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## **Alliances under Ambiguity: Contract Detail as an Inimitable Signal of Competence**

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### **Abstract**

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## Abstract

We demonstrate that contract form can affect the value of strategic alliances in the presence of ambiguity. When no ambiguity is present, contracts that simply articulate a plan-of-action are sufficient to induce value maximizing behavior under the legal institution of compensating damages. When both parties harbor ambiguous beliefs, we show that there are situations in which deliverable-style contracts not only induce efficient behavior, but actually *increase* the joint value of the project. This is interesting because this effect does not arise in the no-ambiguity case. In such situations, compensating damages may act as a blunt form of “ambiguity insurance.” Our main result shows that, in ambiguous settings, a knowledgeable suitor firm can offer a less knowledgeable target partner an extended set of state-contingent transfer payments that: *i*) cannot be imitated by a competitor who is also less knowledgeable than the suitor; and, *ii*) offers the target strictly greater value than the best possible offer from the competitor. In other words, firms can use contract detail (in the form of state-contingent payments) as an effective, inimitable signal of superior competence.

# 1 Introduction

An active research question in management is how the experience and relational capital of business partners affects the content and structure of formal contracts governing their interactions. Findings in this stream are far from conclusive. Some studies identify a positive correspondence between relational capital and contract detail, finding that prior relationships lead to more detailed contracts (e.g., Poppo and Zenger, 2002; Mayer and Argyres, 2004; Argyres et al., 2007). In contrast, a number of other studies find a substitution effect between experience and formal organization – that is, that stronger relationships permit the use of less detailed contracts and, sometimes, do away with the need for formal mechanisms altogether (e.g., Gulati, 1995; Gulati and Singh, 1998; Uzzi, 1997).

Not surprisingly, perhaps, more recent work demonstrates that these effects are subtle. In Ryall and Sampson (2009), for example, experience (both in terms of alliance deals generally and in terms of partner familiarity) is correlated with greater overall contract detail. However, the effect of experience on the inclusion of specific types of clause is mixed: (i) the stipulation of specific technologies to be contributed by each party is greater between experienced versus inexperienced firms; (ii) reviews of specified outcomes are greater between inexperienced versus experienced firms; (iii) the inclusion of specified penalties for underperformance are more likely when at least one of the partners is experienced. Simple explanations, such as learning-by-doing, do not neatly explain these facts.

With respect to formal theory, the contracting literature in economics is extensive. In particular, the stream on formal contracting in the presence of relational governance mechanisms is large and active (e.g., Baker et al., 1994; Bernheim and Whinston, 1998b; Levin, 2003; Kvaloy and Olsen, 2008, to cite a few). This line of work refines our understanding of the interplay between formal and informal governance mechanisms far beyond the original insight of Radner (1981, i.e., that relational mechanisms may substitute for formal mechanisms). That being said, the high degree of mathematical abstraction in this work makes its findings difficult to map down to the detailed kinds of variation in contract structure mentioned above.

In this paper, we contribute to the formal theory of contracts by analyzing the effect of ambiguity on contract structure. By *ambiguity*, we mean that the parties contracting on a joint productive opportunity may be unable to map partner actions to precise likelihoods over all relevant contingencies. Implicit in our analysis is the assumption that more experienced managers have more

precise knowledge about the likely consequences of their partner’s actions and contributions with respect to the alliance project. Our goal is to generate substantive theory about the relationship between the structure of real-world alliance contracts and the relative knowledge of the parties to those contracts.

Specifically, we consider joint productive opportunities in which each firm knows what is required on its end of the project, but may have only a vague understanding of what is required of its partner. Contracts in our model may or may not contain clauses of the following types: *i*) elaboration of requisite actions; *ii*) performance requirements with respect to deliverables (intermediate work product); and, *iii*) specification of state-contingent transfer payments (penalties, bonuses, specified damages, etc.). Our contracts are typically “incomplete” in the traditional sense (i.e., do not specify contingencies for every relevant outcome). In addition, all actions and deliverables are assumed to be verifiable and, hence, enforceable in the courts.<sup>1</sup> We explicitly include the legal institution of compensatory damages. As we will see, this approach allows us to provide an explanation of variation in contract structure in which verifiable actions are included in some contracts governing a particular class of transaction but not in others.

For example, a small electronics firm may have a very refined understanding of how its own activities translate into likelihoods over development of, e.g., a microcontroller for a processor, but only a vague comprehension of what happens during the subsequent integration of the microcontroller into a microprocessor core by its partner. In such a situation, the electronics firm managers may well worry that any specific development plan favored by the partner during negotiations is not, in fact, a “first-best” option. Ambiguity aversion on the part of the electronics firm only amplifies this concern. This creates a substantial contracting problem. If inexperienced managers eye every development proposal with suspicion, negotiations may break down, with no deal ever executed – even though both parties recognize that, under the appropriate plan, they would both enjoy significant economic gain. One of the questions explored here is whether issues of this kind are mitigated or exacerbated by the structure of the contract.

In the following analysis, we examine three basic settings. In all three cases, firms contemplate

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<sup>1</sup>Moral hazard is, of course, a salient concern in most papers about contracts. Here, we focus only upon clauses specifying verifiable actions and deliverables in order to isolate the effect of ambiguity from that of moral hazard. That is, the terms we consider are the ones contracting parties could actually enforce by including them in a contract. Still, moral hazard lurks about implicitly in our analysis – faced with ambiguity, a firm may be concerned that the action plan presented by its partner as value maximizing for the joint endeavor is, instead, designed to maximize its own profits.

the formation of an alliance that involves each of them taking actions that induce the creation of deliverables. The link between one's actions and deliverables is stochastic, reflecting the uncertainty and idiosyncrasy inherent in technology development projects. Jointly, the firms' deliverables determine the overall value of the project. The first case we consider is the benchmark, no-ambiguity case: two experienced firms know not only the stochastic consequences of their own actions, but also those of their partner's actions. In the second case, each firm has only ambiguous knowledge about its partner's activities. Finally, we consider an asymmetric setting, in which two suitor firms compete for a partnership with a target firm (imagine two pharmaceuticals competing for a distribution deal with a biotech firm).

We demonstrate that contract form does, indeed, affect the governance and value of strategic alliances in the presence of ambiguity. Our initial result is that, when no ambiguity is present, plan-of-action type contracts (i.e., deliverables are not specified) are sufficient to implement efficient behavior and maximize joint outcomes. That is, when firms know each other's value maximizing actions, the legal institution of compensatory damages is sufficient to guarantee compliance without the need to resort to contractually-specified penalties.

Next, when both parties harbor ambiguous beliefs, we show that there are conditions under which incomplete, deliverables-style contracts not only induce efficient behavior, but actually increase the joint value of the project *beyond that attainable when actions are directly specified*.<sup>2</sup> This is significant because the prior theoretical literature considers deliverables-style contracts exclusively in the context of moral hazard (e.g., as a second-best solution when actions are hidden). Here we see a subtler role for such terms: mitigating the negative effect of ambiguity when the consequences of partner actions are poorly understood. Faced with a choice between explicitly specifying a partner's actions based upon a shaky understanding of the consequences of those actions versus contracting for a deliverable and relying upon the threat of court-awarded damages to induce the partner to act favorably toward the attainment of that deliverable, managers may have greater confidence in the latter.

Finally, and perhaps of most interest to strategy scholars, our main result shows that a knowledgeable firm can offer an ambiguity-challenged partner an extended set of state-contingent transfer payments that: *i*) cannot be imitated by a competitor who is also less knowledgeable than the suitor; and, *ii*) offers the target strictly greater value than the best possible offer from the competitor. In

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<sup>2</sup>By "deliverables-style" we mean contracts that specify desired outcomes rather than the activities or actions designed to achieve those outcomes.

other words, firms can use contract detail (in the form of state-contingent payments) as an effective, inimitable signal of superior competence.

Because the technical content of the paper is substantial, we begin with an extended example that illustrates all the important points. Readers uninterested in the mathematical generalities can restrict themselves to the example and still gain an understanding of all the essential ideas. In sections presenting our general results, we follow each proposition with an *empirical conjecture* intended to provide our thoughts on how the formal theory maps onto real-world contracts. Our aim is to go beyond the mathematics of the propositions and generate consistent predictions that relate more directly to empirical research.

In the next section, we illustrate ambiguity and ambiguity aversion, describe the technical approaches that have been developed to analyze settings in which ambiguity is present, and briefly discuss some of the work in this growing area of research. Next, in Section 3, we present our extended example. In the first part, Section 3.1, we illustrates all of the key objects in our model in a very simple setting. In Section 3.2, we go on to give numeric demonstrations of each of our propositions. The general model is elaborated in Section 4. Section 5 presents our results. In Section 6, we compare our theoretical findings against some examples taken from real-world contracts. Section 7 wraps up with a few concluding thoughts.

## 2 Ambiguity and ambiguity aversion

In order to develop theory linking real world contracts and ambiguity, we articulate an analytical framework in which natural rationality constraints on well-intentioned managers go hand-in-hand with incomplete contracts (i.e., in the spirit of Simon, 1957, 1961; Williamson, 1979). We do so by adopting a general, existing formalism for analyzing decision making under ambiguity. In our context, ambiguity limits the ability of managers to assess probabilities on all relevant contingencies when evaluating an alliance.

The Ellsberg Paradox (Ellsberg, 1961) provides a simple-yet-compelling illustration the focal phenomenon. Consider the following thought experiment. You are presented with an urn and told it contains 40 red balls and 60 other balls comprised of an unknown mix of green and yellow. You are then offered a choice between the following gambles:

1. Draw a ball from the urn, win \$100 if it is red, versus

2. Draw a ball from the urn, win \$100 if is green.

As a rational Bayesian, you make subjective probability assessment about the likelihood of drawing a green ball (say,  $x\%$ ) and compare it to the known probability of drawing a red ball (40%). Since the payoffs of these bets are equal, you strictly prefer Bet 1 if and only if  $x < .4$ . Before proceeding, you are offered a different pair of bets based upon drawing a ball from the *same* urn:

3. \$100 if red or yellow, versus
4. \$100 if green or yellow.

It should be easy to see that Bet 3 is strictly preferred to Bet 4 if and only if  $x < .4$ , the identical condition for strict preference of Bet 1. Therefore, consistency with the basic axioms of probability (Savage, 1954) implies that one should always always prefer bets 1 and 3 or bets 2 and 4. The problem is that, across a wide range of studies (see, e.g., Camerer and Weber, 1992), people are shown to regularly violate this consistency condition. In the preceding example, most subjects strictly prefer Bet 1 to Bet 2 and, then, Bet 4 to Bet 3.

This phenomenon has been termed *ambiguity aversion*. “Ambiguity” refers to decision problems under uncertainty in which probabilities cannot be observed or precisely estimated, as opposed to those in which they are reasonably well-defined or knowable. In economics, this distinction goes back at least to Knight (1921), who refers to the latter situations as “risky” and the former as “uncertain.” The idea is that humans tend to penalize assessments in which their information is less precise. In the first pair of gambles, the probability of winning Bet 1 is known (40%), while that of winning Bet 2 is not. In the second pair of gambles, the probability of winning Bet 4 is known (60%), while that of winning Bet 3 is not.

A substantial theoretical literature now exists with the goal of formalizing the analysis of choice under ambiguity aversion. The two approaches receiving the most attention are the Choquet expected utility (CEU) model of Schmeidler (1989) and the maxmin expected utility (MMEU) model of Gilboa and Schmeidler (1989). The CEU model uses non-additive probability functions to represent ambiguous beliefs. This approach has the nice feature that the informal notion of managers being incapable of knowing all future states of the world (much less assign precise probabilities to them) maps directly to a formalism in which subjective probabilities, quite literally, are not required to add up.

In this paper, we adopt the MMEU approach due to its analytical elegance and greater generality.<sup>3</sup> To illustrate the methodology, reconsider the Ellsberg Paradox example above. Suppose we wish to model a subject who really has *no sense* of the correct numbers of green and yellow balls. Let  $p = (r, g, y)$  list the probabilities of drawing a red, green or yellow ball, respectively. To represent the subject’s ambiguous beliefs, we assume she has multiple priors. Specifically, let  $p_1 = (.4, .6, 0)$  and  $p_2 = (.4, 0, .6)$ . Given the setup, these describe the two extreme possibilities in which  $p(r) = .4$  and  $p(\{g, y\}) = .6$  which, as we are told, must be true. The idea is that, although the subject knows the probability of red is 40%, she estimates the likelihood of green to be anywhere from 0% to 60% (and, similarly for yellow). Critically, we assume that the subject is “boundedly rational” in the sense of not being able to formulate likelihoods on probability distributions in order to come up with a second-order distribution that can then be used in the usual way.

Ambiguity *aversion* is built into assessments by making the assumption that agents behave pessimistically by evaluating the expected value of each choice using the distribution that minimizes the payoff. Consider Bet 1 (win \$100 if red). Since *both* distributions weight the likelihood of red at 40%, this bet has an expected value of \$40 – nothing new here. Bet 2, however, is ambiguous: the likelihood of green is somewhere between 0% and 60%. The pessimistic value is 0%, resulting in an expected payoff of \$0. Faced with a choice between Bet 1 and Bet 2, therefore, the model says an ambiguity averse subject chooses Bet 1. Using this procedure, it is not hard to show that the expected value of Bet 3 is \$40 (using  $p = (.4, .6, 0)$ ) and that of Bet 4 is \$60. Thus, in keeping with experimental findings, the model predicts ambiguity averse subjects choose Bet 4 in the second case.

In terms of existing work on theoretical applications involving ambiguity aversion, Mukerji (1998) is, to the best of our knowledge, the only paper that considers contracts explicitly. His model analyzes buyer-seller transactions with ambiguous investment hold-up problems. Investments are not contractible, but parties can contract on deliverables (e.g., the quality of product delivered). Using the CEU approach, he demonstrates: *i*) that ambiguity can result in inefficient and incomplete arms-length contracts; and, *ii*) vertical integration can result in strict efficiency improvements. In addition to examining strategic alliances rather than buyer-seller relationships, our analysis departs from Mukerji in that we assume parties can contract either upon actions or outcomes (the former is ruled out in Mukerji) and then examine the conditions under which one

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<sup>3</sup>Under broad conditions, MMEU includes CEU as a special case (Klibanoff, 2001).

structure is preferred to the other. Thus, we seek to explain variation in contract detail for alliances within a particular class of projects. Our main result, which demonstrates when a firm can turn contract detail to its competitive advantage, is obviously aimed more exclusively at a strategy audience.<sup>4</sup>

### 3 Extended Example

We now walk through a much simplified, numeric example to explain the formal objects and illustrate the results. The organization of this section parallels Sections 4 and 5 so that readers can tie the example directly back to the general analysis and *visa versa*.

#### 3.1 Example, Part I: The Model

Consider a joint technology development alliance between two, technologically symmetric firms. Each firm must choose between assigning one of two types of research teams to the project – *team x* or *team y*. Think of the differences between *x* and *y* as arising from team composition (either in terms of specific individuals or, more generally, roles and skills). Then, firm *i*'s *feasible action set* is  $\{x, y\}$ . An *action profile* lists the team contributions for Firm 1 and Firm 2, in that order; e.g.,  $(x, x)$ . Throughout the paper, a “profile” is a list in which the first element is associated with Firm 1 and the second with Firm 2.

