make upfront contracting more attractive; however,

²⁸Tamvada and Shrivastava (2011), using the Kauffman firm survey, provide evidence supporting this prediction.

the effectiveness of these contracts depends on how well milestones correlate with the presence of individual skills. Finally we show that courts protecting founders without formal contracts create counter-intuitive incentives: Founders may contract upfront even though they would have preferred to wait.

This paper takes a first step towards examining the complex dynamics of founder contracts, which are a key determinant for the ownership of corporations. Our model focuses on ex-ante symmetric founders. An interesting next step would be to examine asymmetric partner combinations. The main uncertainty in this paper concerns founder skills, leaving out other potential sources of uncertainty, such as concerning risk-taking behaviors, strategic directions, or interpersonal conflicts. We leave these and other related questions to future research.

Appendix

Proof of Proposition 1.

Founder $f = A, B$ prefers delayed contracting if $EU_u^f \leq EU_d^f$, which is equivalent to

$$[\rho_1 \bar{\rho}_2 + \bar{\rho}_1 \rho_2] [2U^{dream} - U^{solo}] \leq \bar{\rho}_1 \bar{\rho}_2 [U^{solo} - U_J^{dud}]. \quad (5)$$

Using $\Theta \equiv [U^{solo} - U_J^{dud}] / [2U^{dream} - U^{solo}]$ we can write this condition as

$$f(\rho_1, \rho_2) \equiv \frac{\rho_1}{1 - \rho_1} + \frac{\rho_2}{1 - \rho_2} \leq \Theta. \quad (6)$$

Note that the left-hand side of (6) is increasing in both ρ_1 and ρ_2 . Thus, the condition is satisfied for a larger set of (ρ_1, ρ_2) when Θ increases. Now define $\hat{\rho}_1(\rho_2)$ such that $f(\hat{\rho}_1, \rho_2) = \Theta$. Implicitly differentiating $\hat{\rho}_1$ w.r.t. ρ_2 yields

$$\frac{d\hat{\rho}_1}{d\rho_2} = \frac{\frac{d}{d\rho_2} \left[\frac{\rho_2}{1 - \rho_2} \right]}{\frac{d}{d\rho_1} \left[\frac{\rho_1}{1 - \rho_1} \right]} = -1 < 0.$$

Because $d\hat{\rho}_1/d\rho_2 < 0$, the highest value of ρ_1 where (6) still holds satisfies $f(\rho_1, 0) = \rho_1/(1 - \rho_1) = \Theta$, which is equivalent to $\rho_1 = \Theta/(1 + \Theta)$. Moreover, because $d\hat{\rho}_1/d\rho_2 < 0$ and $\rho_1 > \rho_2$, the highest value of ρ_2 where (6) still holds satisfies $f(\rho_2, \rho_2) = 2\rho_2/(1 - \rho_2) = \Theta$, which is equivalent to $\rho_2 = \Theta/(2 + \Theta)$. \square

Renegotiation and Asymmetric Equity Shares.

For our base model we focused on the scenario where renegotiation in a dud team (upfront contracting) as well as in a generalist-specialist team (delayed contracting) does not improve Pareto efficiency. We now show that the main trade-off between upfront and delayed contracting remains intact when allowing for mutually beneficial renegotiation.

Consider first dud teams under upfront contracting. The ineffective partner may then be willing to relinquish some of his equity in order to strengthen the generalist's effort incentives, and thus to enhance the expected payoff from the venture. This is the case whenever $\hat{\alpha}_{i.g} < 1/2$. Consider for example the following specification: $\mu(e_x e_y) = (e_x e_y)^\gamma$ with $0 < \gamma < 1$, and $c(e_x^k + e_y^k) = (e_x^k + e_y^k)^2/2$. For this specification one can show that $\hat{\alpha}_{i.g} = 1 - \gamma$.²⁹ Thus, renegotiation in a dud team is Pareto improving whenever $1/2 < \gamma < 1$. We define $\alpha_{g.i}^*$ as the Nash bargaining outcome for the generalist when renegotiating the equity allocation with the

²⁹The proof is available from the authors upon request.

ineffective partner, with $1 - \hat{\alpha}_{i.g} < \alpha_{g.i}^* < 1$. The expected joint utility of a dud team is then given by

$$U_{J-R}^{dud} = \begin{cases} U_g^{dud}(\alpha_{g.i}^*) + U_i^{dud}(1 - \alpha_{g.i}^*) & \text{if } \hat{\alpha}_{i.g} < 1/2 \\ U_g^{dud}(1/2) + U_i^{dud}(1/2) & \text{if } \hat{\alpha}_{i.g} \geq 1/2. \end{cases}$$

Now consider the generalist-specialist team under delayed contracting. Instead of stealing the idea (as considered in the base model), the generalist could also simply threaten the specialist to leave the partnership in order to obtain more equity. This scenario can only arise if the utility frontier is backward-bending so that $\hat{\alpha}_{g.s} < 1$. Consider again the simple specification with $\mu(e_x e_y) = (e_x e_y)^\gamma$, $0 < \gamma < 1$, and $c(e_x^k + e_y^k) = (e_x^k + e_y^k)^2/2$. One can show that the generalist's preferred equity share is then defined by $\hat{\alpha}_{g.s} = 1/(2\gamma)$.³⁰ Thus, actual idea stealing occurs whenever $\gamma \leq 1/2$, and the threat to steal the idea when $\gamma > 1/2$. We define $\alpha_{g.s}^*$ as the Nash bargaining outcome for the generalist, with $1 - \hat{\alpha}_{s.g} < \alpha_{g.s}^* < \hat{\alpha}_{g.s} (< 1)$, where $\hat{\alpha}_{s.g}$ is the specialist's preferred equity share. The expected joint utility of the generalist-specialist team under delayed contracting, denoted U_J^{steal} , is then given by

$$U_{J-R}^{steal} = \begin{cases} U^{solo} & \text{if } \hat{\alpha}_{g.s} = 1 \\ U_g^{steal}(\alpha_{g.s}^*) + U_s^{steal}(1 - \alpha_{g.s}^*) & \text{if } \hat{\alpha}_{g.s} < 1, \end{cases}$$

where U_g^{steal} is the expected utility of the generalist in case of threatened idea stealing, and U_s^{steal} is the expected utility of the specialist.

It is easy to see that the parameter Θ in the condition from Proposition 1 now becomes

$$\Theta = \frac{U^{solo} - U_{J-R}^{dud}}{2U^{dream} - U_{J-R}^{steal}}. \quad (7)$$

Whether the new Θ is higher or lower depends on whether renegotiation occurs in a dud team and/or a generalist-specialist team. This in turn will shift the boundary in Figure 2 either upwards or downwards. However, the key insight remains the same: The founders choose to contract upfront whenever they are likely to develop the critical skills ($\rho_1 \geq \hat{\rho}_1(\rho_2)$). Otherwise they delay the formal contracting.

³⁰The proof is available from the authors upon request.

Proof of Proposition 2.

Note that

$$\rho_1^+ = \frac{[\rho_1\rho_2 + \rho_1(1 - \rho_2)]\eta}{[\rho_1\rho_2 + \rho_1(1 - \rho_2)]\eta + [1 - \rho_1\rho_2 - \rho_1(1 - \rho_2)](1 - \eta)} = \frac{\rho_1\eta}{\rho_1\eta + (1 - \rho_1)(1 - \eta)}$$

$$\rho_2^+ = \frac{[\rho_1\rho_2 + \rho_2(1 - \rho_1)]\eta}{[\rho_1\rho_2 + \rho_2(1 - \rho_1)]\eta + [1 - \rho_1\rho_2 - \rho_2(1 - \rho_1)](1 - \eta)} = \frac{\rho_2\eta}{\rho_2\eta + (1 - \rho_2)(1 - \eta)}.$$

Likewise,

$$\rho_1^- = \frac{\rho_1(1 - \eta)}{\rho_1(1 - \eta) + (1 - \rho_1)\eta} \quad \rho_2^- = \frac{\rho_2(1 - \eta)}{\rho_2(1 - \eta) + (1 - \rho_2)\eta}.$$