The firms' respective teams produce “deliverables” which jointly determine the success of the project (e.g., technology patents). Suppose the key to success is whether the timing of the deliverable is *rapid* (*r*) or *delayed* (*d*). The timing of a firm's deliverable will depend stochastically upon the type of team assigned to the alliance. Firm *i*'s set of *deliverables* is  $\{r, d\}$  with a *deliverable profile* written, e.g.,  $(r, d)$ .

The overall value generated by the alliance,  $v$ , depends upon deliverables, with  $v(r, r) = 100$ ,  $v(r, d) = v(d, r) = 78$ , and  $v(d, d) = 33$ . Costs also depend upon deliverables. Assume that Firm *i*'s cost is correlated with the timing of its own deliverable:  $c_i(r) = 25$  and  $c_i(d) = 1.5$ . The

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<sup>4</sup>The general theoretical literature on ambiguity aversion is substantial. Interested readers may find the following papers useful: Kelsey and Quiggin (1992), Mukerji (1997), Casadesus-Masanell et al. (2000), Ghirardato and Marinacci (2002), Aragonés et al. (2005), Maccheroni et al. (2006), and Gilboa et al. (2008). Klibanoff et al. (2005) provide a general framework that allows distinct preferences for risk and uncertainty. Chamberlain (2000) develops an econometric algorithm for estimating MMEU choices and applies it in an autoregressive, random-effects model for panel data. Actual applications of the theory are much sparser. Epstein and Zin (1989) provide a well-known examination of asset returns. Lopomo et al. (2004) study mechanism design under ambiguity and show conditions under which a mechanism designer can extract full information rents from an agent.

values of the firms’ outside alternatives are normalized to zero. Deliverables can be thought of as the “states of the world” that determine outcomes. For example, by including a firm’s actions in the deliverables description, we can analyze cases in which firm costs depend only upon their own action choices. In the absence of a contract, we assume firms wind up splitting the joint value  $v$ . This leads to the following deliverables-contingent payoffs:

	Deliverables			
	$r, r$	$r, d$	$d, r$	$d, d$
$\frac{1}{2}v - c_1$	25.0	14.0	37.5	15.0
$\frac{1}{2}v - c_2$	25.0	37.5	14.0	15.0
Total	50.0	51.5	51.5	30

**Firm Types** Uncertainty about the effect of actions on deliverables enters through *firm types*. Here, each firm can be one of two *types*, denoted  $T_1$  and  $T_2$ . Each type maps a firm’s actions to probability distributions on its own deliverables. The assumptions for this example are detailed in Table 1. Thus, if firm 1 is type  $T_1$ , the probability that it delivers rapidly,  $r$ , given deployment of team type  $x$  is 0.90. A *type profile* lists one type for each of the two firms. The four possible type profiles are:  $(T_1, T_1)$ ,  $(T_1, T_2)$ ,  $(T_2, T_1)$ , and  $(T_2, T_2)$ .

Table 1: Firm types correspond to action-induced deliverable likelihoods

$T_1$	Timeliness		$T_2$	Timeliness	
Action	$r$	$d$	Action	$r$	$d$
$x$	.90	.10	$x$	.05	.95
$y$	.05	.95	$y$	.50	.50

Given a type profile, we compute probability distributions over deliverables profiles in the obvious way. For example, given type profile  $(T_1, T_1)$ , the probability of deliverable profile  $(r, r)$  given action profile  $(x, x)$  is  $(.9)(.9) = .81$ . The distributions induced by each of the four possible action profiles under type profile  $(T_1, T_1)$  are provided in the rows of Table 2.

**Contracts** Contracts consist of two parts. The first part is a performance specification. We consider action- and deliverables-based contracts. The second part is a contractually-specified

Table 2: Action-induced distributions on deliverables for types  $(T_1, T_1)$

Action Profile	Deliverable Profile			
	$(r, r)$	$(r, d)$	$(d, r)$	$(d, d)$
$(x, x)$	.8100	.0900	.0900	.0100
$(x, y)$	.0450	.8550	.0050	.0950
$(y, x)$	.0450	.0050	.8550	.0950
$(y, y)$	.0025	.0475	.0475	.9025

schedule of contingent transfer payments. Transfer payments do not enter the example until the last part of the analysis, so we momentarily set them aside. We write  $\lambda = (x, x, 0)$  to denote a contract requiring each firm to contribute a team of type  $x$  and with no specified transfer payment. Alternatively,  $\lambda' = (r, r, 0)$  is a contract requiring rapid completion of deliverables (with no specified transfers). The *null contract* includes no performance requirements or transfers. Under the null contract, Firm  $i$  gets half the joint value,  $v$ , less its own costs,  $c_i$ .

**Compensating Damages** If both firms perform according to their contractual requirements or if both firms fail to perform, the courts make no damages awards. If one firm fails to perform when its partner complies and its partner's payoff is less than expected under full compliance, the court awards damages to the compliant firm. The payoff expected by each firm under full compliance is referred to as the *full performance payoff* (FPP). A firm's FPP depends upon the contract in effect, the actual deliverables outcome and the type profile of the firms.

A firm's FPP under a deliverables-based contract is simply the amount the firm would have gotten under the specified deliverable outcome. For example, Firm 1's FPP under the contract  $\lambda = (r, r, 0)$  is 25. Under action-based contracts, the FPPs are expected values. For example, given type profile  $(T_1, T_1)$  and contract  $\lambda = (x, y, 0)$ , Firm 1's FPP is \$14.71, the expected value of its payoffs taken over deliverables outcomes conditional upon firm types  $(T_1, T_1)$  taking actions  $x$  and  $y$ , respectively.

When damages are awarded, they make up the difference between a firm's actual payoff and its FPP. For example, suppose the contract is  $\lambda = (x, x, 0)$  for firm types  $(T_1, T_1)$ . Suppose Firm 1 complies and Firm 2 breaches: the actual action profile is  $a = (x, y)$ . Then, Firm 2 must compensate Firm 1 under any deliverables outcome in which Firm 1 gets less than 25 (see Table

3). Alternatively, under  $\lambda = (r, r, 0)$ , compliance and damages depend only upon the deliverables outcomes (see Table 4). In this case, both firms are in compliance when the joint deliverables are  $(r, r)$ , regardless of the actions taken. Firm 2 breaches if the outcome is  $(r, d)$ . Clearly, different classes of contract have very different payoff implications.

Table 3: Damages-adjusted payoffs for Firm 1 under  $\lambda = (x, x, 0)$  when  $a = (x, y)$

	Outcomes			
	$r, r$	$r, d$	$d, r$	$d, d$
Unadjusted	25.0	14.0	37.5	15.0
Damages ( $\delta_1$ )	0.0	11.0	0.0	10.0
Net payoff ( $\pi_1$ )	25.0	25.0	37.5	25.0

Table 4: Damages-adjusted payoffs for Firm 1 under  $\lambda = (r, r, 0)$  and any action

	Deliverables			
	$r, r$	$r, d$	$d, r$	$d, d$
Unadjusted	25.0	14.0	37.5	15.0
Damages ( $\delta_1$ )	0.0	10.0	-10.0	0.0
Net payoff ( $\pi_1$ )	25.0	25.0	27.5	15.0

**Subjective Beliefs** The issue in this paper is how firms organize their contracts given ambiguity about the relationship between available action plans and their consequences. To represent this ambiguity, we endow each firm type with *subjective beliefs* about the true type profile. In keeping with the spirit of ambiguity, we do not automatically assume firms know each other's, or even their own, types. Say, the true type profile is  $(T_1, T_1)$  and Firm 1 knows its own type but not that of its partner. Then, formally, its beliefs are represented by the set of type profiles it cannot rule out:  $\{(T_1, T_1), (T_1, T_2)\}$ . We would say these beliefs are *ambiguous* because the set contains more than one element. Referring to Table 1, the interpretation of these beliefs is as follows. Firm 1 knows that *if* Firm 2 is type  $T_1$ , then  $x$  is the type of team that maximizes the likelihood of rapid delivery of its deliverable. On the other hand, type  $T - 2$  partners maximize rapid delivery with  $y$  type teams. Thus, Firm 1 is unsure of whether, say, to write a contract requiring an  $x$  or  $y$  team from

Firm 2.

**Strategies** Firms make their action choices based upon their beliefs. Thus, a *pure strategy* is a map from a firm’s type-contingent beliefs to its available actions. The important aspect about this is that strategies can only change based upon what the firm knows. If Firm 1 only knows its own type, then its strategy specifies two things: its team choice when its type is  $T_1$  versus the team chosen when its type is  $T_2$ . A firm that knows neither its own nor its partner’s type must employ a strategy that always chooses a single action regardless of the actual type profile.

**Ambiguity Aversion** A firm’s subjective expected payoff is determined by several things – the governing contract, the actual type profile, its beliefs (which reflect the ambiguity it faces), and the strategies employed by the firm and its partner. Suppose, for example, we fix the action profile to  $(x, x)$ . Table 5 details the objective expected payoffs to Firm 1 for each of the four possible type profiles. Under the null contract, Firm 1’s payoffs are as shown in the first row. Multiplying these by the row probabilities and summing yields the firm’s actual expected payoff. For example, under  $(T_1, T_1)$ , Firm 1 and Firm 2 both choosing  $x$  results in each firm obtaining an expected payoff of \$25.0.

Table 5: Distributions and true expected payoffs to Firm 1 by type profile

Fix action profile $(x, x)$	Deliverables				Expected Payoff
	$(r, r)$	$(r, d)$	$(d, r)$	$(d, d)$	
Deliverable-contingent payoff $\Rightarrow$	20	10	35	10	–
Type $(T_1, T_1)$	.8100	.0900	.0900	.0100	25.0
Type $(T_1, T_2)$	.0450	.8550	.0050	.0950	14.7
Type $(T_2, T_1)$	.0450	.0050	.8550	.0950	34.7
Type $(T_2, T_2)$	.0025	.0475	.0475	.9025	16.0

The technical method by which we incorporate aversion to ambiguity, is to take expected values using the worst-case elements of the firms’ belief sets given the strategy in play. To see how this works under the null contract, suppose firm types are  $(T_1, T_1)$  and ambiguity exists regarding partner type. Consider things from Firm 1’s perspective. How should it assess its expected payoff under actions  $(x, x)$ ? Its beliefs are represented by the set  $\{(T_1, T_1), (T_1, T_2)\}$ . Thus, referring to Table 5, it does not know whether its expected payoff is 25.0 or 14.7. In order to reflect ambiguity

aversion, we assume the Firm 1 takes the lower assessment, 14.7 (even though true expected value is 25.0).

**Implementation** The last piece of the setup is how to think about which actions, if any, can be implemented under various types of contracts. Informally, given a type profile, we say that a contract *implements* a strategy profile if, for every type profile: (i) each firm’s subjective expected payoff is positive; and, (ii) their strategies maximize subjective expected payoffs given their beliefs and the action of their opponent. The second point ensures that firms always optimize given their subjective beliefs.

Consider the full information case under the null contract. Table 6 summarizes the expected payoffs for every type profile given every pair of actions. Note that, firms of every type profile face their own Prisoner’s Dilemma game. For example, for types  $(T_1, T_1)$ , the efficient action profile is  $(x, x)$ . Unfortunately, barring a governing contract that induces implementation of  $(x, x)$ , the best the firms can hope for – in terms of the incentives inherent in this situation – is  $(y, y)$ . In this case, the null contract implements the strategy profile in which each firm chooses  $x$  if it is type  $T_1$  and  $y$  if it is type  $T_2$ .

Table 6: Expected payoffs by type profile: Firm 1, Firm 2 given action choices

Firm Types: $(T_1, T_2)$		Firm 2 Team Choice	
		$x$	$y$
Firm 1	$x$	25.0, 25.0	14.7, 34.7
Team Choice	$y$	34.7, 14.7	<b>16.0, 16.0</b>

Firm Types: $(T_1, T_2)$		Firm 2 Team Choice	
		$x$	$y$
Firm 1	$x$	14.7, 34.7	20.2, 29.6
Team Choice	$y$	<b>16.0, 16.0</b>	25.9, 15.3

Firm Types: $(T_2, T_1)$		Firm 2 Team Choice	
		$x$	$y$
Firm 1	$x$	34.7, 14.7	<b>16.0, 16.0</b>
Team Choice	$y$	29.6, 20.2	15.3, 25.9

Firm Types: $(T_2, T_2)$		Firm 2 Team Choice	
		$x$	$y$
Firm 1	$x$	<b>16.0, 16.0</b>	25.9, 15.3
Team Choice	$y$	15.3, 25.9	22.9, 22.9

Now, consider the case in which the firms know their own type, but are ambiguous on the type of their partner. As before, assume the null contract is in operation. At this point, attempting to represent the situation with (tables of) tables is too confusing. Instead, consider the extensive

form game in Fig. 1.<sup>5</sup> In this game: “Nature” picks a type profile; Firm 1 learns its type and picks an action; Firm 2 learns its type and picks an action; the type and action profiles determine expected payoffs. The dotted lines and node shadings indicate *information sets*. For example, the shaded nodes for Firm 1 correspond to knowing its type is  $T_2$ , but not being able to distinguish Firm 2’s type. The shaded nodes for Firm 2 correspond to the mirror situation. The top (bottom) row of numbers indicates Firm 1’s (Firm 2’s) true expected payoffs for each branch of the tree; e.g., under  $(T_1, T_1)$  and actions  $(x, x)$ , the actual expected payoff to both firms is 25.0. The extensive form game also indicates that do not observe each others’ actions prior to making their own action commitments.