Let $\alpha(\Gamma^+, \Gamma^-)$ denote the equity share for the positive-signal founder. Moreover, we define $\hat{\alpha}_{j,k}$ as the equity share which maximizes the expected utility of a type j -founder when his partner is of type k , with $j, k \in \{g, s, i\}$. Suppose the generalist in a dud team has the positive signal. The expected joint utility is

$$U_{J(g)}^{dud} \equiv \begin{cases} U_{g,i}(\alpha(\Gamma^+, \Gamma^-)) + U_{i,g}(1 - \alpha(\Gamma^+, \Gamma^-)) & \text{if } \alpha(\Gamma^+, \Gamma^-) \geq 1 - \hat{\alpha}_{i,g} \\ U_{g,i}(\alpha_{g,i}^*(\alpha(\Gamma^+, \Gamma^-))) + U_{i,g}(1 - \alpha_{g,i}^*(\alpha(\Gamma^+, \Gamma^-))) & \text{if } \alpha(\Gamma^+, \Gamma^-) < 1 - \hat{\alpha}_{i,g}, \end{cases}$$

which depends on whether renegotiation occurs ($\alpha \geq 1 - \hat{\alpha}_{i,g}$) or not ($\alpha < 1 - \hat{\alpha}_{i,g}$). Because $d\alpha_{g,i}^*(\cdot)/d\alpha > 0$, we have $dU_{J(g)}^{dud}/d\alpha > 0$. Now suppose the ineffective partner in a dud team has the positive signal. The expected joint utility is

$$U_{J(i)}^{dud} \equiv \begin{cases} U_g^{dud}(1 - \alpha(\Gamma^+, \Gamma^-)) + U_i^{dud}(\alpha(\Gamma^+, \Gamma^-)) & \text{if } \alpha(\Gamma^+, \Gamma^-) \leq \hat{\alpha}_{i,g} \\ U_g^{dud}(1 - \alpha_{i,g}^*(\alpha(\Gamma^+, \Gamma^-))) + U_i^{dud}(\alpha_{i,g}^*(\alpha(\Gamma^+, \Gamma^-))) & \text{if } \alpha(\Gamma^+, \Gamma^-) > \hat{\alpha}_{i,g}, \end{cases}$$

which also depends on whether renegotiation occurs ($\alpha > \hat{\alpha}_{i,g}$) or not ($\alpha \leq \hat{\alpha}_{i,g}$). Because $d\alpha_{i,g}^*(\cdot)/d\alpha < 0$, we have $dU_{J(i)}^{dud}(\cdot)/d\alpha < 0$. Finally consider a $(j - l)$ dream team, with $j, l \in \{g, s\}$, where founder j has the positive signal. The expected joint utility is

$$U_{J(j-l)}^{dream} \equiv \begin{cases} U_{j,l}^{dream}(\alpha(\Gamma^+, \Gamma^-)) + U_{l,j}^{dream}(1 - \alpha(\Gamma^+, \Gamma^-)) & \text{if } \alpha(\Gamma^+, \Gamma^-) \leq \hat{\alpha}_{j,l} \\ U_{j,l}^{dream}(\alpha_{j,l}^*(\alpha(\Gamma^+, \Gamma^-))) + U_{l,j}^{dream}(1 - \alpha_{j,l}^*(\alpha(\Gamma^+, \Gamma^-))) & \text{if } \alpha(\Gamma^+, \Gamma^-) > \hat{\alpha}_{j,l}, \end{cases}$$

which, again, depends on whether renegotiation occurs ($\alpha > \hat{\alpha}_{j,l}$) or not ($\alpha \leq \hat{\alpha}_{j,l}$). Clearly, $d\alpha_{j,l}^*(\cdot)/d\alpha > 0$. Thus, $dU_{J(j-l)}^{dream}(\cdot)/d\alpha < 0$.

We can now derive the optimal vesting scheme $\alpha^*(\Gamma^+, \Gamma^-)$. For parsimony, we make the following definitions: $g^k \equiv \rho_1^k \rho_2^k$, $k \in \{+, -\}$ (founder is generalist), $s^k \equiv \rho_1^k \bar{\rho}_2^k$ (founder has main skill), and $t^k \equiv \bar{\rho}_1^k \rho_2^k$ (founder has secondary skill; *transpose*). Moreover, we define $\lambda^k \equiv g^k + s^k + t^k$ (founder is skilled). If $\Gamma = \{\Gamma^+, \Gamma^-\}$, the positive-signal founder is skilled and the negative-signal founder is unskilled with probability η^2 . We can focus on the case where the skilled founder is a generalist as in all other cases the expected payoff is zero. Thus, the expected joint utility is $\frac{g^+}{\lambda^+}(1 - \lambda^-)U_{J(g)}^{dud}$. With probability $\bar{\eta}^2$, the positive-signal founder is unskilled, and the negative-signal founder skilled. We can again focus on the case where the skilled founder is a generalist. Thus, the expected joint utility is $\frac{g^-}{\lambda^-}(1 - \lambda^+)U_{J(i)}^{dud}$. With probability $\eta\bar{\eta}$, both founders are skilled. We then have the following potential constellations where the first founder has the positive signal: (i) (*x-specialist; y-specialist*) or (*y-specialist; x-specialist*) with probability $(s^+s^- + t^+t^-)/(\lambda^+\lambda^-)$, (ii) (*x-specialist; x-specialist*) or (*y-specialist; y-specialist*) with probability $(s^+t^- + s^-t^+)/(\lambda^+\lambda^-)$, (iii) (*generalist; y-specialist*) or (*generalist; x-specialist*) with probability $g^+(s^- + t^-)/(\lambda^+\lambda^-)$, (iv) (*x-specialist; generalist*) or (*y-specialist; generalist*) with probability $g^-(s^+ + t^+)/(\lambda^+\lambda^-)$; and (v), (*generalist; generalist*) with probability $g^+g^-/(\lambda^+\lambda^-)$. Thus, with probability $\eta\bar{\eta}$, the expected joint utility is $1/(\lambda^+\lambda^-)U_J^{dream}$, where

$$U_J^{dream} \equiv (s^+s^- + t^+t^-)U_{J(s.s)}^{dream} + g^+(s^- + t^-)U_{J(g.s)}^{dream} + g^-(s^+ + t^+)U_{J(s.g)}^{dream} + g^+g^-U_{J(g.g)}^{dream}.$$

With probability $\bar{\eta}\eta$, both founders are unskilled. The expected joint utility is then 0. The total expected joint utility, denoted $EU^J(\alpha(\Gamma^+, \Gamma^-))$, is thus given by

$$EU^J(\alpha(\Gamma^+, \Gamma^-)) = \eta^2 \frac{g^+}{\lambda^+} (1 - \lambda^-) U_{J(g)}^{dud} + (1 - \eta)^2 \frac{g^-}{\lambda^-} (1 - \lambda^+) U_{J(i)}^{dud} + \eta(1 - \eta) \frac{1}{\lambda^+\lambda^-} U_J^{dream}.$$

The optimal equity share for the positive-signal founder, denoted $\alpha^*(\eta)$, is characterized by the first-order condition:

$$\eta^2 \frac{g^+}{\lambda^+} (1 - \lambda^-) \underbrace{\frac{dU_{J(g)}^{dud}}{d\alpha}}_{>0} + (1 - \eta)^2 \frac{g^-}{\lambda^-} (1 - \lambda^+) \underbrace{\frac{dU_{J(i)}^{dud}}{d\alpha}}_{<0} + \eta(1 - \eta) \frac{1}{\lambda^+\lambda^-} \underbrace{\frac{dU_J^{dream}}{d\alpha}}_{\leq 0} = 0. \quad (8)$$

We now show that $d\alpha^*(\eta)/d\eta > 0$ as long as (8) is satisfied. Note that $dU_{J(g.s)}^{dream}/d\alpha = dU_{J(g.g)}^{dream}/d\alpha$ for $\alpha \geq 1/2$ because both positive-signal founders (generalists) exert the same

total effort, and can choose any effort allocation at the same cost. Using this observation, we can re-write (8) as follows:

$$\begin{aligned} \Phi \equiv & \underbrace{\frac{\eta}{1-\eta}(1-\lambda^-)}_{\equiv \phi_1} \frac{dU_{J(g)}^{dud}}{d\alpha} + \underbrace{\frac{1-\eta}{\eta} \frac{g^- \lambda^+}{\lambda^- g^+} (1-\lambda^+)}_{\equiv \phi_2} \frac{dU_{J(i)}^{dud}}{d\alpha} + \frac{dU_{J(g-s)}^{dream}}{d\alpha} \\ & + \frac{\lambda^+}{g^+} \left[\underbrace{\frac{s^+ s^- + t^+ t^-}{\lambda^+ \lambda^-}}_{\equiv \phi_3} \frac{dU_{J(s-s)}^{dream}}{d\alpha} + \underbrace{\frac{g^-(s^+ + t^+)}{\lambda^+ \lambda^-}}_{\equiv \phi_4} \frac{dU_{J(s-g)}^{dream}}{d\alpha} \right] = 0. \end{aligned} \quad (9)$$