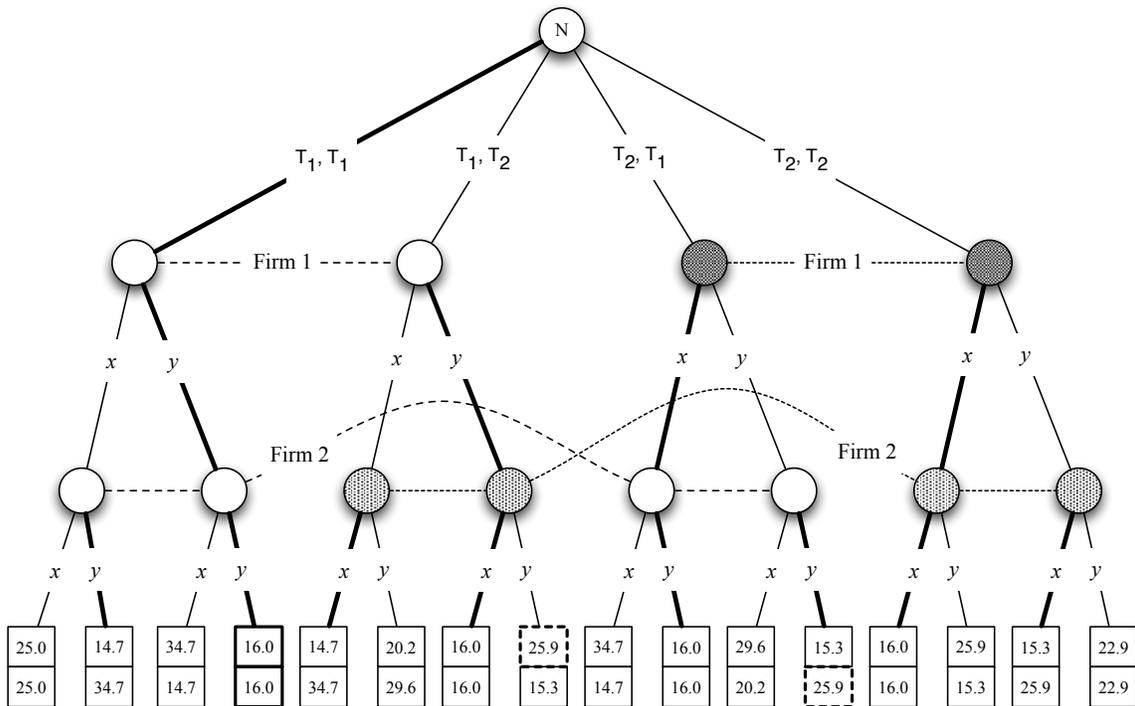


Figure 1: Supporting strategy:  $(y, y)$  implemented by null contract for  $(T_1, T_1)$

In Fig. 1, beliefs correspond to partitions of Nature’s type choices (the firms’ information sets

<sup>5</sup>Here, we assume readers have basic familiarity with extensive form games.

in the game tree). Thus, a pure strategy specifies a choice of team composition ( $x$  or  $y$ ) at every information set. Suppose both firms choose  $y$  if type  $T_1$  and  $x$  if type  $T_2$ . These strategies are illustrated by the bold branches in the figure. Does the null contract implement this strategy profile? The answer is: yes. Implementability requires each firm to employ a pure supporting strategy that maximizes its subjective expected payoff at every information set. It should not be hard to see that the strategies illustrated in Fig. 1 satisfy this condition. If Firm 1 learns its type is  $T_1$  then, under this strategy profile, it does not know whether its payoff is 16.0 (bold box) or 25.9 (dashed box). Under ambiguity aversion, it assumes its partner is type  $T_1$  and assesses its own choice of  $y$  at 16.0.

### 3.2 Example, Part II: Illustration of Results

**Full Knowledge Result** As we saw in Table 6, in the full information case with no governing contract, the best the alliance partners (of any type) can hope for is an expected payoff of \$16.0. Suppose types are  $(T_1, T_1)$ . Does the action-based contract  $\lambda = (x, x, 0)$  implement the value maximizing action profile  $(x, x)$ ? The answer is: yes. The game induced by  $\lambda = (x, x, 0)$  under full information is shown in Figure 2 (the implemented strategy is shown by the bold branches in the tree). Comparing the expected payoffs with those enumerated in Table 6, we see that the action-based contract does induce compliance on the part of both firms.

As we demonstrate in Proposition 1, this result holds much more generally. Corollary 1 proves that, under full information, the best deliverables-based contract can never outperform the best action-based contract in terms of aggregate value generation. Sometimes, the former does strictly worse. To see this in the context of our example, consider the obvious deliverables-based contract: specify rapid ( $r$ ) timing for both parties. The extensive form game under this contract are shown in Fig. 3. In this case, there is no implementable strategy in which type  $(T_1, T_1)$  choose the efficient action profile  $(x, x)$ . It is not hard to show that there is no deliverables-style contract that achieves  $(x, x)$  for types  $(T_1, T_1)$ .

**Ambiguous Partner Type** Assume that each firm knows its own type, but not that of its partner. It is not hard to show that, in lieu of any contractual arrangement, the only implementable actions are the ones shown in Table 6. Consider the focal type profile  $(T_1, T_1)$ . Does the action-based contract  $\lambda = (x, x, 0)$  still achieve  $(x, x)$  for these types? The answer, in this case, is yes. The

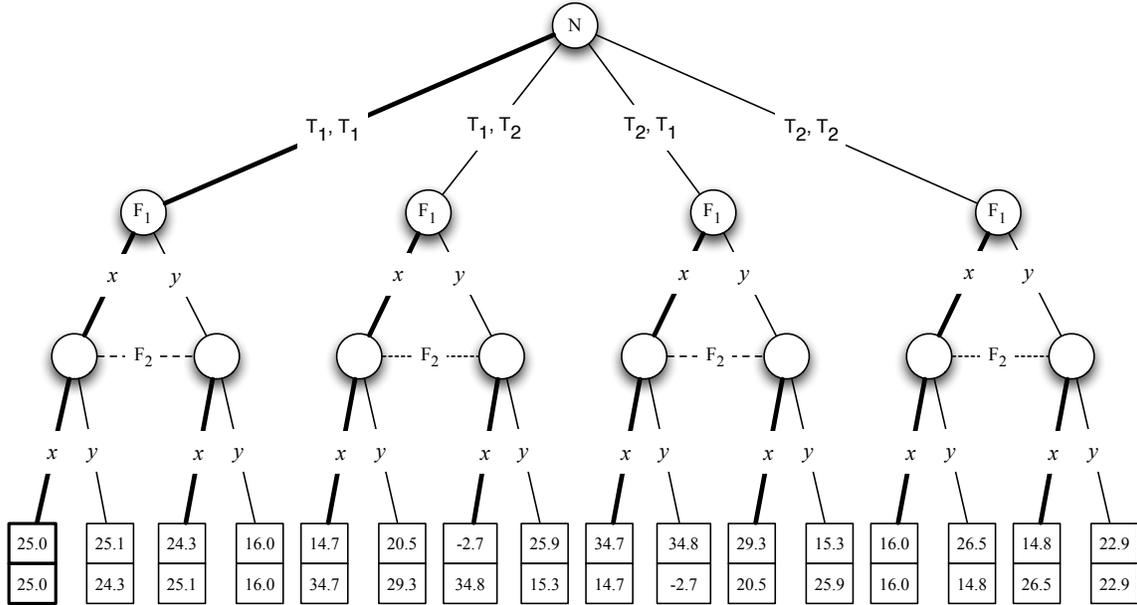


Figure 2: Efficiency  $a_* = (x, x)$  implemented by  $\lambda = (x, x, 0)$  for  $\theta = (T_1, T_1)$

game tree and implemented strategy is shown in Fig. 4. There is an important caveat, however. The addition of ambiguity and aversion to it results in subjective expected payoffs of only \$14.7, not the objective value of \$25.0. It is in Firm  $i$ 's interest to provide  $x$ . Moreover, in doing so, the firm knows it is in its partner's interest to do the same. The problem, however, is that Firm  $i$  worries that the success of the venture may actually depend upon its partner contributing a  $y$  team. Ambiguity aversion causes it to assume the worst.

What happens under the deliverables-based contract  $\lambda = (r, r, 0)$ ? The result is surprising: not only does this contract achieve  $(x, x)$  for types  $(T_1, T_1)$ , but the expected value to each firm of \$24.6 significantly exceeds that obtainable under the action-based contract (see Fig. 5). Note the reversal with respect to the full information case: there, the deliverables-based contract failed to achieve  $(x, x)$  and resulted in lower expected payoffs. Now, with the addition ambiguity, the

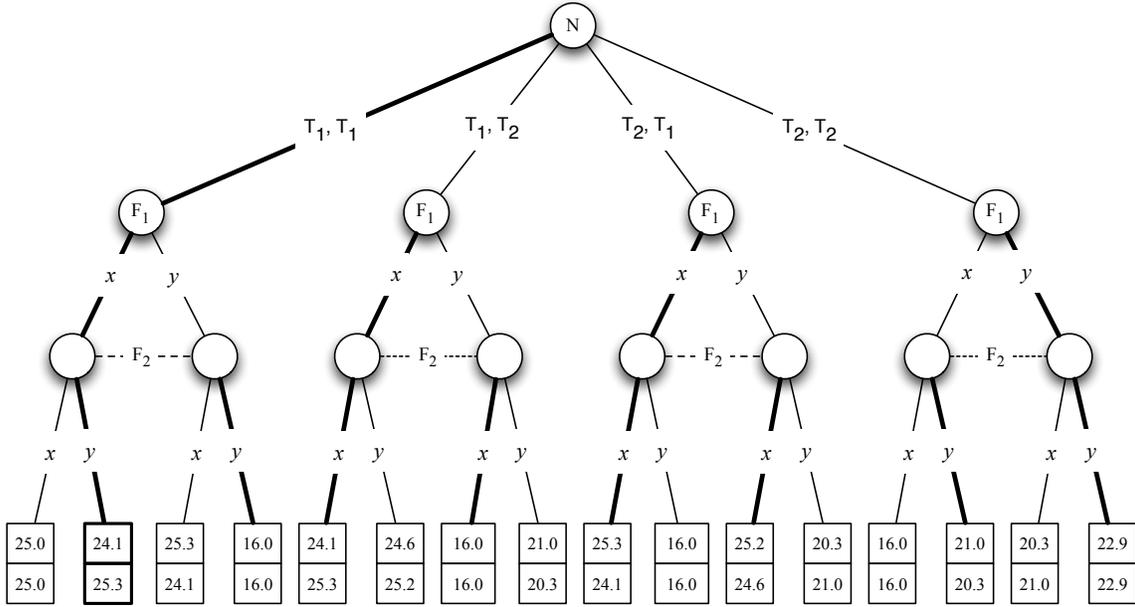


Figure 3: Efficiency  $a_* = (x, x)$  not implementable by  $\lambda = (r, r, 0)$  for  $\theta = (T_1, T_1)$

deliverables-based contract is strictly preferred. As we show in Corollary 1, this kind of reversal is only possible in our model when ambiguity is present. Under ambiguity, the firm knows its partner will, indeed, implement the action specified in the action-based contract. Yet, because it cannot be sure that action specified is the one actually desired, it assumes the worst. Alternatively, the deliverables contract gives *all types* the incentive to implement the value-maximizing action. Thus, although Firm  $i$  does not know its partner's type, it can rest assured that the value-maximizing action will be chosen.

**Contract Detail as a Signal of Competence** Deliverables-style contracts can, under certain circumstances, increase the value of the partnership to both participants via court awarded damages transfers. Damages, in essence create a rudimentary form of “ambiguity insurance.” In the context

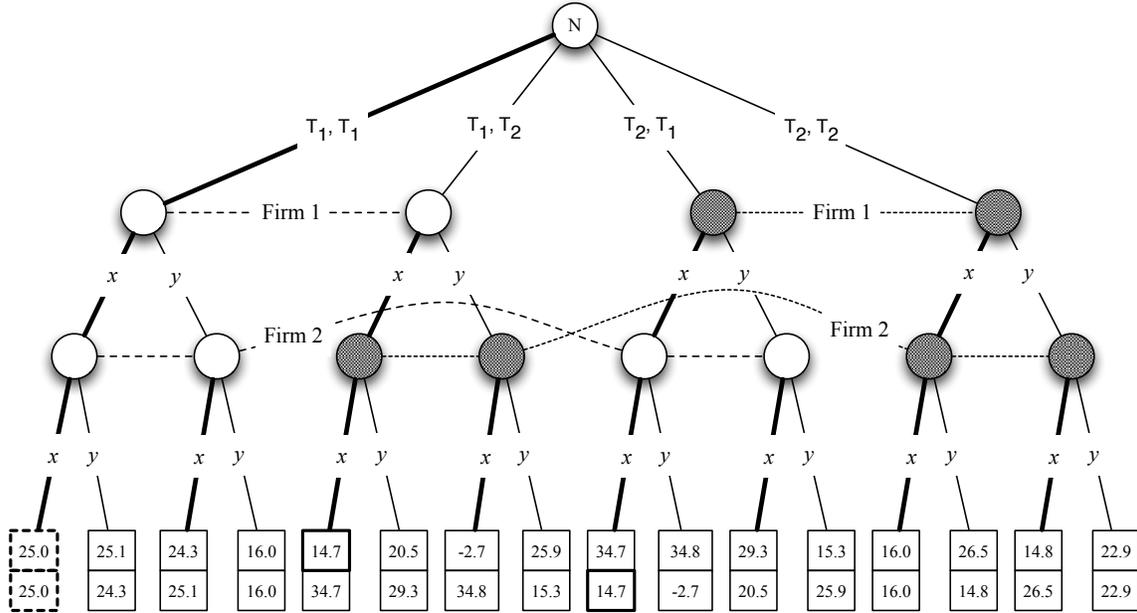


Figure 4:  $a_* = (x, x)$  implemented by  $\lambda = (x, x, 0)$  for  $\theta = (T_1, T_1)$

of business strategy, this is an interesting finding because it raises the possibility that contractually-specified transfer payments can be *engineered* to increase the value of a deal to a firm. As we now show, not only can such arrangements be made, but they can be made in a way that separates firms possessing extensive knowledge resources from poseurs claiming to have such resources.

Let  $S_1$  be an experienced, fully knowledgeable alliance suitor, and  $\tau$  a desirable target partner. Assume  $\tau$  faces partner ambiguity. Add a second suitor, firm  $S_2$ , that purports to have the same alliance-relevant knowledge as  $S_1$  but, in fact, is ignorant not only of  $\tau$ 's type but also of its own ( $S_2$  has no relevant knowledge). The target does not know which suitor is the capable one and which is the impostor.

Suppose all types are  $T_1$ . Begin with suitor  $S_2$  and consider the greatest amount of value it can deliver to target  $\tau$  using either an action- or deliverable-style contract. After grinding through

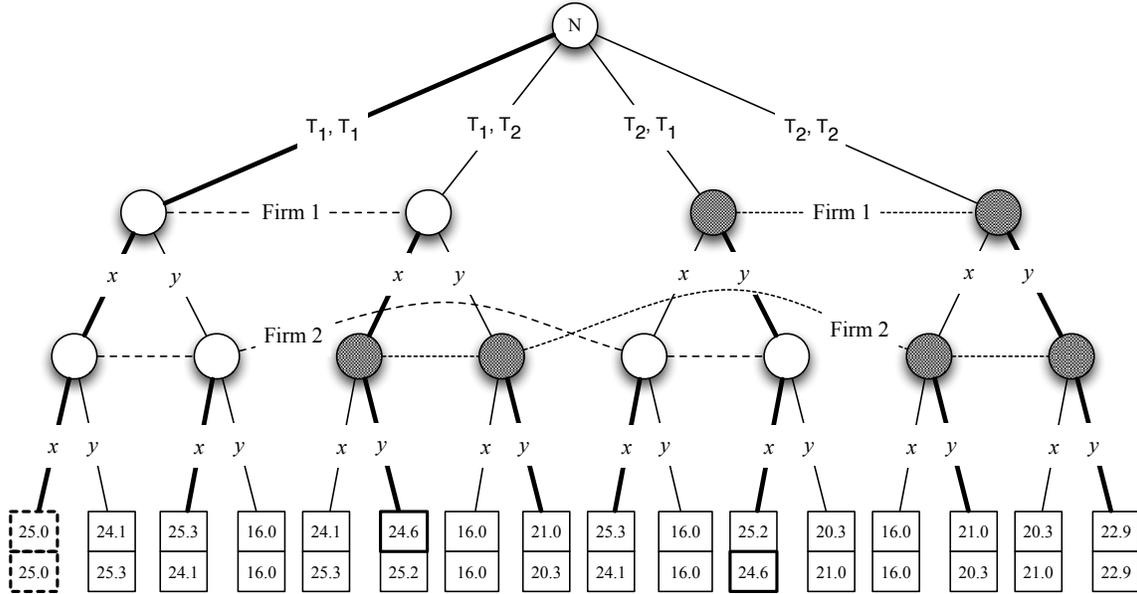


Figure 5:  $a_* = (x, x)$  implemented by  $\lambda = (r, r, 0)$  for  $\theta = (T_1, T_1)$

through all the possibilities, it turns out that the *best* case for  $\tau$  (involving an implementable strategy) is for  $S_2$  to offer the deliverables contract  $\lambda = (r, r, 0)$ . This implements the strategy profile in which  $S - 2$  chooses  $x$  no matter the type profile (since it cannot distinguish any types, its strategy always boils down to choosing one action), and target  $\tau$  chooses  $x$  if it is  $T_1$  and  $y$  if it is  $T_2$ . The subjective expected payoff to  $\tau$  (type  $T_1$ ) under this arrangement is \$24.1 and to  $S_2$  is 21.0. Again, this is the best  $S_2$  can offer the target under the various performance options available.