$\underbrace{\hspace{15em}}_{\equiv \Omega}$

Implicit differentiation yields

$$\frac{d\alpha^*(\eta)}{d\eta} = \frac{\frac{\partial \phi_1}{\partial \eta} \overbrace{\frac{dU_{J(g)}^{dud}}{d\alpha}}^{>0} + \frac{\partial \phi_2}{\partial \eta} \overbrace{\frac{dU_{J(i)}^{dud}}{d\alpha}}^{<0} + \frac{\partial}{\partial \eta} \left(\frac{\lambda^+}{g^+} \right) \overbrace{\Omega}^{<0} + \frac{\lambda^+}{g^+} \left[\frac{\partial \phi_3}{\partial \eta} \overbrace{\frac{dU_{J(s-s)}^{dream}}{d\alpha}}^{<0} + \frac{\partial \phi_4}{\partial \eta} \overbrace{\frac{dU_{J(s-g)}^{dream}}{d\alpha}}^{<0} \right]}{-\frac{d\Phi}{d\alpha}}, \quad (10)$$

where the denominator must be strictly negative due to the second-order condition. Thus, $d\alpha^*(\eta)/d\eta > 0$ if the numerator of (10) is strictly positive. For this, it is sufficient to show that (i) $\partial \phi_1/\partial \eta > 0$, (ii) $\partial \phi_2/\partial \eta < 0$, (iii) $\partial(\lambda^+/g^+)/\partial \eta < 0$, (iv) $\partial \phi_3/\partial \eta < 0$; and (v) $\partial \phi_4/\partial \eta < 0$. Consider first ϕ_1 . Clearly, $\eta/(1-\eta)$ is increasing in η . Moreover, note that $\lambda^- = \rho_1^- - \rho_1^- \rho_2^- + \rho_2^-$. Thus, $\partial \lambda^-/\partial \eta = \partial \rho_1^-/\partial \eta (1-\rho_2^-) + \partial \rho_2^-/\partial \eta (1-\rho_1^-)$, which is strictly negative because $\partial \rho_1^-/\partial \eta, \partial \rho_2^-/\partial \eta < 0$. Thus, $(1-\lambda^-)$ is increasing in η . Likewise, one can show that $\partial(1-\lambda^+)/\partial \eta < 0$. Therefore, $\partial \phi_1/\partial \eta > 0$. Now consider ϕ_2 . Clearly, $(1-\eta)/\eta$ is decreasing in η . Moreover, we can write $\lambda^-/g^- = 1/\rho_2^- + 1/\rho_1^- - 1$. Because $\partial \rho_1^-/\partial \eta, \partial \rho_2^-/\partial \eta < 0$, we have $\partial(\lambda^-/g^-)/\partial \eta > 0$. Thus, $\partial(g^-/\lambda^-)/\partial \eta < 0$. Likewise, one can show that $\partial(\lambda^+/g^+)/\partial \eta < 0$ as $\partial \rho_1^+/\partial \eta, \partial \rho_2^+/\partial \eta > 0$. These observations imply that $\partial \phi_2/\partial \eta < 0$. Now consider ϕ_3 . We can write

$$\frac{s^+ s^-}{\lambda^+ \lambda^-} = \frac{\rho_1^+ (1-\rho_2^+) \rho_1^- (1-\rho_2^-)}{(\rho_1^+ - \rho_1^+ \rho_2^+ + \rho_2^+) (\rho_1^- - \rho_1^- \rho_2^- + \rho_2^-)} = \frac{\frac{1-\rho_2^+}{\rho_2^+} \frac{1-\rho_2^-}{\rho_2^-}}{\underbrace{\left(\frac{1}{\rho_2^+} - 1 + \frac{1}{\rho_1^+} \right)}_{\equiv \chi^+} \underbrace{\left(\frac{1}{\rho_2^-} - 1 + \frac{1}{\rho_1^-} \right)}_{\equiv \chi^-}}.$$

Using the definitions of ρ_1^+ and ρ_2^+ , we get

$$\frac{1 - \rho_2^+}{\rho_2^+} = \frac{1 - \rho_2}{\rho_2} \cdot \frac{1 - \eta}{\eta} \quad \frac{1 - \rho_2^-}{\rho_2^-} = \frac{1 - \rho_2}{\rho_2} \cdot \frac{\eta}{1 - \eta}.$$

Let $\chi \equiv \chi^+ \chi^-$. Thus,

$$\frac{\partial}{\partial \eta} \left(\frac{s^+ s^-}{\lambda^+ \lambda^-} \right) = \frac{\partial}{\partial \eta} \left(\frac{\frac{(1-\rho_2)^2}{\rho_2^2}}{\chi} \right) = \frac{-\frac{(1-\rho_2)^2}{\rho_2^2} \frac{\partial \chi}{\partial \eta}}{\chi^2}. \quad (11)$$

Clearly, $\frac{\partial}{\partial \eta} \left(\frac{s^+ s^-}{\lambda^+ \lambda^-} \right) < 0$ if $\partial \chi / \partial \eta > 0$. We get

$$\frac{\partial \chi}{\partial \eta} = \left[-\frac{1}{(\rho_2^+)^2} \frac{\partial \rho_2^+}{\partial \eta} - \frac{1}{(\rho_1^+)^2} \frac{\partial \rho_1^+}{\partial \eta} \right] \chi^- + \left[-\frac{1}{(\rho_2^-)^2} \frac{\partial \rho_2^-}{\partial \eta} - \frac{1}{(\rho_1^-)^2} \frac{\partial \rho_1^-}{\partial \eta} \right] \chi^+.$$

It is straightforward to show that

$$\begin{aligned} \frac{1}{(\rho_2^+)^2} \frac{\partial \rho_2^+}{\partial \eta} &= \frac{1 - \rho_2}{\rho_2} \cdot \frac{1}{\eta^2} & \frac{1}{(\rho_1^+)^2} \frac{\partial \rho_1^+}{\partial \eta} &= \frac{1 - \rho_1}{\rho_1} \frac{1}{\eta^2} \\ \frac{1}{(\rho_2^-)^2} \frac{\partial \rho_2^-}{\partial \eta} &= -\frac{1 - \rho_2}{\rho_2} \cdot \frac{1}{(1 - \eta)^2} & \frac{1}{(\rho_1^-)^2} \frac{\partial \rho_1^-}{\partial \eta} &= -\frac{1 - \rho_1}{\rho_1} \frac{1}{(1 - \eta)^2}. \end{aligned}$$

Thus, $\partial \chi / \partial \eta > 0$ if $\eta^2 \chi^+ > \chi^-(1 - \eta)^2$. Simple transformation yields

$$\begin{aligned} \chi^+ &= 1 + \frac{\rho_1(1 - \rho_2)(1 - \eta) + \rho_2(1 - \rho_1)(1 - \eta)}{\rho_1 \rho_2 \eta} \\ \chi^- &= 1 + \frac{\rho_1(1 - \rho_2)\eta + \rho_2(1 - \rho_1)\eta}{\rho_1 \rho_2 (1 - \eta)}. \end{aligned}$$

Hence, the condition $\eta^2 \chi^+ > \chi^-(1 - \eta)^2$ can be written as

$$\begin{aligned} \eta^2 + \frac{[\rho_1(1 - \rho_2)(1 - \eta) + \rho_2(1 - \rho_1)(1 - \eta)] \eta}{\rho_1 \rho_2} &> (1 - \eta)^2 + \frac{[\rho_1(1 - \rho_2)\eta + \rho_2(1 - \rho_1)\eta](1 - \eta)}{\rho_1 \rho_2} \\ \Leftrightarrow \eta^2 &> (1 - \eta)^2, \end{aligned}$$

which is always satisfied for $\eta > 1/2$. Thus, $\partial\chi/\partial\eta > 0$. This implies that $\frac{\partial}{\partial\eta} \left(\frac{s^+s^-}{\lambda^+\lambda^-} \right) < 0$. Likewise, one can show that $\frac{\partial}{\partial\eta} \left(\frac{t^+t^-}{\lambda^+\lambda^-} \right) < 0$. Consequently, $\partial\phi_3/\partial\eta < 0$. Finally consider ϕ_4 . We can write

$$\frac{g^-s^+}{\lambda^+\lambda^-} = \frac{\rho_1^- \rho_2^- \rho_1^+ (1 - \rho_2^+)}{(\rho_1^+ - \rho_1^+ \rho_2^+ + \rho_2^+) (\rho_1^- - \rho_1^- \rho_2^- + \rho_2^-)} = \frac{1 - \rho_2^+}{\rho_2^+}.$$

Using that $(1 - \rho_2^+)/\rho_2^+ = [(1 - \rho_2)(1 - \eta)]/(\rho_2\eta)$, we get

$$\frac{\partial}{\partial\eta} \left(\frac{g^-s^+}{\lambda^+\lambda^-} \right) = \frac{\partial}{\partial\eta} \left(\frac{\frac{1-\rho_2}{\rho_2} \cdot \frac{1-\eta}{\eta}}{\chi} \right) = \frac{-\frac{1-\rho_2}{\rho_2} \left[\frac{1}{\eta^2} \chi + \frac{1-\eta}{\eta} \frac{\partial\chi}{\partial\eta} \right]}{\chi^2}.$$

Because $\partial\chi/\partial\eta > 0$, we have $\frac{\partial}{\partial\eta} \left(\frac{g^-s^+}{\lambda^+\lambda^-} \right) < 0$. Likewise, one can show that $\frac{\partial}{\partial\eta} \left(\frac{g^-t^+}{\lambda^+\lambda^-} \right) < 0$. Consequently, $\partial\phi_4/\partial\eta < 0$. Thus, $d\alpha^*(\eta)/d\eta > 0$ as long as (8) is satisfied.

We now evaluate (9) at the extreme values $\eta \in \{1/2, 1\}$. Suppose $\eta = 1$. Then, (9) simplifies to $dU_{J(g)}^{dud}/d\alpha = 0$. Since $dU_{J(g)}^{dud}/d\alpha > 0$, we get a corner solution with $\alpha^*(1) = 1$. Because $d\alpha^*(\eta)/d\eta > 0$ and the fact that (9) cannot be satisfied for $\eta \rightarrow 1$, there must exist a threshold $\bar{\eta}$, with $\bar{\eta} < 1$, such that $\alpha^*(\eta) = 1$ for $\eta > \bar{\eta}$. Now suppose $\eta = 1/2$. Note that $\rho_1^+ = \rho_1^- = \rho_1$ and $\rho_2^+ = \rho_2^- = \rho_2$ for $\eta = 1/2$, and thus $\lambda^+ = \lambda^- \equiv \lambda$. Consequently, (9) simplifies to

$$\frac{dU_{J(g)}^{dud}}{d\alpha} + \frac{dU_{J(i)}^{dud}}{d\alpha} + \frac{dU_{J(g,s)}^{dream}}{d\alpha} + \frac{s^2 + t^2}{g\lambda} \frac{dU_{J(s,s)}^{dream}}{d\alpha} + \frac{s + t}{\lambda} \frac{dU_{J(s,g)}^{dream}}{d\alpha} = 0. \quad (12)$$

Keep in mind that $d\alpha^*(\eta)/d\eta > 0$ implies that a solution to (12) must be unique. Moreover, note that

$$\left. \frac{dU_{J(g)}^{dud}}{d\alpha} \right|_{\alpha=1/2} = - \left. \frac{dU_{J(i)}^{dud}}{d\alpha} \right|_{\alpha=1/2}.$$

We now show that $dU_{J(j,l)}^{dream}/d\alpha \Big|_{\alpha=1/2} = 0$, with $j, l \in \{g, s\}$. W.l.o.g. suppose that founder A has at least the x -skill, and founder B at least the y -skill. We can then write the joint utility for a given equity allocation α as

$$U^A(\alpha) + U^B(1 - \alpha) = \alpha\pi\mu(e_x e_y) - c(e_x^A + e_y^A) + (1 - \alpha)\pi\mu(e_x e_y) - c(e_x^B + e_y^B).$$

Using the Envelope Theorem, we get the following condition which characterizes the jointly efficient equity allocation α^J :

$$\alpha \left[\frac{\partial \mu(\cdot)}{\partial e_x^B} \frac{de_x^B}{d\alpha} (e_y^A + e_y^B) + \frac{\partial \mu(\cdot)}{\partial e_y^B} \frac{de_y^B}{d\alpha} (e_x^A + e_x^B) \right] = -(1-\alpha) \left[\frac{\partial \mu(\cdot)}{\partial e_x^A} \frac{de_x^A}{d\alpha} (e_y^A + e_y^B) + \frac{\partial \mu(\cdot)}{\partial e_y^A} \frac{de_y^A}{d\alpha} (e_x^A + e_x^B) \right],$$

where $de_x^A/d\alpha \geq 0$, $de_y^A/d\alpha \geq 0$, $de_x^B/d\alpha \leq 0$, and $de_y^B/d\alpha \leq 0$; with strict equality in case the founder does not possess the relevant skill. Suppose $\alpha = 1/2$. Then, because only total effort matters, $e_x^A = e_y^B > 0$, $e_y^A = e_x^B = 0$, $de_y^B/d\alpha = -de_x^A/d\alpha$, and $\partial \mu(\cdot)/\partial e_y^B = \partial \mu(\cdot)/\partial e_x^A$. Thus, for $\alpha = 1/2$, the first-order condition is satisfied. This implies that $\alpha^J = 1/2$ is a maximum. Because founders' disutility $c(\cdot)$ is convex in total effort, $\alpha^J = 1/2$ is also a global maximum. Thus, $dU_{J(j,l)}^{dream}/d\alpha \Big|_{\alpha=1/2} = 0$, with $j, l \in \{g, s\}$. Consequently, $\alpha = 1/2$ satisfies (12) for $\eta = 1/2$. Because $d\alpha^*(\eta)/d\eta > 0$, we have $\alpha^*(\eta) > 1/2$ for all $\eta > 1/2$. \square

Optimal Contingent Contract for two Symmetric Signals.

Suppose both signals are symmetric ($\{\Gamma_A^+, \Gamma_B^+\}$ and $\{\Gamma_A^-, \Gamma_B^-\}$). Because both founders are symmetric when writing the contract upfront at date 0, and the IP rights are allocated to the firm, only the following two scenarios are possible: First, the contract can stipulate to dissolve the firm. Both founders can then decide whether to pursue the business opportunity alone, or to stay together. Second, the contract can preserve the team with the symmetric equity allocation $\alpha^* = 1/2$. The next proposition specifies the optimal contingent contract for symmetric signals.

Proposition 8 *Suppose the signals are symmetric.*

- (i) *It is optimal to dissolve the venture whenever (ρ_1^-, ρ_2^-) (two negative signals) or (ρ_1^+, ρ_2^+) (two positive signals) satisfy the condition for delayed contracting (see Proposition 1). Otherwise, it is always optimal to preserve the team with $\alpha^* = 1/2$.*
- (ii) *Define $\hat{\rho}_1^i(\rho_2^i)$, $i \in \{+, -\}$, such that $f(\hat{\rho}_1^i, \rho_2^i) = \Theta$. Then $\hat{\rho}_1^+(\rho_2^+)$ is decreasing in the signal precision η with $\hat{\rho}_1^+(\rho_2^+) = \hat{\rho}_1(\rho_2)$ for $\eta = 1/2$, while $\hat{\rho}_1^-(\rho_2^-)$ is decreasing in η with $\hat{\rho}_1^-(\rho_2^-) = \hat{\rho}_1(\rho_2)$ for $\eta = 1/2$.*

Proof: First suppose $\Gamma = \{\Gamma_A^+, \Gamma_B^+\}$. If the team is kept together with $\alpha^* = 1/2$, the expected utility of founder $f = A, B$ is given by

$$\begin{aligned} EU_u^f(\rho_1^+, \rho_2^+) &= [(\rho_1^+ \rho_2^+)^2 + (2\rho_1^+ \rho_2^+)(\rho_1^+ \bar{\rho}_2^+ + \rho_2^+ \bar{\rho}_1^+) + (\rho_1^+ \bar{\rho}_2^+)^2 + (\bar{\rho}_1^+ \rho_2^+)^2] U^{dream} \\ &\quad + \rho_1^+ \bar{\rho}_1^+ \bar{\rho}_2^+ U_J^{dud}, \end{aligned}$$

where $\bar{\rho}_1^+ = 1 - \rho_1^+$ and $\bar{\rho}_2^+ = 1 - \rho_2^+$. Likewise, if the venture will be dissolved, the expected utility of founder $f = A, B$ is

$$\begin{aligned} EU_d^f(\rho_1^+, \rho_2^+) &= [\rho_1^+ \rho_2^+ \bar{\rho}_1^+ \bar{\rho}_2^+ + (\rho_1^+)^2 \rho_2^+ \bar{\rho}_2^+ + \rho_1^+ (\rho_2^+)^2 \bar{\rho}_1^+] U^{solo} \\ &\quad + [(\rho_1^+ \rho_2^+)^2 + (\rho_1^+)^2 (\bar{\rho}_2^+)^2 + (\rho_2^+)^2 (\bar{\rho}_1^+)^2] U^{dream}. \end{aligned}$$