Now, building on this contract, can knowledgeable suitor  $S_1$  add specified transfers to make an offer to  $\tau$  that  $S_2$  cannot imitate? The answer is: yes. Without going into the details of its derivation (see the proof of Proposition 4 for the general details), the schedule of transfer payments is ( $> 0$  is a payment from  $S_1$  to  $\tau$  and  $< 0$  is one from  $\tau$  to  $S_1$ ): \$2.6 under  $(r, r)$ ,  $-\$65.3$  under  $(r, d)$ , \$52.6 under  $(d, r)$ , and \$56.2 under  $(d, d)$ .

Given the focal type of  $T_1$  for everyone, this new contract achieves a subjective expected payoff of \$26.6 for  $\tau$  and \$23.4 for  $S_1$ . Sadly for  $S_2$ , it achieves a negative subjective expected payoff no matter what action it chooses. In other words, by adding detail in the form of specified payments,  $T_1$  can create a contract that makes the target strictly better off and to which its competitor cannot profitably agree. The basis of this result is  $S_1$ 's superior knowledge to both its competitor and the target. It is worth noting that the joint expected payoff to  $\xi_1$  and  $\tau$  is \$50.0, the efficient amount under full knowledge. Not only does the target get a strictly better deal, but  $S_1$  does strictly better than its competitor does under the original contract. These are both features that arise in the general case.

## 4 The Model

As in the preceding example, we consider two firms contemplating a strategic alliance designed to take advantage of some joint technology opportunity. Each firm controls a project-relevant set of resources. The value ultimately generated by the alliance is an uncertain consequence of how these resources are organized and used.

First, a few general comments regarding the following setup. Project ambiguity will be introduced using the standard game theoretic device of assigning types to firms, where a “type” maps a firm’s feasible actions to probability distributions over outcomes. Firms may then face ambiguity regarding partner type. Unless otherwise indicated, all sets are finite.

The sequence of real world events we have in mind is: 1) Firms who know something about their own type and the type of their partner are presented with a valuable alliance opportunity; 2) the firms negotiate a contract; 3) with a contract in place, they each decide which actions to undertake on behalf of the alliance; 4) Deliverables are stochastically generated according to firm types and actions chosen; 5) Firms receive (possibly court-adjusted) payoffs. The sequence actually used on our model is (see, e.g., Fig. 2): 1) The contract and information structure of the game are fixed; 2) “Nature” picks firm types; 3) actions are simultaneously taken (i.e., are hidden at the time of choice); 4) Deliverables are generated; 5) Payoffs are awarded (at which point, type, actions and deliverables implicitly become public information).

The key difference between the reality we have in mind and the model we actually use is that we skip the added complexity of including of a negotiating subgame in the model. Instead, we take a contract as fixed at the start and consider its behavioral and performance implications. This

distinction matters because our ultimate interest is the contract structures agreeable to firms of specific types. Thus, our analysis proceeds by defining a notion of strategic implementation under a contract (see below) that applies to all types and then examining the implications for an arbitrary, focal type. Hence, the preamble to most of our propositions, “Given an arbitrary type profile  $\theta$ , ...”

**The Partnership Opportunity** Firms  $i \in \{1, 2\}$  choose from a set of at least two *feasible actions*  $A_i$ . Although we refer to the elements  $a_i \in A_i$  as *actions*, they are allowed to be multidimensional and should be interpreted as detailed descriptions of the sequences of activities, resource allocations and so on to be conducted by  $i$  on behalf of the alliance. The firms agree that  $A_1$  and  $A_2$  describe all the relevant possibilities. An *action profile* is a list of actions, one for each firm  $a \equiv (a_1, a_2)$  and the set of all such profiles is  $A \equiv A_1 \times A_2$ .

As we elaborate below, firm actions generate stochastic consequences, which we refer to as *deliverables* but can be thought of more generally as states of the world. Let  $W_i$  denote the set of firm  $i$ -specific deliverables. The set of potential *joint deliverables* is  $W \equiv W_1 \times W_2$  with typical element  $w = (w_1, w_2)$ . Each of  $W_1$  and  $W_2$  is assumed to have at least two elements. Importantly, both actions and deliverables are assumed to be verifiable by an outside third party (i.e., the ones that would actually be include included a formal contract).

The aggregate value produced by the partnership depends upon the joint deliverable profile as do each firm’s costs. Specifically, define: (i) the *project value*,  $v : W \rightarrow \mathbb{R}_+$ ; and, (ii) the *cost for firm  $i$* ,  $c_i : W \rightarrow \mathbb{R}_+$ . If  $w$  is the joint deliverables outcome, then  $v(w)$  is the aggregate value generated and  $c_i(w)$  is the cost incurred by firm  $i$ . It is worth noting that this formulation allows interactions between deliverable outcomes in the costs as well as the value produced; i.e., Firm 1 failing to deliver on time may increase the cost of Firm 2 achieving its deliverable. In an alliance without a formal contract, the split of value is reached by some (unmodeled) ex-post process of negotiation. In such situations, we simply assume that the expected outcome is a 50/50 split. Thus, given  $w$ , firm  $i$  receives  $\gamma_i \equiv \frac{1}{2}v(w) - c_i(w)$  under the null contract (defined below).

**Types** Let  $\theta_i$  indicate a *type* for firm  $i$  and  $\Theta_i$  a set of at least two distinct types. A type associates each action with a probability distribution over deliverables. Formally,  $\theta_i : A_i \rightarrow \Delta(W_i)$ , where  $\theta_i(w_i|a_i)$  is the probability that outcome  $w_i$  is generated following the implementation of action

plan  $a_i$  by type  $\theta_i$ .<sup>6</sup> A *type profile* is a pair  $\theta \equiv (\theta_1, \theta_2)$  and  $\Theta \equiv \Theta_1 \times \Theta_2$  is a set of such profiles. Given a type profile  $\theta \in \Theta$ , we define the *distribution on deliverable outcomes*,  $f^\theta$ , as:

$$\forall w \in W, a \in A, f^\theta(w|a) \equiv \theta_1(w_1|a_1)\theta_2(w_2|a_2). \quad (1)$$

Thus, the effects of firm actions on their own deliverable outcomes are independent (as discussed, interaction effects are introduced through  $v$  and the  $c_i$ s).

**Contracts** A contract is a list  $\lambda \equiv (\bar{x}_1, \bar{x}_2, t)$ . The  $\bar{x}_i$  terms are *performance requirements*. We investigate contracts that indicate *either* a joint action profile,  $(\bar{x}_1, \bar{x}_2) \in A$ , *or* joint deliverable performance,  $(\bar{x}_1, \bar{x}_2) \in W$ . The last component,  $t = (t_1, t_2)$ , elaborates deliverables-based *transfer payments*). Formally,  $t : W \rightarrow \mathbb{R}_2$ . Transfers are balanced:  $t_1(w) = -t_2(w)$ .<sup>7</sup> We write  $\lambda = (\bar{x}_1, \bar{x}_2, 0)$  to indicate a contract with no specified transfer payments. Let  $\bar{x}_i = \emptyset$  denote no performance requirement for firm  $i$ . The *null* contract is  $\lambda_\emptyset \equiv (\emptyset, \emptyset, 0)$ . The null contract implies 50-50 ex-post value sharing, as described in the preceding section. When the contract is not obvious from the context, we indicate it as an extra argument in square brackets; e.g.,  $t_i[\lambda](w)$  is firm  $i$ 's transfer as required by  $\lambda$  when the deliverable outcome is  $w$ .

**Legal Institutions** Given a contract  $\lambda = (\bar{x}_1, \bar{x}_2, t)$  and an action-deliverable outcome  $(a_1, a_2, w_1, w_2)$ , firm  $i$  fails to perform – *breaches* – if  $\bar{x}_i \notin \{a_i, w_i\}$ . Otherwise  $i$  is *in compliance* with  $\lambda$ . In what follows, we assume that courts award damages to a firm in compliance only if its partner breaches. If both firms comply or both firms breach, no awards are made.<sup>8</sup> Since  $\emptyset \in \{a_i, w_i\}$ , both firms are always in compliance with the null contract.

In order to quantify the damages due to a breach of contract, courts must decide what would have happened had both parties complied. Therefore, given  $\theta \in \Theta$ , define the *full performance payoff to  $i$  under  $\lambda = (\bar{x}_1, \bar{x}_2, t)$*  as

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<sup>6</sup> $\Delta(\cdot)$  indicates the set of probability distributions on a set.

<sup>7</sup>Since deliverables are stochastic,  $t$  essentially allows for state-contingent transfers. Since both actions and deliverables are verifiable,  $t$  could be strengthened to include action-dependent transfers as well. Since our results hold without this extension, we do not include it. Note that the financial implications of an equity stake can be represented via appropriate choice of  $t$ .

<sup>8</sup>Implicitly, when both firms breach, their damages have expected value of zero. This simplifies our analysis by eliminating the need to make precise assessments of contributory (relative) damages in such cases.

$$\mathbb{F}_i^\theta[\lambda] \equiv \sum_{w \in W} (\gamma_i(w) + t_i(w)) g^\theta[\lambda](w), \quad (2)$$

where

$$g^\theta[\lambda](w) \equiv \begin{cases} f^\theta(w|a) & \text{if } (\bar{x}_1, \bar{x}_2) = a \\ 1 & \text{if } (\bar{x}_1, \bar{x}_2) = w \\ 0 & \text{otherwise} \end{cases} .$$

$\mathbb{F}_i^\theta[\lambda]$  is  $i$ 's expected profit when  $\lambda$ 's mutual performance requirements are met. If  $\lambda$  specifies  $(\bar{x}_1, \bar{x}_2) = (a_1, a_2)$ , then  $\mathbb{F}_i^\theta[\lambda]$  is firm  $i$ 's objective expected profit when the parties faithfully implement  $(a_1, a_2)$ . If  $(\bar{x}_1, \bar{x}_2) = (w_1, w_2)$ , then  $\mathbb{F}_i^\theta[\lambda]$  is the actual payoff at  $(w_1, w_2)$ .<sup>9</sup> Given  $\lambda$ ,  $\theta \in \Theta$  and an outcome  $(a, w)$  the *damages to firm  $i$* ,  $\delta_i^\theta[\lambda](w|a)$ , is defined as:

$$\delta_i^\theta[\lambda](w|a) \equiv \begin{cases} \max\{0, \mathbb{F}_i^\theta[\lambda] - \gamma_i(w)\} & \text{if } t(w) = 0, \bar{x}_i \in \{a_i, w_i\}, \bar{x}_{-i} \notin \{a_{-i}, w_{-i}\} \\ - \max\{0, \mathbb{F}_{-i}^\theta[\lambda] - \gamma_i(w)\} & \text{if } t(w) = 0, \bar{x}_i \notin \{a_i, w_i\}, \bar{x}_{-i} \in \{a_{-i}, w_{-i}\} \\ 0 & \text{otherwise} \end{cases} , \quad (3)$$

where “ $-i$ ” is our notational convention denoting  $i$ 's partner. Note that damages are balanced.

Suppose firm  $i$ 's partner breaches the contract. The court observes the outcome  $(a, w)$ . If the contract has no transfer payments specified, the court compares  $i$ 's actual profit,  $\gamma_i(w)$ , against its expected payoff had both parties performed,  $\mathbb{F}_i^\theta$ . If the former is less than the latter, then damages are incurred and the court awards firm  $i$  the difference. In this setup, firm  $i$  is not awarded damages if its payoff under  $(a, w)$  is more than its expected payoff under full performance even though  $d_i(a, w) = 1$  (i.e., since it is not, in fact, damaged by its partner's breach). When transfers are contractually specified for a particular deliverables result ( $t(w) \neq 0$ ), the court defers to the contract (i.e.,  $t$  is treated as “contractually specified remedies”).

**Subjective Beliefs** Firm  $i$ 's *beliefs* are defined to be a partition of  $\Theta$ , denoted  $\mathbf{B}_i \equiv \{B_i^1, \dots, B_i^n\}$ .

Thus,  $\cup_{B_i^j \in \mathbf{B}_i} B_i^j = \Theta$  and, for all  $B_i^j \neq B_i^k$ ,  $B_i^j \cap B_i^k = \emptyset$ . The idea is that  $\mathbf{B}_i$  elaborates the degree to which firm  $i$  can distinguish between types. Given a type profile  $\theta$ ,  $B_i^\theta \equiv B_i^j \in \mathbf{B}_i$  such that

<sup>9</sup>Under the null contract,  $\mathbb{F}_i^\theta[\lambda_0] = 0$  because  $g^\theta[\lambda] = 0$ . In this case, the value of  $\mathbb{F}_i^\theta[\lambda_0]$  is irrelevant because both firms are always in compliance.

$\theta \in B_i^j$ .  $B_i^\theta$  is the set of type profiles that cannot be ruled out by  $i$  when the true type profile is  $\theta$ .

We examine three basic cases:

1. **Full Knowledge**  $\mathbf{B}_i = \cup_{\theta \in \Theta} B_i^\theta$  where  $B_i^\theta = \{\theta\}$ ;
2. **Partner Ambiguity**  $\mathbf{B}_i = \cup_{\theta \in \Theta} B_i^\theta$  where  $B_i^\theta = \{\theta_i\} \times \Theta_{-i}$ ;
3. **Complete Ambiguity**  $\mathbf{B}_i = \Theta$ .

An interaction that is not full knowledge is *ambiguous*.

**Strategies** A *mixed strategy* for firm  $i$  is a map  $s_i : \mathbf{B}_i \rightarrow \Delta(A_i)$ ; that is, a belief-contingent randomization over actions. Strategies do not map from types, but from the beliefs about types.<sup>10</sup> In the total ambiguity case, for example, there is no variation in beliefs. Hence, under total ambiguity, a strategy boils down to selecting a single action that is always chosen regardless of  $\theta$ .

A *pure strategy* is a mixed strategy under which a specific action is chosen with probability 1. While mixed strategies are required to guarantee existence of solutions, our results focus entirely upon pure strategies. When firm types are  $\theta$ , we write  $s_i(B_i^\theta) = a_i$  to indicate that firm  $i$ 's action choice is  $a_i$  given its beliefs  $B_i^\theta$ . Since  $B_i^\theta$  is uniquely associated with  $\theta$ , we can simplify this notation to  $s_i(\theta)$  without confusion. The set of all such strategies is  $S_i$ . A *strategy profile* is a list of strategies  $s = (s_1, s_2)$ , with the set of all such profiles denoted  $S$ . We write  $a_{s(\theta)}$  to indicate the action profile implied by type profile  $\theta$  under strategy profile  $s$ .

**Expected Payoffs** Given a type  $\theta$  and an outcome  $(a, w)$ , the *payoff to firm  $i$*  is:

$$\pi_i^\theta[\lambda](w|a) \equiv \gamma_i(w) + t_i[\lambda](w) + \delta_i^\theta[\lambda](w|a). \quad (4)$$

It is worth pausing to note that the link between a contract and firm  $i$ 's payoff is only through the  $t_i$  and  $\delta_i$  terms (specified transfers and damages). Moreover, when  $\lambda$  is a deliverables type contract, actions are irrelevant to damages. In such cases, we can write  $\delta_i^\theta[\lambda](w)$  to simplify notation without ambiguity.<sup>11</sup> The *objective* expected value to firm  $i$  generated by a strategy profile  $s$  when the type

<sup>10</sup>As seen in the example section,  $\mathbf{B}_i$  defines firm  $i$ 's information sets the extensive form game.

<sup>11</sup>Note also that  $\gamma_i(w) = \pi_i[\lambda_\emptyset](w|a)$ .

profile is  $\theta$  and the contract is  $\lambda$  is:

$$\mathbb{E}_i^\theta[\lambda](s) = \sum_{w \in W} \pi_i^\theta[\lambda](w|a_{s(\theta)}) f^\theta(w|a_{s(\theta)}), \quad (5)$$

This is the expected value under full information (see below).

Given a contract  $\lambda$  and type profile  $\theta \in \Theta$ , the *subjective expected payoff to firm  $i$  under strategy profile  $s$*  is defined as

$$\tilde{\mathbb{E}}_i^\theta[\lambda](s) \equiv \min_{\theta' \in B_i^\theta} \mathbb{E}_i^{\theta'}[\lambda](s), \quad (6)$$

where we adopt the notational convention of using a tilde to indicate *subjective* variables and operators. Definition (6) is a generalized form of expected value, one that tends to penalize ambiguity.<sup>12</sup>

**Implementable Strategies and Actions** One of the issues of interest here is what firm behaviors are consistent with a given contract. To address this issue, we provide the following definition.

**Definition 1.** *A contract  $\lambda$  is said to implement a strategy  $s \in S$  if, for  $i \in \{1, 2\}$  and all  $\theta' \in \Theta$  :* (i)  $\tilde{\mathbb{E}}_i^{\theta'}[\lambda](s) \geq 0$ ; and, (ii) *for all  $s'_i \neq s_i$ ,  $\tilde{\mathbb{E}}_i^{\theta'}[\lambda](s) \geq \tilde{\mathbb{E}}_i^{\theta'}[\lambda](s'_i, s_{-i})$ .*

If there exists a strategy  $s$  such that  $\lambda$  implements  $s$  and  $s(\theta) = a$ , then  $a$  is also said to be implemented by  $\lambda$  (for type  $\theta$ ). In this context, we refer to  $s$  as a *supporting* strategy. Conditions (i) and (ii) ensure that the focal strategy is stable under the contract. A firm would opt for its outside alternative (the expected value of which we have normalized to zero) rather than a strategy failing item (i). Item (ii) ensures that  $s$  is subjectively rational for all types under  $\lambda$  (incentive compatibility requirement).<sup>13</sup> Since strategies are constant on the elements of  $\mathbf{B}_i$ , it suffices to check (ii) for each  $B_i^j \in \mathbf{B}_i$ .

**Value Creation** Given  $\lambda$ , the *expected surplus under strategy profile  $s$  given  $\theta$*  is  $\tilde{\mathbb{S}}^\theta[\lambda](s) \equiv \tilde{\mathbb{E}}_1^\theta[\lambda](s) + \tilde{\mathbb{E}}_2^\theta[\lambda](s)$ . By the finiteness of  $A$ , there exists a pure strategy profile  $s$  such that,

$$s(\theta) \in \arg \max_{s' \in S} \tilde{\mathbb{S}}^\theta[\lambda](s'). \quad (7)$$

<sup>12</sup>Under full knowledge, (6) collapses to (5).

<sup>13</sup>The authors thank Peter Klibanoff for bringing the importance of this condition to our attention. One implication is that when firms make their subjective assessments according to (6), they implicitly assume that every partner type is playing a best reply to their strategy under the contract in question.

A pure strategy satisfying (7) under full knowledge is said to be *efficient with respect to  $\theta$* . Given  $\theta$  and  $s$  satisfying (7),  $a_e^\theta \equiv s(\theta)$  is *an efficient action with respect to  $\theta$* . An *efficient strategy profile* (i.e., without reference to type), denoted  $s_e = (s_{1e}, s_{2e})$ , indicates a strategy  $s$  such that *for all*  $\theta \in \Theta$ ,  $s(\theta) = a_e^\theta$ . The gains to partnering are always greatest under full information because (6) implies the expected surplus is (weakly) decreasing in ambiguity. An efficient strategy  $s_e$  thus provides a useful benchmark.

Since damages  $\delta_i$  and contingent payments  $t_i$  are balanced,  $\pi_1 + \pi_2 = v - c_1 - c_2$ . Therefore, an efficient strategy  $s_e$  maximizes the expected value of  $(v - c_1 - c_2)$  for each type under full information. The *efficient surplus* for  $\theta$  is defined as  $\mathbb{S}_e^\theta \equiv \mathbb{E}_1^\theta[\lambda_\theta](s_e) + \mathbb{E}_2^\theta[\lambda_\theta](s_e)$ .<sup>14</sup> Our analysis is based upon the premise that forming the partnership is objectively rational in the sense that, under the right action plan, value can be generated beyond what the firms could get from their next-best alternative, normalized to 0. Therefore, for all  $\theta \in \Theta$  and efficient strategies  $s_e$ , assume  $\mathbb{E}_1^\theta[\lambda_\theta](s_e), \mathbb{E}_2^\theta(s_e)[\lambda_\theta] > 0$ .

## 5 Analysis

### 5.1 Full Knowledge Result

We begin by analyzing the efficacy of contracts under full-knowledge. It is well known that, in such cases, the efficient surplus  $\mathbb{S}_e^\theta$  can generally be attained by a contract of the form  $\lambda = (\emptyset, \emptyset, t)$  in which  $t$  specifies an appropriate set of outcome-contingent transfers designed to induce the adoption of  $a_e^\theta$  even when actions are not verifiable.<sup>15</sup> Alternatively, given a desired action plan, firms of type  $\theta$  could simply write a contract of the form  $\lambda = (a_e^\theta, 0)$ , and then leave it to the courts to elaborate appropriate transfer payments in the event of noncompliance. Does this also work? The following proposition demonstrates that it does.

**Proposition 1.** *Given an arbitrary type profile  $\theta \in \Theta$  and unambiguous beliefs, the contract  $\lambda = (a_e^\theta, 0)$  implements  $a_e^\theta$ .*

Proposition 1 shows that the legal institution of compensatory damages is sufficient to induce compliance under full knowledge. This provides an explanation for a frequent observation in the

<sup>14</sup> $\mathbb{S}_e^\theta$  is actually independent of  $\lambda$  due to balancedness.

<sup>15</sup>Legros and Matsushima (1991) characterize the conditions under which efficiency in a partnership can be sustained by a balanced transfer rule when outcomes are stochastic. We do not reproduce their result here, but simply note that deliverables independence and a unique  $a_e^\theta$  are sufficient to construct an efficiency-inducing transfer rule  $t$ .

management literature: namely, that firms with substantial experience partnering with one another often write contracts that contain nothing more than a description of their joint action plans (i.e., without any elaboration of state-contingent penalties). A popular interpretation of this finding is that contracts between trusting partners serve primarily as planning instruments to define what needs to be done in order to execute a successful project, rather than as legal constraints on undesired behavior (e.g., Argyres and Mayer, 2007). However, according to Proposition 1, it is precisely because these action plans (often embodied as a ‘Statement of Work’ or ‘SOW’) have legal ramifications in the context of a contract that they act as an effective governance mechanism.

This raises the question of whether, alternatively, firms can always construct a deliverables-based contract that similarly implements the efficient action profile. By Proposition 1, we know that a deliverables-based contract can never deliver *more* value than one based upon the efficient action profile. As we demonstrated in our introductory example, efficiency is sometimes impossible using pure, deliverables-based contracts.

**Corollary 1.** *Given  $\theta \in \Theta$  and full information, suppose  $\lambda = (w_1, w_2, 0)$  implements some action profile  $a$ . Then, for all strategy profiles  $s \in S$  that support the implementation of  $a$  by  $\lambda$ ,  $\tilde{S}^\theta[\lambda](s) \leq \mathbb{S}_e^\theta$ .*

Summing up: the value-maximizing set of actions for a joint project can generally be implemented by a contract that simply elaborates those actions *if* managers are confident in their assessments of the uncertainties associated with the alternative plans before them. Such confidence, in turn, suggests substantial experience in the type of project at hand. It may well be that the process of pre-contractual exploration, elaboration, and negotiation establishes the foundation for such confidence. Sometimes, the same effect can be induced by deliverables-based contracts (but, not always). This suggests that, typically, more experienced firms will simply opt for action-based contracts. This leads to the following informal empirical conjecture.

**Empirical Conjecture 1.** *Contracts governing partnerships between firms with extensive experience in similar alliances are more likely to contain action specifications and less likely to contain deliverables performance clauses and penalties than cases in which firms are relatively inexperienced.*

## 5.2 Results for ambiguous partner type

In this section, assume firms know their own type, but not that of their partner: for  $i \in \{1, 2\}$ ,  $\mathbf{B}_i = \cup_{\theta \in \Theta} B_i^\theta$  where  $B_i^\theta = \{\theta_i\} \times \Theta_{-i}$ . The following definition will prove useful.

**Definition 2.** *Given  $\lambda$ , Firm  $i$  faces a worst partner type under  $s$  if, for all  $\theta \in \Theta$ , there exists a unique  $\hat{\theta}_{-i} \in \Theta_{-i}$  such that:*

1.  $\tilde{\mathbb{E}}_i^\theta[\lambda](s_i, s_{-i}) = \mathbb{E}_i^{(\theta_i, \hat{\theta}_{-i})}[\lambda](s_i, s_{-i})$ , and
2. If  $\hat{s}_i \in \arg \max_{s'_i \in S_i} \tilde{\mathbb{E}}_i^\theta[\lambda](s'_i, s_{-i})$ , then  $\tilde{\mathbb{E}}_i^\theta[\lambda](\hat{s}_i, s_{-i}) = \mathbb{E}_i^{(\theta_i, \hat{\theta}_{-i})}[\lambda](\hat{s}_i, s_{-i})$ .

One interpretation Definition 2 is that, fixing  $s_{-i}$ , each  $\theta_i$  has a “most dreaded” type that could be the one playing that strategy.<sup>16</sup> The technical advantage of this condition is being able to focus upon a unique minimizing type for each  $\theta_i/s_{-i}$  combination, which greatly simplifies the statement and proof of the next proposition. The type  $\hat{\theta}_{-i}$  in Definition 2 is referred to as *the worst partner type for  $\theta_i$  under  $\lambda$  and  $s$* .

A notational simplification will also be helpful. For Firm  $i$  given  $\theta$ ,  $s$  and  $w_i$ , let

$$\bar{\gamma}_i^\theta(s|w_i) \equiv \sum_{w'_{-i} \in W_{-i}} \gamma_i(w_i, w'_{-i}) \theta_{-i}(w'_{-i} | a_{s_{-i}}(\theta_{-i})).$$

$\bar{\gamma}_i^\theta(s|w_i)$  is the objective expected unadjusted payoff to  $i$  under  $s$  and  $\theta$  conditional on  $w_i$ . We now state the main proposition of this section. Explanation and interpretation follows.

**Proposition 2.** *Consider an arbitrary  $\theta \in \Theta$  and assume there exist two contracts,  $\lambda = (a_\theta^\theta, 0)$  and  $\lambda' = (w^*, 0)$ , such that the following five conditions hold:*

1.  $\lambda$  implements a strategy  $s$  such that, for all  $\theta' \in \Theta$ ,  $s(\theta') = a_\theta^\theta$ ;
2. For  $i \in \{1, 2\}$ , given  $\lambda'$ , Firm  $i$  faces a worst partner type under any efficient strategy  $s_\mathbf{e}$ ,
3. For  $i \in \{1, 2\}$  and all  $\theta' \in \Theta$ , if  $\hat{\theta}_{-i}$  is the worst partner type for  $\theta'_i$  under  $\lambda'$  and  $s_\mathbf{e}$ , then

$$\mathbb{E}_i^{(\theta'_i, \hat{\theta}_{-i})}[\lambda'](s_\mathbf{e}) > \mathbb{E}_i^{(\theta'_i, \hat{\theta}_{-i})}[\lambda_\emptyset](s);$$

<sup>16</sup>More precisely, if  $\hat{\theta}_{-i}$  is the minimizing type facing  $\theta_i$  under  $s$ , then it is also the minimizing type with respect to any best reply to  $s_{-i}$  by  $\theta_i$ . Note, the  $\hat{\theta}_{-i}$ s may vary with the  $\theta_i$ s.

4. For all  $\theta' \in \Theta$  and efficient strategies  $s_e \in S$ ,

$$a_{s_{ie}(\theta'_i)} \in \arg \max_{a_i \in A_i} \theta'_i(w_i^* | a_i);$$

5. For  $i \in \{1, 2\}$ , all  $w_i \in W_i \setminus \{w_i^*\}$ , and all  $\hat{\theta} \in \Theta$  such that  $\hat{\theta}_{-i}$  is  $\hat{\theta}_i$ 's worst partner type under  $\lambda'$  and  $s_e$ ,

$$\bar{\gamma}_i^{\hat{\theta}}(s_e | w_i) - \gamma_i(w^*) \leq \delta_{-i}[\lambda'](w_i, w_{-i}^*) \hat{\theta}_{-i}(w_{-i}^* | a_{s_{-ie}(\hat{\theta}_{-i})}) \leq \bar{\gamma}_i^{\hat{\theta}}(s_e | w_i).$$

Then,  $\lambda'$  implements  $s_e$  and, for  $i \in \{1, 2\}$  and all  $\theta' \in \Theta$ ,

$$\tilde{\mathbb{E}}_i^{\theta'}[\lambda'](s_e) > \tilde{\mathbb{E}}_i^{\theta'}[\lambda](s). \quad (8)$$

Since the conditions of the premise are somewhat less than transparent, let us pause and explain them. Item 1 says that the action-based contract designed to implement the efficient action  $a_e^\theta$  for  $\theta$  is sufficiently strong to induce *all* types to implement  $a_e^\theta$ .<sup>17</sup> Item 2 is as discussed above. Given our focus on ambiguity aversion, it seems reasonable to imagine that each firm type worries about a “bogyman” partner whose minimizing effects are hard to escape. Item 3 says that efficient strategies under  $\lambda'$  outperform  $s$  under the null contract. In other words, it is not efficient to choose  $a_e^\theta$  regardless of type. Items 4 and 5 are required to implement  $s_e$ . Item 4 says that the efficient action for a type is one that also happens to maximize the likelihood of the deliverable required by  $\lambda'$ . This is natural for the viability of any contract specifying deliverables. Item 5 is a local condition (“local” in the sense of conditioning on  $w_i$ ) on the range of expected damages imposed by  $\lambda'$  under  $s_e$ .