Notice that we get the same expected utility levels as in the absence of verifiable signals, with the exception that we now have the updated probability ρ_1^+ instead of ρ_1 , and ρ_2^+ instead of ρ_2 . Thus, we can infer from Proposition 1 that the venture will be dissolved if

$$f(\rho_1^+, \rho_2^+) \equiv \frac{\rho_1^+}{1 - \rho_1^+} + \frac{\rho_2^+}{1 - \rho_2^+} \leq \Theta. \quad (13)$$

Define $\hat{\rho}_1^+(\rho_2^+)$ such that $f(\hat{\rho}_1^+, \rho_2^+) = \Theta$. Recall from Proposition 1 that $\partial \hat{\rho}_1(\rho_2)/\partial \rho_2 < 0$ and note that $\partial \rho_2^+/\partial \eta > 0$. Thus, $\partial \hat{\rho}_1^+/\partial \eta < 0$. Finally note that $\lim_{\eta \rightarrow 1} \rho_1^+ = \lim_{\eta \rightarrow 1} \rho_2^+ = 1$. Thus, (13) cannot be satisfied for $\eta \rightarrow 1$. Now suppose $\Gamma = \{\Gamma_A^-, \Gamma_B^-\}$. It is straightforward to show that the venture will be dissolved if

$$f(\rho_1^-, \rho_2^-) \equiv \frac{\rho_1^-}{1 - \rho_1^-} + \frac{\rho_2^-}{1 - \rho_2^-} \leq \Theta. \quad (14)$$

Define $\hat{\rho}_1^-(\rho_2^-)$ such that $f(\hat{\rho}_1^-, \rho_2^-) = \Theta$. It is straightforward to show that $\partial \hat{\rho}_1^-/\partial \eta > 0$. Moreover, $\lim_{\eta \rightarrow 1} \rho_1^- = \lim_{\eta \rightarrow 1} \rho_2^- = 0$. Hence, (14) is always satisfied for $\eta \rightarrow 1$. \square

When both founders are sufficiently likely to have some skills, it is always optimal to preserve the team in order to prevent opportunistic behavior of a generalist. To what extent the dissolution of the venture is optimal in order to prevent the dud team problem, depends on the quality of the signals. For uninformative signals ($\eta = 1/2$), it does not matter whether both signals are positive or negative; dissolving the venture is always optimal if $\rho_1 < \hat{\rho}_1$.³¹ The more informative the signals, the smaller the region where dissolving the venture is optimal for two positive signals, and the larger the region where a dissolution is optimal for two negative signals (as $\partial \hat{\rho}_1^+/\partial \eta < 0$ and $\partial \hat{\rho}_1^-/\partial \eta > 0$). For sufficiently precise signals ($\eta \rightarrow 1$), keeping the team together with $\alpha^* = 1/2$ is always optimal in case of two positive signals ($\Gamma = \{\Gamma_A^+, \Gamma_B^+\}$), and dissolving the venture is always optimal in case of two negative signals ($\Gamma = \{\Gamma_A^-, \Gamma_B^-\}$). Note also that founders prefer delayed contracting for sufficiently low values of ρ_1 and ρ_2 . In fact, the result on the dissolution of the venture in case of two positive signals only applies to a

³¹In fact, founders would then never write a contract upfront; see Proposition 1.

parameter region where the founders would prefer delayed contracting anyway.

Proof of Proposition 3.

We define $\hat{\rho}_1^s(\eta)$ as the threshold between upfront and delayed contracting in the presence of verifiable signals. Suppose $\eta = 1/2$. Recall from Proof of Proposition 2 that $\rho_1^+ = \rho_1^- = \rho_1$ and $\rho_2^+ = \rho_2^- = \rho_2$ for $\eta = 1/2$, and $\alpha^* = 1/2$. This implies that $\hat{\rho}_1^+(\rho_2^+) = \hat{\rho}_1^-(\rho_2^-) = \hat{\rho}_1(\rho_2)$ for $\eta = 1/2$. Thus, the expected utility of upfront contracting with signals, denoted $EU_u^s(\eta)$, equals the expected utility of upfront contracting without signals, EU_u , for $\eta = 1/2$. Consequently, $\hat{\rho}_1^s(\eta) = \hat{\rho}_1$ for $\eta = 1/2$. Delayed contracting is thus optimal for $\eta = 1/2$ when the condition from Proposition 1 is satisfied. Now suppose that $\eta > 1/2$. We know from Proposition 2 that $d\alpha^*/d\eta > 0$ for upfront contracting. Thus, $dEU_u^s(\eta)/d\eta > 0$. This has the following two implications: (i) $\hat{\rho}_1^s(\eta) < \hat{\rho}_1$ for all $\eta > 1/2$; and (ii), $d\hat{\rho}_1^s(\eta)/d\eta < 0$. Finally suppose that $\eta = 1$. Then we know from Proposition 2 that $\alpha^* = 1$. Thus, $U_J^{dud}(\alpha^* = 1) = U^{solo}$. Moreover, note that $\eta = 1$ ensures that only an ineffective founder in a dud team loses his vested shares. Because $\alpha^*(\eta = 1) = 1$, it is then straightforward to show that $EU_u^s(\eta = 1) > EU_d$ for all $\rho_1, \rho_2 > 0$. \square

Proof of Proposition 4.

We can write the founders' expected utilities as

$$U^A(d_A, \alpha) = d_A + \alpha\mu(e_x e_y)\pi - c(e_x^A + e_y^A) \quad (15)$$

$$U^B(d_B, \alpha) = d_B + (1 - \alpha)\mu(e_x e_y)\pi - c(e_x^B + e_y^B), \quad (16)$$

where $d_B = \pi_L - d_A$. Note that both founders are symmetric at date 0, so the optimal ex-ante contract must be symmetric: $d_A^* = d_B^* = \pi_L/2$ and $\alpha^* = 1/2$. Now consider upfront contracting, and suppose that A turns out to be a generalist at date 1, and B is ineffective. The contract stipulates the equity allocation $\alpha = 1/2$, while the jointly efficient equity allocation is $\alpha = 1$. From (15) and (16) we can see that the debt claims d_A and d_B do not affect the generalist's effort incentives. The generalist can offer the ineffective partner some of his debt claim in exchange for some equity. Thus, as long as $\pi_L > 0$ (which implies $d_A > 0$) renegotiation leads to a Pareto improvement. Let $d_{A-B}(\alpha_{B-A})$ denote the debt claim that A transfers to B in exchange for the equity stake α_{B-A} , where $d_{A-B}(\alpha_{B-A})$ needs to satisfy $d_{A-B}(\alpha_{B-A}) \leq \pi_L/2$ and $U^B(\pi_L/2 + d_{A-B}(\alpha_{B-A}), 1/2 - \alpha_{B-A}) \geq U^B(\pi_L/2, 1/2)$. Joint surplus is maximized for $\alpha_{B-A} = 1/2$, so that $\alpha = 1$. Let $\hat{\pi}_L$ denote the required value of π_L so that $\alpha_{B-A} = 1/2$, where

$\widehat{\pi}_L > 0$. Thus, for $\pi_L \geq \widehat{\pi}_L$ the renegotiation outcome is $\alpha^* = 1$ and $d_B^* > d_A^* \geq 0$. And for $\pi_L < \widehat{\pi}_L$ we have $1/2 < \alpha^* < 1$ and $d_B^* = \pi_L > d_A^* = 0$.

Now consider delayed contracting, and suppose that A is a generalist and B is a specialist. Consider the pure idea stealing scenario with $\widehat{\alpha}_{g.s} = 1$. Joint surplus can be improved if the generalist transferred some equity to the specialist, so that also the specialist exerts some effort (where joint surplus is maximized at $\alpha = 1/2$). However, since $\widehat{\alpha}_{g.s} = 1$ this requires the specialist to compensate the generalist for his lost utility. Recall that the generalist gets $\delta\pi_L$ of the downside returns under idea stealing, while the specialist gets $(1 - \delta)\pi_L$. Thus, renegotiation is only Pareto improving if $\delta < 1$. If $\delta = 1$ we have $\alpha^* = 1$ and $d_A^* = \pi_L > d_B^* = 0$. Suppose $\delta < 1$, and let $d_{B-A}(\alpha_{A-B})$ denote the debt claim that B transfers to A in exchange for the equity stake α_{A-B} . Joint surplus is maximized when $\alpha_{A-B} = 1/2$. Define $\widehat{\pi}_L$ as the required value of π_L so that $\alpha_{A-B} = 1/2$. It is easy to see that $\widehat{\pi}_L$ is increasing in δ . Thus, for $\pi_L \geq \widehat{\pi}_L$ the equilibrium contract is given by $\alpha^* = 1/2$ and $\pi_L \geq d_A^* > 0$ and $d_B^* \geq 0$. Moreover, for $\pi_L < \widehat{\pi}_L$ we have $\alpha^* \in (1/2, 1)$ and $d_A^* = \pi_L > d_B^* = 0$. Now consider idea stealing threatened. The only difference to pure idea stealing is that for $\delta = 1$ the generalist keeps the entire downside return π_L , but now offers the specialist an equity share, so that $\alpha^* \in (1/2, 1)$. \square

Proof of Proposition 5.

First consider upfront contracting. Suppose the investor could offer a contingent contract with (i) I^{dream} in case of a dream team, and (ii) I^{dud} in case of a dud team. Consider first the dream team. Note that $\gamma(I)$ would then be defined by

$$\mu^{dream}(e_x(\gamma)e_y(\gamma))\gamma\pi = I.$$

The two founders would choose I , with $I \geq K$, to maximize $2U^{dream}(\gamma(I), I)$. Let EU_u^I denote the expected utility of the outside investor. Noting that $EU_u^I = 0$ in equilibrium, the optimal investment I^{dream} maximizes $EU_J \equiv EU_u^A + EU_u^B + EU_u^I$, which can be written as

$$\begin{aligned}
EU_J(I) &= \frac{1 - \gamma(I)}{2} \mu^{dream}(e_x(\gamma(I))e_y(\gamma(I)))\pi + \frac{I}{2} - c(e_x^A(\gamma(I)) + e_y^A(\gamma(I))) \\
&\quad + \frac{1 - \gamma(I)}{2} \mu^{dream}(e_x(\gamma(I))e_y(\gamma(I)))\pi + \frac{I}{2} - c(e_x^B(\gamma(I)) + e_y^B(\gamma(I))) \\
&\quad + \mu^{dream}(e_x(\gamma(I))e_y(\gamma(I)))\gamma(I)\pi - I \\
&= \frac{1}{2} \mu^{dream}(e_x(\gamma(I))e_y(\gamma(I)))\pi - c(e_x^A(\gamma(I)) + e_y^A(\gamma(I))) \\
&\quad + \frac{1}{2} \mu^{dream}(e_x(\gamma(I))e_y(\gamma(I)))\pi - c(e_x^B(\gamma(I)) + e_y^B(\gamma(I))) \\
&= 2U^{dream}(\gamma(I)).
\end{aligned}$$

Because $de_x(\gamma)/d\gamma < 0$ and $de_y(\gamma)/d\gamma < 0$, we have $dU^{dream}(\gamma)/d\gamma < 0$. Thus, $I^{dream} = K$, so that $\gamma = \gamma(K)$. Now consider the dud team. Note that $\gamma(I)$ is then defined by

$$\mu^{dud}(e_x(\gamma)e_y(\gamma))\gamma\pi = I. \quad (17)$$

Suppose that only the ineffective partner receives the excess payment $I - K$ and has to give up the equity share γ . The expected utility of the ineffective partner is then

$$U_i^{dud}(\gamma(I), I - K) = \left(\frac{1}{2} - \gamma(I)\right) \mu^{dud}(e_x e_y)\pi + I - K.$$

Using (17) we get

$$U_i^{dud}(\gamma(I), I - K) = \frac{1}{2} \mu^{dud}(e_x e_y)\pi - K,$$

which only depends on K . Thus, raising the extra amount $I - K$ does not affect U_i^{dud} in case the ineffective partner gets I in exchange for the equity stake $\gamma(I)$. Now suppose that the generalist receives the payment I and has to give up γ . It is then optimal for the generalist to use $I - K$ to buy as much equity from the ineffective partner as possible. From the above we can infer that the generalist would give up exactly $\gamma(I) - \gamma(K)$ in exchange for $I - K$, so that in equilibrium the generalist is back to his initial equity share $1/2$. Thus, raising the extra capital $I - K$ does

not affect U_J^{dud} in case the generalist gets I in exchange for giving up $\gamma(I)$. Overall this implies that $I^{dud} = K$, so that $\gamma = \gamma(K)$. Because $I^{dream} = I^{dud} = K$ in case of a contingent contract, it must also hold that $I_u^* = K$ in the absence of a contingent contract.

Now consider delayed contracting. We first note that any transfer from the specialist to the generalist must maximize joint surplus; otherwise the generalist would always reject the specialist's offer. Let EU_d^I denote the expected utility of the outside investor. Recall that $EU_d^I = 0$ in equilibrium; thus, I_d^* maximizes $EU_J(I) \equiv EU_d^A + EU_d^B + EU_d^I$. Without loss of generality, let founder A be the generalist, and founder B the specialist. Noting that $(1 - \gamma(I))\pi$ is the remaining total payoff for A and B , we can write $EU_J(I)$ as

$$\begin{aligned}
EU_J(I) &= (1 - \gamma(I))\alpha_{g.s}(I)\mu(e_x(\gamma(I))e_y(\gamma(I)))\pi + I - K - c(e_x^A(\gamma(I)) + e_y^A(\gamma(I))) \\
&\quad + (1 - \gamma(I))(1 - \alpha_{g.s}(I))\mu(e_x(\gamma(I))e_y(\gamma(I)))\pi - c(e_x^B(\gamma(I)) + e_y^B(\gamma(I))) \\
&\quad + \mu(e_x(\gamma)e_y(\gamma))\gamma\pi - (I - K) \\
&= (1 - \gamma(I))\alpha_{g.s}(I)\mu(e_x(\gamma(I))e_y(\gamma(I)))\pi - c(e_x^A(\gamma(I)) + e_y^A(\gamma(I))) \\
&\quad + (1 - \alpha_{g.s}(I)(1 - \gamma(I)))\mu(e_x(\gamma(I))e_y(\gamma(I)))\pi - c(e_x^B(\gamma(I)) + e_y^B(\gamma(I))) \\
&= U_{g.s}(\alpha_{g.s}(I), \gamma(I)) + U_{s.g}(\alpha_{g.s}(I), \gamma(I)).
\end{aligned}$$

We note that $d\alpha_{g.s}(I)/dI < 0$. Because $\gamma'(I) > 0$, we then have $de_x^A/dI, de_y^A/dI < 0$. Moreover, note that the total surplus that is split between both founders, $(1 - \gamma(I))\pi$, is decreasing in I . Thus, $d(e_x^A + e_x^B)/dI, d(e_y^A + e_y^B)/dI < 0$. Consequently, $d[U_{g.s}(\cdot) + U_{s.g}(\cdot)]/dI < 0$, which implies $I_d^* = K$. \square

Outside Investors – Alternative Contracts.

Let $\Psi_u \equiv \{\alpha_u(K), \beta_u(K), \gamma_u(K)\}$ denote the optimal contract under upfront contracting when $I = K$ (see Proposition 5), and $\Psi_d \equiv \{\alpha_d(K), \beta_d(K), \gamma_d(K)\}$ the optimal contract under delayed contracting, where A gets α , B gets β , and the outside investor gets γ . We now show that there exists no alternative contract $\Psi'_j, j \in \{u, d\}$, that is strictly Pareto superior to the contract Ψ_j .