Proposition 2 is significant because, by Corollary 1, we know that result (8) is impossible under full information. Since damages are balanced, one cannot make *both* partners strictly better off in the no-ambiguity case than they would be under the efficiency-inducing contract  $\lambda = (a_e^\theta, 0)$ . Thus, in the presence of ambiguity, there are cases in which a deliverables-based contract strictly improves upon the expected payoffs for both firms over an action-based contract – even though the latter successfully implements the efficient action plan for the focal type. In such cases, firms

<sup>17</sup>In designing examples for this paper, we did not come across any cases failing this condition which, while far short of a proposition, does suggest that this is not a difficult condition to fulfill.

without a good understanding of what their partners need to do are better off not trying to define required actions but, instead, by specifying deliverables performance.

It should be noted that what this result is primarily driven by finding a deliverables-based contract that changes payoffs in such a way as to induce bad partner types to switch from inefficient to efficient actions. It is not surprising that changing the payoff structure (by changing the contract from  $\lambda$  to  $\lambda'$ ) leads to different equilibrium behaviors. What is interesting is that the structure imposed by a deliverables contract is substantively different from its action-based counterpart in its ability to mitigate concerns about partner type. Even though ambiguity aversion still leads a firm to base its assessment on a minimizing partner type, the overall assessment improves because all partner types are induced to choose efficient actions. Under a deliverables-based contract, Firm  $i$  does not care *how* its partner maximizes the likelihood of  $w_i$ , just so long as it does.

As the next proposition shows, deliverables-based contracts have an another effect, entirely distinct from changing behavior, that may yet cause them to be strictly preferred (by both parties) over action-based contracts. For the following proposition, given a deliverables-style contract  $\lambda'$ , let  $W_i^+ \subset W$  be the subset of deliverables on which  $i$ 's damages are strictly positive. When  $\theta \in \Theta$  is understood from the context, let  $\theta_{-i}^\lambda \in \arg \min_{\theta'_{-i} \in \Theta_{-i}} \mathbb{E}_i^{(\theta_i, \theta'_{-i})}[\lambda](s)$  denote a minimizing partner type; i.e.,  $\tilde{\mathbb{E}}_i^\theta[\lambda](s) = \mathbb{E}_i^{(\theta_i, \theta_{-i}^\lambda)}[\lambda](s)$ .

**Proposition 3.** *Consider an arbitrary  $\theta \in \Theta$  and two contracts,  $\lambda = (a_{\mathbf{e}}^\theta, 0)$  and  $\lambda' = (w^*, 0)$ , such that both implement  $a_{\mathbf{e}}^\theta$  for all types, supported by  $s$ . For  $i \in \{1, 2\}$ , assume:*

1. *Damages are nontrivial:  $|W_i^+| \geq 1$ .*
2. *Self-confident likelihoods: For all minimizing  $\theta_i^\lambda$  and  $\theta_{-i}^\lambda$  and all  $(w_i^*, w_{-i}) \in W_i^+$ ,*

$$\frac{\theta_i(w_i^* | a_{\mathbf{e}}^\theta)}{\theta_i^\lambda(w_i^* | a_{\mathbf{e}}^\theta)} \geq \frac{\theta_{-i}(w_{-i} | a_{\mathbf{e}}^\theta)}{\theta_{-i}^\lambda(w_{-i} | a_{\mathbf{e}}^\theta)}, \quad (9)$$

*with the inequality strict in at least one case.*

*Then, for  $i \in \{1, 2\}$ ,  $\tilde{\mathbb{S}}^\theta[\lambda'](s) > \tilde{\mathbb{S}}^\theta[\lambda](s)$ .*

In order to isolate ambiguity effects from behavioral effects, Proposition 3 assumes the same supporting strategy under both contracts. The result shows that a deliverables contract in combination with the legal institution of compensating damages can, under certain circumstances, increase the value of an alliance – even under identical action plans. The first assumption is self-explanatory

(obviously, the result cannot obtain if there are no damages payments under  $\lambda'$ ). Condition (9) says, e.g., that the true likelihood that Firm 1 satisfies its own deliverable requirement relative to Firm 2's subjective assessment of that likelihood is greater than the true likelihood that Firm 2 fails to meet its deliverable relative to Firm 1's subjective assessment that it fails. Put differently, Firm 1 receives damages compensation in outcomes it subjectively overweights relative to Firm 2.

This demonstrates an entirely different purpose for the inclusion of outcome-contingent performance clauses than those explored in the extant contract literature. The traditional wisdom is that these types of clauses serve as governance mechanisms to alleviate moral hazard problems (i.e., by assuring appropriate action choices in a fashion similar to Proposition 2). Given our setup, in which actions are verifiable, Proposition 3 says that deliverables clauses may be strictly preferred to action specifications because they actually increase the aggregate expected value of a joint project at the time of signing. The deliverables-based contract literally uses the legal institution of compensating damages to create a kind of externally enforced “ambiguity insurance” – one that can make both firms strictly better off by transferring cash from one firm to the other in states deemed more likely by the latter than the former (see the extended example for an illustration).

To the best of our knowledge, this is the first paper to identify such a role for deliverables clauses. Note that beliefs are the primitives here. Therefore, the parties might well choose their deliverables requirements in such a way as to maximize this effect: Firm 1 is confident it can deliver  $w_1^*$  and is willing to take it on as a requirement to allay Firm 2's pessimism. It is worth noting that the effect illustrated by Proposition 3 cannot arise in conventional settings that assume second order probabilities and common priors.

Contrasting these results from those in the previous section, we see how variation in contract structure – the substitution of verifiable deliverables requirements for verifiable action requirements – can relate to variation in knowledge. This contrasts with situations of moral hazard due to unverifiable actions, in which the literature tells us to focus on deliverables requirements.

**Empirical Conjecture 2.** *Versus their experienced counterparts, firms with less experience are more likely to substitute verifiable deliverables clauses for action requirements in contracts governing their joint projects.*

### 5.3 Contract Detail as Inimitable Signal of Competence

The case we wish to examine now is one in which there are two types of suitors attempting to ally with a target partner – those with a highly refined understanding of how to make the project successful and those whose understanding is poor. The target wishes to ally with the suitor possessing the most extensive knowledge of the project. The problem is that less knowledgeable suitors may have incentives to misrepresent their level of expertise in order to capture a lucrative deal with the target.

For example, multiple large electronics firms may wish to ally with a specialty electronics firm on joint development and commercialization. If the specialty firm’s products are sufficiently promising, some of the larger firms may exaggerate their development capabilities in order to win the deal. The specialty firm’s first priority is to ally with a firm that knows what needs to be done, but needs a mechanism to identify the highly capable firm(s). The mechanism we demonstrate below is contract detail; truly knowledgeable firms can use detail, such as outcome contingent penalties and rewards, as a costless signal of superior competence.

Consider two suitors, referred to as firms 1 and 2, and a single target, labelled  $\tau$ . There is a single, economically valuable project available to the target and a single suitor. The target knows the stochastic consequences of its own actions, but not those of its potential suitors. Assume Suitor 1 has the competence in the sense that it knows the implications of both the target’s and its own actions. Suitor 2 does not share 1’s competence – it is ambiguous about the consequences of its *own* actions in addition to those of the target. Aside from the knowledge asymmetry, the suitors are identical. When referring to a generic suitor, we use a “ $\sigma$ ” subscript; e.g.,  $\lambda = (\bar{x}_\sigma, \bar{x}_\tau, 0)$  where  $\bar{x}_\sigma$  is the performance requirement that would apply to either Suitor 1 or 2 under  $\lambda$ .

Since the suitors are identical,  $\Theta_1 = \Theta_2$ . Therefore, we write  $\Theta = \Theta_\sigma \times \Theta_\tau$ . Suitor 1 knows the true stochastic consequences of its own and its partner’s actions. Hence, given  $\theta \in \Theta$ , its beliefs are  $B_1^\theta = \{\theta\}$ . Like the firms in the preceding section, the target knows its own type but not that of the suitor: given  $\theta \in \Theta$ ,  $B_\tau^\theta = \{\theta_\tau\} \times \Theta_1$ . Suitor 2 does not know the consequences of anyone’s actions: given  $\theta \in \Theta$ , its beliefs are  $B_2^\theta = \Theta$ .

We now demonstrate conditions under which the more knowledgeable suitor can differentiate itself from its ill-informed competitor via strategic use of contract detail. The key requirement is that the state space  $W$  be “sufficiently large” relative to the dimensionality of the target’s belief space. The technical details are put forth in Condition 1 (see the Appendix). This condition is

immediately satisfied if the number of joint deliverable outcomes (i.e., the cardinality of  $W$ ) is greater than the sum of the cardinalities of  $\Theta_\sigma$ ,  $A_\tau$  and  $A_\sigma$ . Condition 1 seems easily satisfied in most real-world applications, reflecting the complexity and uncertainty of many deals where, for example, the underlying technologies or markets are nascent. This brings us to our main proposition.

**Proposition 4.** *Given  $\theta \in \Theta$ , let  $\tilde{\mathbb{E}}_\tau^\theta[\lambda](s)$  denote the maximum expected value obtainable for  $\tau$  under a contract of the form  $(\bar{x}_\sigma, \bar{x}_\tau, 0)$  between  $\tau$  and Suitor 2, where  $\lambda$  and  $s = (s_2, s_\tau)$  are a jointly maximizing contract and implementable strategy, respectively. Assume that (due to ambiguity),  $\tilde{\mathbb{S}}^\theta[\lambda](s_2, s_\tau) < \mathbb{S}_e^\theta$ . Let  $L \equiv \frac{1}{2} \left( \mathbb{S}_e^\theta - \tilde{\mathbb{S}}^\theta[\lambda](s) \right)$ . Then, if  $\Theta$  meets Condition 1, there exists a transfer schedule  $t$  such that, for all strategies  $s'$  implemented by  $\lambda' = (\bar{x}_\sigma, \bar{x}_\tau, t)$  between Suitor 1 and  $\tau$ ,*

$$\tilde{\mathbb{E}}_\tau^\theta[\lambda'](s') \in \left[ \tilde{\mathbb{E}}_\tau^\theta[\lambda](s) + \frac{1}{2}L, \tilde{\mathbb{E}}_\tau^\theta[\lambda](s) + \frac{1}{2}L + \epsilon \right], \quad (\text{P3.1})$$

$$\tilde{\mathbb{E}}_1^\theta[\lambda'](s') \in \left[ \tilde{\mathbb{E}}_2^\theta[\lambda](s) + \frac{1}{2}L - \epsilon, \tilde{\mathbb{E}}_2^\theta[\lambda](s) + \frac{1}{2}L \right], \quad (\text{P3.2})$$

for all  $\epsilon \in (0, \frac{1}{2}L)$ ; i.e.,  $\epsilon$  arbitrarily close to zero. In addition, for all strategies  $s''$ ,

$$\tilde{\mathbb{E}}_2^\theta[\lambda'](s'') < 0. \quad (\text{P3.3})$$

Proposition (4) says that, starting with a purely deliverables- or action-based contract that delivers the best deal Suitor 2 can offer  $\tau$ , there exists an alternative contract that can be offered by Suitor 1 – differing from the first only by the addition of state-contingent transfer payments – that acts as an inimitable competence signaling device. By P3.1, the new contract strictly increases the value of the alliance to the target. By P3.2, Suitor 1’s expected earnings are strictly positive, exceeding the payoff to Suitor 2 under the latter’s best offer to  $\tau$ . By P3.3, the ignorant Suitor 2 cannot profitably enter into the alternative contract  $\lambda'$ .

Proposition 4 demonstrates that a full-knowledge suitor can signal its superior competence by carefully elaborating a set of state-contingent penalties and rewards that its competitor cannot match. This is, of course, the pristine theoretical case. In the real world, we imagine that as firms negotiate with one another, the less experienced managers express concern about certain outcomes that the experienced partner recognizes as overblown. As a result, the experienced

firm offers performance guarantees to allay these concerns. True to the logic of our proposition, there are obvious gains from trade in such guarantees under ambiguity: the inexperienced firm values the guarantees more than they cost the experienced firm to provide. In actual business settings, particularly with other firms competing for the partnership, it may be difficult for the experienced firm to demand offsetting payments from the target (implying some net cost to the suitor of implementing this strategy). However, we expect that firms with superior understanding of alliance technologies will use their knowledge to offer guarantees that simply cannot be met by less competent rivals. This brings us to the following empirical conjecture.

**Empirical Conjecture 3.** *When one party to a strategic alliance has extensive prior experience in the relevant class of projects relative to its partner, the formal contract governing that alliance is more likely to include contingent payment clauses – in particular, clauses that tend to mitigate bad outcomes for the less experienced partner via performance bonuses for the latter and/or penalties on the former.*

## 6 Real World Contracts

Although a major empirical study of our preceding conjectures is beyond the scope of this paper, we can provide some anecdotal examples of real world contract terms that are suggestive of our results. The following are taken from the set of joint technology development contracts that formed the empirical sample in Ryall and Sampson (2009). Consistent with empirical conjectures 1, 2 and 3, our contract illustrations fall within the following three respective categories: (1) where both partners have significant alliance experience; (2) where neither partner has significant alliance experience; and (3) where one partner is experienced and the other relatively inexperienced, reflecting significant ambiguity asymmetry between partners.

The contract between Fujitsu and AMD Semiconductors (dated 3/26/93) is an illustration that falls within the first category; both partners have significant prior alliance experience in the area of joint technology development. This alliance, for developing CMOS (flash memory) technology, contains significant detail on actions the firms are to take over the course of the alliance. The development processes are set out in detail, specifying explicit steps for both new processes and new products. For example, the contract requires that the partners set up engineering development teams with co-leaders from each firm who will meet to determine products to be developed and

any changes to be made over the course of product development. Another feature of the action plans that AMD and Fujitsu provide in their contract is the detail on the development process to be followed:

Section 4.1. Development steps for the 0.5 micron Process. The development steps for the subject technology related to the 0.5 micron process shall be as follows:

1. The parties shall first compare and evaluate each unit process of both parties existing 0.5 micron wafer process to assess their applicability to the production of JV products at the JVs facility.
2. The parties shall then establish a target process flow ...
3. ...the parties shall discuss and decide how to perform such modification or development and at which facility the work will be performed ...
4. The parties shall then assemble all unit processes selected, modified and developed ...conduct a test run ... and evaluate the results thereof ...
5. If a test run does not succeed, the relevant process team shall discuss the failure with the relevant device design team and apply the necessary changes or process adjustments and repeat the test run.
6. Once both parties have confirmed the successful completion of the 0.5 micron JV process, the parties shall decide which party is responsible for taking the lead in transferring the confirmed subject technology ...

These clauses, among others, set out a detailed procedure for actions to be taken at various points of the joint development process. As far as deliverables are concerned, the contract specifies that all intellectual property developed is shared equally by Fujitsu and AMD, but does not specify explicit deliverables or outcomes from the project. In contrast, the contract between Benchmark Microelectronics and Sanyo Energy is between firms with little prior alliance experience.<sup>18</sup> This agreement, dated 4/17/95 is for the joint development of integrated circuits by Benchmark that can be used with batteries developed by Sanyo. This agree has little information on the actions required from each party. There are some general requirements, such as requiring each firm to,

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<sup>18</sup>In the five years prior to this alliance, Benchmark has engaged in only one prior alliance, while Sanyo Energy has engaged in none. Data on prior alliance activity is taken from the Securities Data Corporation Database on Alliances and Joint Ventures.

... assign sufficient knowledgeable employees to assure timely performance of each of their responsibilities under this agreement.

Unlike the contract between Fujitsu and AMD, there are no detailed process steps to be taken. However, deliverables under the contract are reasonably well specified:

## 2.1 Development of ICs

(a) ... Sanyo Energy shall provide Benchmarq performance, design and manufacturing specifications for ICs to be used in Batteries ("Specifications").

(b) Benchmarq shall design ICs in conformity with the Specifications and prepare and submit to Sanyo Energy designs, plans and prototypes and samples for such ICs.

Finally, the contract between Ross Technology and Fujitsu illustrates an agreement between firms that have greater ambiguity asymmetry; Ross Technology does not have prior experience in collaborative ventures, while Fujitsu does. This contract, dated 4/1/97, surrounds the development of a microprocessor core for Fujitsu based on Ross proprietary microcontroller technology. Actions in terms of process or product development are not specified in this agreement. Some limited contributions of technologies are specified; some technologies to be shared by Fujitsu with Ross Technology are set out. In contrast, the contract is quite detailed as to deliverables, specifying dates for development milestones. Further, the contract details a payment schedule, from Fujitsu to Ross Technology, that is contingent on reaching specific milestones. These payments appear to map onto the state-contingent transfer payments anticipated by our analysis above. Further, there are also penalty payments to the experienced firm from the inexperienced firm, which appear as a form of off-setting guarantees as anticipated by Proposition 4 above:

## 6.2 Rejection.

(b) ... For each Deliverable that is delivered more than thirty (30) days late... and for which there is an applicable milestone payment, Ross will accrue a late delivery penalty equal to ten percent of such milestone payment ...

Note that, in addition to the contract detailed above, Fujitsu also took a sixty percent equity stake in Ross Technology at the time of the joint development deal. It is possible that such an

equity stake serves as an off-setting guarantee as anticipated by our theory above. [MR: this is outside the contract, though - this seems to matter, no?] The payment for equity in Ross serves as a guaranteed payment, should the alliance outcome be poor. Further the value of the equity to Fujitsu declines in value should the alliance fail to deliver.

In TCE parlance, this equity arrangement aligns incentives between the parties, ideally leading to higher value outcomes. However, under ambiguity aversion, the equity is not so much to align incentives, but rather to induce the less experienced party to enter the alliance to begin with. By insuring against poorly understood downsides, the more experienced firm can lead the hesitant, less experienced firm to enter a valuable deal that might otherwise be foregone. However, it is only the experienced firm with the ability to execute appropriate joint development steps that can afford to make such guarantees.<sup>19</sup>

It is interesting to note that the contract between Ross and Fujitsu, in addition to including state contingent payments, does specify some actions, largely in terms of the more experienced partner, but primarily specifies detailed deliverables that are tied to the contingent payments. While not directly anticipated by our theory above, these clause types appear very consistent with what we might expect; the experienced firm has some actions specified, while the less experienced firm is tied to deliverables.

These comparisons are illustrative of the way in which firms might craft contractual clauses along the lines of our results. They also show how our theory developed can be used to explain contractual choices in a systematic way. In this sense, we see several contributions of this paper to both the economics and management literatures. First, the theory developed here helps explain puzzles noted in prior empirical work on contracts. As noted earlier, while contracts do appear to become more detailed overall when partners have greater prior alliance experience, learning by doing arguments do not neatly explain the content of this increased detail: the likelihoods of some types of clauses increases with experience while others decrease. What accounts for this? The preceding analysis suggests that greater detail may be explained by the use of joint action plans – which tend to incorporate more detailed terms on development steps, for example by experienced partners (i.e., those who face relatively lower ambiguity regarding the likely outcomes of various actions). When firms are less experienced, they more likely specify required outcomes and have

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<sup>19</sup>In some cases, the only guarantee that may be sufficiently convincing is a complete acquisition. While this is beyond the scope of the paper, we note that the theory developed above may explain some merger and acquisition activity.

less detailed contracts as a result. Finally, experience or ambiguity asymmetry leads firms to set transfer payments, which may take the form of penalties, milestone payments and/or equity stakes.

## 7 Conclusions

In this paper, we apply ambiguity and ambiguity aversion to explain contract design. Specifically, we link different levels of ambiguity in joint development alliances to two different types of contracts: action-based and deliverables-based. As the names imply, action-based contracts specify the actions contracting parties need to take, while deliverables-based contracts do not specify required actions, but rather required outcomes. Our theoretical results demonstrate that action-based contracts lead to a first best outcome when allying firms have a low level of ambiguity. Translating from our setting to the real world, we imagine that experienced firms can map actions onto desired outcomes with greater precision. However, given that experienced firms know the necessary actions and that outcomes are still subject to stochastic processes, these firms would rather commit themselves to the required actions than to delivering outcomes that have an element of uncertainty. Our results suggest that deliverables-based contracts are more likely when firms have insufficient experience to accurately map actions onto outcomes. When firms lack relevant experience, they have very vague ideas of what actions are necessary to create the desired outcomes and are reluctant to commit themselves to specific actions that may or may not be required over the course of the project.

Cases in which there is experience or ambiguity asymmetry between the partners present a unique challenge. The experienced firm typically has an idea of the necessary actions to achieve the desired outcome, but the inexperienced firm does not. The experienced firm would prefer to contract on actions, while the inexperienced firm may: (1) undervalue the project and be unwilling to undertake the project; and/or (2) prefer to contract on deliverables. In order to induce the inexperienced firm to enter an alliance, the experienced firm may make contingency payments that insure against the outcomes that the inexperienced firm is most concerned about. While the straightforward interpretation of this is a penalty payment levied against the experienced firm, another form is an equity stake taken by the experienced firm in the inexperienced firm, where the equity loses value if the project does not yield as the experienced firm has suggested.

Examples taken from actual joint technology development contracts illustrate our theoretical results. These illustrations show a more direct link of the theory with empirical work and can explain patterns observed that do not fit neatly with current explanations. For example, greater

contract detail has often been attributed to learning by doing arguments; i.e., more experienced partners lead to more details included in contracts. However, such arguments do not explain why some clauses are less likely with experience or the form that terms take when partners have more or less experience. With these empirical examples, we hope that the theory developed above will have more direct application to future empirical work on contracts, to better refine our understanding of the types of terms firms use in different circumstances.

Our analysis explicitly incorporates partner asymmetry in contract design. Much of the empirical literature largely tables the issue of partner differences and how these differences might alter contract design. We account for the fact that some partners are more knowledgeable about their transaction technology and thus enjoy a superior contracting capability. Such asymmetries have implications for how parties negotiate and help explain the propensity of more experienced partners to make state-contingent transfer payments to counter the greater ambiguity of the less experienced partner. Since these transfer payments are only feasible for experienced firms, who can best map actions onto outcomes, willingness to make such payments signals the superior capabilities of the experienced firm to the less experienced firm.

The theory developed in this paper goes beyond the current formal theory in the economics literature by generating conjectures about contract observables as opposed to terms in the abstract. This has the advantage of mapping more explicitly onto the empirical context, as illustrated above, allowing more direct empirical testing and facilitating more rapid development of the literature linking firm characteristics with inter-organization form. While this paper makes a novel contribution to the theory of contract design, we note that our findings are consistent with prior theoretical work showing, for example, that optimal contracts may not be very detailed (Levin, 2003; Bernheim and Whinston, 1998a).<sup>20</sup> In this sense, our analysis bridges the empirical and theoretical literatures by providing an explanation for the contracts we observe that is still consistent with prior theoretical work. Further refinements, through empirical analysis, will improve our understanding of how firms design organization.

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<sup>20</sup>Our finding that deliverables-based contracts, which tend to be less detailed, are efficient in cases of significant ambiguity asymmetry between partners would be an illustration of this point.

## A Appendix – proofs & other technical details

### A.1 Proof of Proposition 1

Given  $\theta \in \Theta$ , consider  $\lambda = (a_{1\mathbf{e}}, a_{2\mathbf{e}}, 0)$  where  $a_{\mathbf{e}}^\theta = (a_{1\mathbf{e}}, a_{2\mathbf{e}})$  is an efficient action profile for  $\theta$ . Let  $s \in S$  satisfy  $s(\theta) = a_{\mathbf{e}}^\theta$  and, for all  $\theta' \neq \theta$ ,  $s(\theta')$  constitutes a (possibly mixed) Nash equilibrium of the subgame defined by  $\theta'$  in the full information game. Then, for  $i \in \{1, 2\}$ ,

$$\begin{aligned} \mathbb{E}_i^\theta[\lambda](s) &= \sum_{w \in W} \left( \frac{1}{2}v(w) - c_i(w_i) + t_i(w) + \delta_i^\theta[\lambda](w|a_{\mathbf{e}}) \right) p(w|a_{\mathbf{e}}) \\ &= \sum_{w \in W} \left( \frac{1}{2}v(w) - c_i(w_i) \right) p(w|a_{\mathbf{e}}), \\ &= \mathbb{F}_i^\theta[\lambda], \end{aligned}$$

where the second line holds because  $t = 0$  and  $\delta_i^\theta = 0$  due to the fact that neither firm breaches under  $a_{\mathbf{e}}$ .

There is an efficient strategy  $s_{\mathbf{e}}$  such that  $s_{\mathbf{e}}(\theta) = s(\theta)$ . By assumption, for  $i \in \{1, 2\}$ ,  $\mathbb{E}_i^\theta[\lambda](s_{\mathbf{e}}) > 0$ . Therefore, for  $i \in \{1, 2\}$ ,  $\mathbb{E}_i^\theta[\lambda](s) > 0$ . Hence, part (i) of Definition 1 (implementation) is satisfied. Moreover, under full information,  $\mathbb{E}_1^\theta[\lambda](s) + \mathbb{E}_2^\theta[\lambda](s) = \mathbb{S}_{\mathbf{e}}^\theta$ . Therefore,  $\mathbb{F}_1^\theta[\lambda] + \mathbb{F}_2^\theta[\lambda] = \mathbb{S}_{\mathbf{e}}^\theta$ .

Suppose  $\lambda$  does not implement  $a_{\mathbf{e}}$ . Then, it must be the case that there is a strategy  $s'_1 \neq s_1$  for Firm 1 (without loss of generality) such that, for some  $\theta' \in \Theta$ ,  $\mathbb{E}_1^{\theta'}[\lambda](s'_1, s_2) > \mathbb{E}_1^{\theta'}[\lambda](s)$ . By construction of  $s$ , the only possibility is  $\theta' = \theta$ . Thus,

$$\mathbb{F}_1^\theta[\lambda] < \mathbb{E}_1^\theta[\lambda](s'_1, s_2). \tag{10}$$

To simplify notation, let  $\alpha_1 \in \Delta(A_1)$  be the distribution on actions indicated by strategy  $s_1(\theta)$ .

The expected payoff to firm 2 under this deviation is:

$$\begin{aligned}
\mathbb{E}_2^\theta(s'_1, s_2) &= \sum_{a_1 \in A_1} \sum_{w \in W} \left( \frac{1}{2}v(w) - c_2(w_2) + d_2[\lambda](w|a_1, a_{2e}) \right) p(w|a_1, a_{2e}) \alpha_1(a_1) \\
&= \sum_{a_1 \in A_1} \sum_{w \in W_x} \left[ \frac{1}{2}v(w) - c_2(w_2) + \left( \mathbb{F}_2^\theta[\lambda] - \frac{1}{2}v(w) + c_2(w_2) \right) \right] p(w|a_1, a_2^*) \alpha_1(a_1) \\
&\quad + \sum_{a_1 \in A_1} \sum_{w \in W_y} \left( \frac{1}{2}v(w) - c_2(w_2) \right) p(w|a_1, a_{2*}) \alpha_1(a_1) \\
&= \sum_{a_1 \in A_1} \left( \sum_{w \in W_x} \mathbb{F}_2^\theta[\lambda] p(w|a_1, a_{2*}) + \sum_{w \in W_y} \left( \frac{1}{2}v(w) - c_2(w_2) \right) p(w|a_1, a_{2*}) \right) \alpha_1(a_1)
\end{aligned}$$

where  $W_x \equiv \{w \in W | \mathbb{F}_2^\theta[\lambda] - \frac{1}{2}v(w) + c_2(w_2) > 0\}$  and  $W_y \equiv W \setminus W_x$ . Since  $(w \in W_x) \Rightarrow (\mathbb{F}_2^\theta[\lambda] > \frac{1}{2}v(w) - c_2(w_2))$ , the preceding implies:

$$\mathbb{E}_2^\theta[\lambda](s'_1, s_2) \geq \mathbb{F}_2^\theta[\lambda]. \quad (11)$$

Combining (10) and (11),

$$\mathbb{E}_1^\theta[\lambda](s'_1, s_2) + \mathbb{E}_2^\theta[\lambda](s'_1, s_2) > \mathbb{S}_e^\theta,$$

which contradicts the premise that  $a_e^\theta$  is efficient.

## A.2 Proof of Proposition 2

Assume the conditions of the premise. We begin by demonstrating (8) for Firm 1. By the definition of subjective expected value (6), for all  $\theta \in \Theta$ ,

$$\tilde{\mathbb{E}}_1^\theta[\lambda'](s_e) = \min_{\theta' \in B_1^\theta} \mathbb{E}_1^{\theta'}[\lambda'](s_e),$$

Under the ambiguity assumption,  $\mathbf{B}_1 = \cup_{\theta \in \Theta} B_1^\theta$  where  $B_1^\theta = \{\theta_1\} \times \Theta_2$ . Therefore, for all  $\theta \in \Theta$ ,

$$\tilde{\mathbb{E}}_1^\theta[\lambda'](s_e) = \min_{\theta'_2 \in \Theta_2} \mathbb{E}_1^{(\theta_1, \theta'_2)}[\lambda'](s_e).$$

By Item 2 of the premise, for each  $\theta \in \Theta$ , there exists a unique minimizing type  $\hat{\theta}_2$  such that

$$\tilde{\mathbb{E}}_1^\theta[\lambda'](s_e) = \mathbb{E}_1^{(\theta_1, \hat{\theta}_2)}[\lambda'](s_e). \quad (12)$$

Now, consider  $\lambda$  and  $s$ . Again, by Definition (6), for all  $\theta \in \Theta$ ,

$$\tilde{\mathbb{E}}_1^\theta[\lambda](s) = \min_{\theta'_2 \in \Theta_2} \mathbb{E}_1^{(\theta_1, \theta'_2)}[\lambda](s).$$

By the definition of  $\lambda$  and  $s$ , for all  $\theta \in \Theta$  and all  $w \in W$ ,  $\delta_1^\theta[\lambda](a_{s(\theta)}, w) = 0$  and  $t_1[\lambda](w) = 0$ .