Consider upfront contracting. We first note that the contract Ψ_u , with $\alpha_u(K) = \beta_u(K) = (1 - \gamma_u(K))/2$, maximizes the joint surplus of dream teams. We can therefore focus on the dud team. W.l.o.g. suppose that A is the generalist and B ineffective. Recall that $dU_J/d\alpha_u > 0$, with $U_J = U^A + U^B + U^I$. Thus, a Pareto superior contract must comprise an equity stake α'_u for A with $\alpha'_u = \alpha_u(K) + \varepsilon_u, \varepsilon_u > 0$. We denote this contract by Ψ'_u . This contract then

requires that $\beta'_u + \gamma'_u = \beta_u(K) + \gamma_u(K) - \varepsilon_u$, i.e., either B or the investor, or both, need to relinquish some equity. Because $\hat{\beta} = \hat{\alpha}_{i.g} \geq 1/2$, as assumed for our base model, we have $U^B(\beta'_u) < U^B(\beta_u(K))$. Thus, the investor needs to make a transfer payment to B in order to compensate him for his loss of utility. Recall that B and the investor are both unproductive. Thus, making a transfer payment to B is equivalent to transferring some of the investor's equity, which we denote by $\bar{\gamma}_u$. Moreover, both being unproductive implies that B and the investor have symmetric preferences with respect to their own equity stakes, so that $\hat{\beta} = \hat{\gamma} \geq 1/2$. Thus, $dU^I/d\bar{\gamma}_u < 0$, so that for any $\bar{\gamma}_u > 0$ the investor's zero-profit condition is violated. This also implies that it is never optimal for the outside investor to transfer some of his equity directly to A . Consequently, there exists no alternative contract Ψ'_u , with $\Psi'_u \neq \Psi_u$, which is Pareto superior.

For delayed contracting we know that the contract Ψ_d maximizes the joint surplus of dream teams. Thus, we can focus on a generalist-specialist team, where the generalist steals the idea. W.l.o.g. suppose that A is the generalist and B the specialist. Recall that $dU_J/d\beta > 0$ for $\beta \in [0, 1/2)$. Thus, a Pareto superior contract must consist of an equity stake $\beta'_d > 0$ for B ; we denote this contract by Ψ'_d . Note that offering $\beta'_d > 0$ then requires that $\alpha'_d + \gamma'_d = \alpha_d(K) + \gamma_d(K) - \varepsilon_d$ i.e., either A or the investor, or both, need to give up some equity. The generalist (A) prefers the equity stake $\hat{\alpha} = 1$, so that giving up some his equity requires compensation from the investor. Note that the investor would then prefer transferring equity as a compensation (instead of making a lump sum payment), as this also improves the generalist's effort incentives. Moreover, for any fixed $\beta < 1$ it is easy to see that the investor's expected utility $U^I(\gamma)$ is strictly increasing in γ for $\gamma < \hat{\gamma}$, and decreasing in γ for $\gamma \geq \hat{\gamma}$ (this is because the investor behaves exactly as the ineffective partner in a dud team). Thus, there exist two values of γ that satisfy the investor's zero-profit condition ($U^I(\gamma) = K$), which we denote for now $\gamma_1(K)$ and $\gamma_2(K)$, with $\gamma_1(K) < \gamma_2(K)$. Note that the founders always offer the investor $\gamma(K) \equiv \gamma_1(K)$ in order to maximize their own expected utilities. Thus, $dU^I(\gamma)/d\gamma > 0$ for the relevant parameter range. This implies that it is never optimal for the outside investor to relinquish some of his equity (to either compensate A or to increase B 's stake). Consequently, there exists no alternative contract Ψ'_d which is strictly Pareto superior to Ψ_d .

Proof of Proposition 6.

First note that a higher Λ compromises the effort incentives of the generalist; thus, $dU^{solo}(1 - \Lambda)/d\Lambda < 0$. Consider a generalist/ineffective team, and let $U_J^{dud}(\Lambda) \equiv U^{solo}(1 - \Lambda) + U_i^{dud}(\Lambda)$. It follows immediately that $dU_J^{dud}(\Lambda)/d\Lambda < 0$. Now consider a generalist/specialist team (idea stealing), and let $U_J^{steal}(\Lambda) \equiv U^{solo}(1 - \Lambda) + U_{s.g}(\Lambda)$. Because the specialist obtains Λ after the production stage, the entire effort is provided by the generalist. Thus, $dU_J^{steal}(\Lambda)/d\Lambda < 0$.

Following along the lines of Proof of Proposition 1, one can show that founder $f = A, B$ prefers to sign a contract upfront if

$$f(\rho_1, \rho_2) = \frac{\rho_1}{1 - \rho_1} + \frac{\rho_2}{1 - \rho_2} \leq \Theta(\Lambda), \quad \Theta(\Lambda) = \frac{U_J^{dud}(\Lambda) - U_J^{dud}}{2U^{dream} - U_J^{steal}(\Lambda)}.$$

Because $dU_J^{dud}(\Lambda)/d\Lambda < 0$ and $dU_J^{steal}(\Lambda)/d\Lambda < 0$, it follows that $d\Theta(\Lambda)/d\Lambda < 0$. Moreover, it is straightforward to show that $\Theta(0) = \Theta$. This implies that $d\hat{\rho}_1(\rho_2, \Lambda)/d\Lambda < 0$, with $\hat{\rho}_1(\rho_2, 0) = \hat{\rho}_1(\rho_2)$; see Proof of Proposition 1. \square

Founders' Incentives to Invest in Skills.

Because of symmetry, we can focus on founder A 's incentives to invest in his main skill; founder B 's incentives are identical. The expected utility of founder A is given by

$$EU^A(s^A) = \rho_1^A \rho_2 V_{11} + \rho_1^A \bar{\rho}_2 V_{10} + \bar{\rho}_1^A \rho_2 V_{01} + \bar{\rho}_1^A \bar{\rho}_2 V_{00} - c(s^A),$$

where

$$\begin{aligned} V_{11} &= \rho_1^B \rho_2 U_{g,g} + (\rho_1^B \bar{\rho}_2 + \bar{\rho}_1^B \rho_2) U_{g,s} + \bar{\rho}_1^B \bar{\rho}_2 U_{g,i} & V_{00} &= \rho_1^B \rho_2 U_{i,g} \\ V_{10} &= \rho_1^B \rho_2 U_{s,g} + \rho_1^B \bar{\rho}_2 U_{s,s} & V_{01} &= \rho_1^B \rho_2 U_{s,g} + \bar{\rho}_1^B \rho_2 U_{s,s} \end{aligned}$$

Founder A 's optimal choice of s^A is defined by the following first-order condition:

$$\psi z^A = c'(s^A), \tag{18}$$

where

$$z^A = \rho_2 (V_{11} - V_{01}) + \bar{\rho}_2 (V_{10} - V_{00}).$$

We note that z^A measures the strength of founder A 's incentives to develop his main skill. For example, if some effort level s^A satisfies (18) for upfront contracting so that $\psi z_u^A = c'(s^A)$, then delayed contracting leads to a higher effort if and only if $z_d^A > z_u^A$ at the same value of s^A . To measure the relative strength of incentives we can therefore focus on $\Delta z^A = z_d^A - z_u^A$. Using the utility levels for the various skill combinations under upfront and delayed contracting then yields Δz^A .

To see this more formally, we use the symmetry condition $\rho_1^A = \rho_1^B \equiv \rho_1$ to simplify Δz^A :

$$\Delta z^A = \rho_2 [\rho_1 \rho_2 (U^{dream} - U_s^{steal}) + \rho_1 \bar{\rho}_2 \Omega + \bar{\rho}_1 \rho_2 (U_g^{steal} - U^{dream}) + \bar{\rho}_1 \bar{\rho}_2 (U^{solo} - U_g^{dw})]$$

where

$$\Omega = U_i^{dw} + U_J^{steal} - 2U^{dream}.$$

The term Ω depends on the shape of utility functions and can be positive or negative. We note that Δz^A is always positive if $\Omega \geq 0$. Even for $\Omega < 0$ the other three terms are likely to ensure that Δz^A remains positive. In fact, Δz^A becomes negative only if $\rho_1 \bar{\rho}_2$ becomes the dominant term among the four probability terms. This requires that both ρ_1 is sufficiently large and ρ_2 is sufficiently small. The following lemma provides a more formal statement for this.

Lemma 1

- (i) If $\Omega \geq 0$, then $\Delta z^A > 0$.
- (ii) If $\Omega < 0$ and $\rho_2 > \hat{\rho}_2 \equiv \frac{-\Omega}{U^{dream} - U_s^{steal} - \Omega}$ ($< \frac{1}{2}$), then $\Delta z^A > 0$.
- (iii) If $\Omega < 0$ and $\rho_2 \leq \hat{\rho}_2$, then there exists a threshold $\hat{\rho}_1$ so that $\rho_1 < \hat{\rho}_1$ implies $\Delta z^A > 0$.
The threshold $\hat{\rho}_1$ is increasing in ρ_2 .

Proof: We first define

$$\tilde{z} \equiv \rho_1 \rho_2 (U^{dream} - U_s^{steal}) + \rho_1 \bar{\rho}_2 \Omega + \bar{\rho}_1 \rho_2 (U_g^{steal} - U^{dream}) + \bar{\rho}_1 \bar{\rho}_2 (U^{solo} - U_g^{dw}).$$

Clearly, $\Delta z^A > 0$ if $\tilde{z} > 0$. Note that $\tilde{z} > 0$ is satisfied whenever $\Omega \geq 0$. We now focus on the case where $\Omega < 0$, and derive conditions so that $\tilde{z} > 0$ is still satisfied. We define $\hat{\rho}_1$ as the value of ρ_1 which satisfies $\tilde{z} = 0$ for a given ρ_2 . Below we show that $d\hat{\rho}_1/d\rho_2 > 0$. Thus, to find the upper bound of ρ_2 so that $\tilde{z} > 0$, we can focus on the extreme case $\rho_1 = 1$. The condition $\tilde{z} > 0$ then becomes

$$\rho_2 (U^{dream} - U_s^{steal}) + \bar{\rho}_2 \Omega > 0,$$

which is equivalent to

$$\rho_2 > \frac{-\Omega}{U^{dream} - U_s^{steal} - \Omega} \equiv \hat{\rho}_2.$$

Note that the denominator of $\hat{\rho}_2$ is strictly positive as $\Omega < 0$. Using the definition of Ω we can show that $\hat{\rho}_2 < 1/2$:

$$\begin{aligned} \frac{1}{2} &> \frac{-U_i^{dw} - U_s^{steal} - U_g^{steal} + 2U^{dream}}{U^{dream} - U_s^{steal} - U_i^{dw} - U_s^{steal} - U_g^{steal} + 2U^{dream}} \\ \Leftrightarrow U_i^{dw} + U_g^{steal} &> U^{dream}, \end{aligned}$$

which is always satisfied as $U_g^{steal} > U^{dream}$. Thus, $\widehat{\rho}_2 < 1/2$. Next, we solve $\widetilde{z} > 0$ for ρ_1 :

$$\rho_1 < \frac{\rho_2(U_g^{steal} - U^{dream}) + \bar{\rho}_2(U^{solo} - U_g^{dw})}{\underbrace{\rho_2(U_J^{steal} - 2U^{dream})}_{\equiv y_1} + \underbrace{\bar{\rho}_2(U^{solo} - U_g^{dw} - \Omega)}_{\equiv y_2}} \equiv \widehat{\rho}_1.$$

Note that $y_1 < 0$ and $y_2 > 0$. Recall that $\widehat{\rho}_2 < 1/2$. Thus, to show that the denominator of $\widehat{\rho}_1$ is always positive, we can evaluate the denominator at $\rho_2 = 1/2$:

$$\begin{aligned} \frac{1}{2}(U_J^{steal} - 2U^{dream}) + \frac{1}{2}(U^{solo} - U_g^{dw} + 2U^{dream} - U_i^{dw} - U_J^{steal}) &> 0 \\ \Leftrightarrow (U^{solo} - U_J^{dw}) &> 0. \end{aligned}$$

Finally we evaluate $\widehat{\rho}_1$ at $\rho_2 = 0$:

$$\widehat{\rho}_1(\rho_2 = 0) = \frac{U^{solo} - U_g^{dw}}{U^{solo} - U_g^{dw} - \Omega} = \frac{U^{solo} - U_g^{dw}}{(U^{solo} - U_J^{dw}) + (2U^{dream} - U_J^{steal})} < 1.$$

To summarize, we have $\widehat{\rho}_1(\rho_2 = 0) < 1 = \widehat{\rho}_1(\rho_2 = \widehat{\rho}_2)$.

Next, we show that $d\widehat{\rho}_1/d\rho_2 > 0$. Recall that $\widehat{\rho}_1$ is defined by $\widetilde{z} = 0$. Implicit differentiating $\widehat{\rho}_1$ with respect to ρ_2 yields

$$\frac{d\widehat{\rho}_1}{d\rho_2} = -\frac{\frac{d\widetilde{z}}{d\rho_2}}{\frac{d\widetilde{z}}{d\rho_1}}.$$

Consider the derivative $d\widetilde{z}/d\rho_1$:

$$\frac{d\widetilde{z}}{d\rho_1} = \rho_2(U^{dream} - U_s^{steal}) + \bar{\rho}_2\Omega - \rho_2(U_g^{steal} - U^{dream}) - \bar{\rho}_2(U^{solo} - U_g^{dw}).$$

Using $\widetilde{z} = 0$ we get

$$\rho_2(U^{dream} - U_s^{steal}) + \bar{\rho}_2\Omega = -\frac{\bar{\rho}_1}{\rho_1}\rho_2(U_g^{steal} - U^{dream}) - \frac{\bar{\rho}_1}{\rho_1}\bar{\rho}_2(U^{solo} - U_g^{dw}).$$

Using this relationship we can rewrite $d\widetilde{z}/d\rho_1$ as follows:

$$\frac{d\widetilde{z}}{d\rho_1} = -\frac{\bar{\rho}_1}{\rho_1}\rho_2 \underbrace{(U_g^{steal} - U^{dream})}_{>0} - \frac{\bar{\rho}_1}{\rho_1}\bar{\rho}_2 \underbrace{(U^{solo} - U_g^{dw})}_{>0} - \rho_2 \underbrace{(U_g^{steal} - U^{dream})}_{>0} - \bar{\rho}_2 \underbrace{(U^{solo} - U_g^{dw})}_{>0}.$$

Thus, $d\tilde{z}/d\rho_1 < 0$. Now consider the derivative $d\tilde{z}/d\rho_2$:

$$\frac{d\tilde{z}}{d\rho_2} = \rho_1(U^{dream} - U_s^{steal}) - \rho_1\Omega + \bar{\rho}_1(U_g^{steal} - U^{dream}) - \bar{\rho}_1(U^{solo} - U_g^{dw}).$$

Using $\tilde{z} = 0$ we get

$$\rho_1(U^{dream} - U_s^{steal}) + \bar{\rho}_1(U_g^{steal} - U^{dream}) = -\frac{\bar{\rho}_2}{\rho_2}[\rho_1\Omega + \bar{\rho}_1(U^{solo} - U_g^{dw})].$$

Thus,

$$\begin{aligned} \frac{d\tilde{z}}{d\rho_2} &= -\frac{\bar{\rho}_2}{\rho_2}[\rho_1\Omega + \bar{\rho}_1(U^{solo} - U_g^{dw})] - \rho_1\Omega - \bar{\rho}_1(U^{solo} - U_g^{dw}) \\ &= \left[-\frac{\bar{\rho}_2}{\rho_2} - 1\right][\rho_1\Omega + \bar{\rho}_1(U^{solo} - U_g^{dw})] \\ &= -\frac{1}{\rho_2}[\rho_1\Omega + \bar{\rho}_1(U^{solo} - U_g^{dw})]. \end{aligned}$$

Recall that at $\rho_2 = 0$ we have

$$\hat{\rho}_1(\rho_2 = 0) = \frac{U^{solo} - U_g^{dw}}{U^{solo} - U_g^{dw} - \Omega}.$$

Therefore,

$$1 - \hat{\rho}_1(\rho_2 = 0) = \frac{-\Omega}{U^{solo} - U_g^{dw} - \Omega}.$$

Using $\hat{\rho}_1(\rho_2 = 0)$ and $1 - \hat{\rho}_1(\rho_2 = 0)$ we can write $d\tilde{z}/d\rho_2$ as

$$\frac{d\tilde{z}}{d\rho_2} = -\frac{1}{\rho_2} \left[\frac{U^{solo} - U_g^{dw}}{U^{solo} - U_g^{dw} - \Omega} \Omega + \frac{-\Omega}{U^{solo} - U_g^{dw} - \Omega} (U^{solo} - U_g^{dw}) \right] = 0.$$

This implies that $d\tilde{z}/d\rho_2 > 0$ for all $\rho_2 > 0$. Thus, $d\hat{\rho}_1/d\rho_2 > 0$. □

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