This implies, for all  $\theta \in \Theta$ ,

$$\min_{\theta'_2 \in \Theta_2} \mathbb{E}_1^{(\theta_1, \theta'_2)}[\lambda](s) = \min_{\theta'_2 \in \Theta_2} \mathbb{E}_1^{(\theta_1, \theta'_2)}[\lambda_\emptyset](s).$$

The last two equations imply, for all  $\theta \in \Theta$ ,

$$\tilde{\mathbb{E}}_1^\theta[\lambda](s) = \min_{\theta'_2 \in \Theta_2} \mathbb{E}_1^{(\theta_1, \theta'_2)}[\lambda_\emptyset](s). \quad (13)$$

According to Item 3 of the premise, for all  $\theta \in \Theta$ ,

$$\mathbb{E}_1^{(\theta_1, \hat{\theta}_2)}[\lambda'](s_e) > \mathbb{E}_1^{(\theta_1, \hat{\theta}_2)}[\lambda_\emptyset](s). \quad (14)$$

Of course, for all  $\theta \in \Theta$ ,

$$\mathbb{E}_1^{(\theta_1, \hat{\theta}_2)}[\lambda_\emptyset](s) \geq \min_{\theta'_2 \in \Theta_2} \mathbb{E}_1^{(\theta_1, \theta'_2)}[\lambda_\emptyset](s). \quad (15)$$

Together, (12), (13), (14), and (15) imply, for all  $\theta \in \Theta$ ,

$$\tilde{\mathbb{E}}_1^\theta[\lambda'](s_e) > \tilde{\mathbb{E}}_1^\theta[\lambda](s), \quad (16)$$

thereby proving (8) for Firm 1.

With this, it remains to be shown that  $\lambda'$  implements  $s_e$ . We must demonstrate that  $s_e$  meets the two implementation conditions. Satisfaction of Condition (i) of Definition 1 is almost immediate. By Item 1 of the premise,  $\lambda$  implements  $s$ . Therefore, for all  $\theta \in \Theta$ ,  $\tilde{\mathbb{E}}_1^\theta[\lambda](s) \geq 0$ . Thus, by (16), for all  $\theta \in \Theta$ ,  $\tilde{\mathbb{E}}_1^\theta[\lambda'](s_e) > 0$ .

To complete the proof, it must be shown that Condition (ii) of Def. 1 also holds: for all  $\hat{\theta} \in \Theta$

and  $\hat{s}_1 \neq s_{1e}$ ,  $\tilde{\mathbb{E}}_1^{\hat{\theta}}[\lambda'](\hat{s}_1, s_{2e}) \leq \tilde{\mathbb{E}}_1^{\hat{\theta}}[\lambda'](s_e)$ . Begin by defining the following partition of  $W$ :

Both parties perform	$W_{++} \equiv \{(w_1^*, w_2^*)\}$
Damages possibly due firm 1	$W_{+-} \equiv \{w \in W   w_1 = w_1^*, w_2 \neq w_2^*\}$
Damages possibly due firm 2	$W_{-+} \equiv \{w \in W   w_1 \neq w_1^*, w_2 = w_2^*\}$
Both parties breach	$W_{--} \equiv \{w \in W   w_1 \neq w_1^*, w_2 \neq w_2^*\}$

Consider an arbitrary  $\hat{\theta} \in \Theta$ . Let  $\theta'_2$  be the worst partner type for  $\hat{\theta}_1$ . For notational convenience, let  $\hat{\theta}' \equiv (\hat{\theta}_1, \theta'_2)$ . Similarly, define  $a^* \equiv a_{s_e(\hat{\theta}'})$  and, keeping in mind that under the assumed belief structure, firm strategies vary only on own type, for some  $\hat{s}_1 \neq s_{1e}$  let  $\hat{a} \equiv (a_{\hat{s}_1(\hat{\theta}_1)}, a_{s_{2e}(\theta'_2)})$ . Under  $\lambda'$ , damages depend only upon  $w$ ; actions and type have no effect. Therefore, we write, e.g.,  $\pi_1[\lambda'](w)$  without ambiguity (rather than, e.g.,  $\pi_1^{\hat{\theta}}(w|\hat{a})$ ). Then, by the definition of a worst partner type,

$$\begin{aligned}
\tilde{\mathbb{E}}_1^{\hat{\theta}}[\lambda'](s_e) &= \mathbb{E}_1^{\hat{\theta}'}[\lambda'](s_e), \\
&= \sum_{w \in W} \pi_1[\lambda'](w) f^{\hat{\theta}'}(w|a_e); \text{ and} \\
\tilde{\mathbb{E}}_1^{\hat{\theta}}[\lambda'](\hat{s}_1, s_{2e}) &= \mathbb{E}_1^{\hat{\theta}'}[\lambda'](\hat{s}_1, s_{2e}), \\
&= \sum_{w \in W} \pi_1[\lambda'](w) f^{\hat{\theta}'}(w|\hat{a}).
\end{aligned}$$

Thus, given the partition of  $W$  defined above,

$$\tilde{\mathbb{E}}_1^{\hat{\theta}}[\lambda'](s_e) - \tilde{\mathbb{E}}_1^{\hat{\theta}}[\lambda'](\hat{s}_1, s_{2e}) = \sum_{w \in W} \pi_1[\lambda'](w) f^{\hat{\theta}'}(w|a_e) - \sum_{w \in W} \pi_1[\lambda'](w) f^{\hat{\theta}'}(w|\hat{a}) \quad (17)$$

$$= \sum_{w \in W_{++} \cup W_{+-}} \pi_1[\lambda'](w) \left( f^{\hat{\theta}'}(w|a_e) - f^{\hat{\theta}'}(w|\hat{a}) \right) \quad (18)$$

$$+ \sum_{w \in W_{-+} \cup W_{--}} \pi_1[\lambda'](w) \left( f^{\hat{\theta}'}(w|a_e) - f^{\hat{\theta}'}(w|\hat{a}) \right) \quad (19)$$

The only element in  $W_{++}$  is  $w^*$ , which yields a payoff to Firm 1 of  $\pi_1[\lambda'](w^*)$ . For all  $(w_1^*, w_2) \in W_{+-}$ , the damages institution (3) under  $\lambda'$  ensures that  $\pi_1[\lambda'](w) = \pi_1[\lambda'](w^*)$ . This and (1) imply

(18) can be written

$$\pi_1[\lambda'](w^*) \sum_{w \in W_{++} \cup W_{+-}} \hat{\theta}_1(w_1^* | a_{1\mathbf{e}}) \theta_2'(w_2 | a_{2\mathbf{e}}) - \hat{\theta}_1(w_1^* | \hat{a}_1) \theta_2'(w_2 | a_{2\mathbf{e}}).$$

Rearranging terms, this can be rewritten

$$\pi_1[\lambda'](w^*) \sum_{w \in W_{++} \cup W_{+-}} \left( \hat{\theta}_1(w_1^* | a_{1\mathbf{e}}) - \hat{\theta}_1(w_1^* | \hat{a}_1) \right) \theta_2'(w_2 | a_{2\mathbf{e}}),$$

or, since  $W_{++} \cup W_{+-} = \{w_1^*\} \times W_2$ ,

$$\pi_1[\lambda'](w^*) \left( \hat{\theta}_1(w_1^* | a_{1\mathbf{e}}) - \hat{\theta}_1(w_1^* | \hat{a}_1) \right). \quad (20)$$

Now, consider (19). Using the specification of  $W_{-+}$  and  $W_{--}$  and expanding,

$$(19) = \sum_{w_1 \neq w_1^*} \sum_{w_2 \in W_2} \pi_1[\lambda'](w) \left( f^{\hat{\theta}'}(w | a_{\mathbf{e}}) - f^{\hat{\theta}'}(w | \hat{a}) \right), \quad (21)$$

$$= \sum_{w_1 \neq w_1^*} \sum_{w_2 \in W_2} \pi_1[\lambda'](w_1, w_2) \left( \hat{\theta}_1(w_1 | a_{1\mathbf{e}}) \theta_2'(w_2 | a_{2\mathbf{e}}) - \hat{\theta}_1(w_1 | \hat{a}_1) \theta_2'(w_2 | a_{2\mathbf{e}}) \right), \quad (22)$$

$$= \sum_{w_1 \neq w_1^*} \sum_{w_2 \in W_2} \pi_1[\lambda'](w_1, w_2) \theta_2'(w_2 | a_{2\mathbf{e}}) \left( \hat{\theta}_1(w_1 | a_{1\mathbf{e}}) - \hat{\theta}_1(w_1 | \hat{a}_1) \right), \quad (23)$$

$$= \sum_{w_1 \neq w_1^*} \left( \hat{\theta}_1(w_1 | a_{1\mathbf{e}}) - \hat{\theta}_1(w_1 | \hat{a}_1) \right) \sum_{w_2 \in W_2} \pi_1[\lambda'](w_1, w_2) \theta_2'(w_2 | a_{2\mathbf{e}}). \quad (24)$$

Under  $\lambda'$ ,  $\pi_1[\lambda'](w) = \gamma_1(w) + \delta_1[\lambda'](w)$ ; i.e.,  $t_1 = 0$  and actions are irrelevant with respect to damages. Note that, in all of  $W_{-+} \cup W_{--}$ , there is only one element,  $w = (w_1, w_2^*)$ , for which it may be true that  $\delta_1[\lambda'](w) > 0$ . Therefore,

$$\sum_{w_2 \in W_2} \pi_1[\lambda'](w_1, w_2) \theta_2'(w_2 | a_{2\mathbf{e}}) = \bar{\gamma}_1^{\hat{\theta}'}(s_{\mathbf{e}} | w_1) + \delta_1[\lambda'](w_1, w_2^*) \theta_2'(w_2^* | a_{2\mathbf{e}}) \quad (25)$$

$$= \bar{\gamma}_1^{\hat{\theta}'}(s_{\mathbf{e}} | w_1) - \bar{\delta}_2[\lambda'](w_1), \quad (26)$$

where

$$\bar{\delta}_2[\lambda'](w_1) \equiv \delta_2[\lambda'](w_1, w_2^*) \theta_2'(w_2^* | a_{2\mathbf{e}})$$

By Item 5 of the premise, for all  $w_1 \neq w_1^*$ ,

$$0 \leq \bar{\gamma}_1^{\hat{\theta}'}(s_e|w_1) - \bar{\delta}_2[\lambda'](w_1) \leq \gamma_1(w^*).$$

Under  $\lambda'$ ,  $\gamma_1(w^*) = \pi_1[\lambda'](w^*)$ . Therefore,

$$0 \leq \bar{\gamma}_1^{\hat{\theta}'}(s_e|w_1) - \bar{\delta}_2[\lambda'](w_1) \leq \pi_1[\lambda'](w^*). \quad (27)$$

Finally, note that,

$$\sum_{w_1 \neq w_1^*} \left( \hat{\theta}_1(w_1|a_{1e}) - \hat{\theta}_1(w_1|\hat{a}_1) \right) = - \left( \hat{\theta}_1(w_1^*|a_{1e}) - \hat{\theta}_1(w_1^*|\hat{a}_1) \right). \quad (28)$$

Combining (24), (26), (27), and (28),

$$\pi_1[\lambda'](w^*) \left( \hat{\theta}_1(w_1^*|a_{1e}) - \hat{\theta}_1(w_1^*|\hat{a}_1) \right) \geq (19) \geq 0. \quad (29)$$

Together, (20) and (29) imply  $\tilde{\mathbb{E}}_1^{\hat{\theta}}[\lambda'](s_e) - \tilde{\mathbb{E}}_1^{\hat{\theta}}[\lambda'](\hat{s}_1, s_{2e}) \geq 0$ . This establishes Condition (ii) of Def. 1.

Follow the same logic for Firm 2 and the proof is complete.

### A.3 Proof of Proposition 3

According to the premise,  $s$  implements  $a_e^\theta$  for all types. By definition, for all  $\theta \in \Theta$ ,

$$\tilde{S}^\theta[\lambda](s) = \tilde{\mathbb{E}}_1^\theta[\lambda](s) + \tilde{\mathbb{E}}_2^\theta[\lambda](s).$$

Recalling the notation introduced for the proposition,

$$\begin{aligned} \tilde{\mathbb{E}}_1^\theta[\lambda](s) &= \mathbb{E}_1^{(\theta_1, \hat{\theta}_2^\lambda)}[\lambda](s), \\ \tilde{\mathbb{E}}_2^\theta[\lambda](s) &= \mathbb{E}_2^{(\hat{\theta}_1^\lambda, \theta_2)}[\lambda](s). \end{aligned}$$

Under  $\lambda = (a_{\mathbf{e}}^\theta, 0)$ ,  $s$  implies zero damages payments for all types. Therefore,

$$\begin{aligned}\tilde{\mathbb{E}}_1^\theta[\lambda](s) &= \sum_{w \in W} \gamma(w) \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^\lambda(w_2 | a_{2\mathbf{e}}^\theta), \\ \tilde{\mathbb{E}}_2^\theta[\lambda](s) &= \sum_{w \in W} \gamma(w) \hat{\theta}_1^\lambda(w_1 | a_{1\mathbf{e}}^\theta) \theta_2(w_2 | a_{2\mathbf{e}}^\theta).\end{aligned}$$

Under  $\lambda'$ ,

$$\begin{aligned}\tilde{\mathbb{E}}_1^\theta[\lambda'](s) &= \sum_{w \in W} \gamma(w) \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta) + \sum_{w \in W} \delta_1[\lambda'](w) \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta), \\ \tilde{\mathbb{E}}_2^\theta[\lambda'](s) &= \sum_{w \in W} \gamma(w) \hat{\theta}_1^{\lambda'}(w_1 | a_{1\mathbf{e}}^\theta) \theta_2(w_2 | a_{2\mathbf{e}}^\theta) + \sum_{w \in W} \delta_2[\lambda'](w) \hat{\theta}_1^{\lambda'}(w_1 | a_{1\mathbf{e}}^\theta) \theta_2(w_2 | a_{2\mathbf{e}}^\theta).\end{aligned}$$

Consider Firm 1. Recall,  $W_1^+$  is the set of deliverables such that  $(w_1^*, w_2) \in W_1^+ \Rightarrow \delta_1[\lambda'](w_1^*, w_2) > 0$ . Due to the balancedness of damages,  $(w_1, w_2^*) \in W_2^+ \Rightarrow \delta_1[\lambda'](w_1, w_2^*) < 0$ . For all  $w \notin W_1^+ \cup W_2^+$ ,  $\delta_1[\lambda'](w) = 0$ . Therefore,

$$\begin{aligned}\sum_{w \in W} \delta_1[\lambda'](w) \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta) &= \sum_{(w_1^*, w_2) \in W_1^+} \delta_1[\lambda'](w_1^*, w_2) \theta_1(w_1^* | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta) \\ &\quad + \sum_{(w_1, w_2^*) \in W_2^+} \delta_1[\lambda'](w_1, w_2^*) \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2^* | a_{2\mathbf{e}}^\theta).\end{aligned}$$

Let  $D$  be the sum of the damages payments to both firms; that is,

$$D \equiv \sum_{w \in W} \delta_1[\lambda'](w) \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta) + \sum_{w \in W} \delta_2[\lambda'](w) \hat{\theta}_1^{\lambda'}(w_1 | a_{1\mathbf{e}}^\theta) \theta_2(w_2 | a_{2\mathbf{e}}^\theta).$$

From the preceding disaggregation,

$$\begin{aligned}D &= \sum_{(w_1^*, w_2) \in W_1^+} \delta_1[\lambda'](w_1^*, w_2) \theta_1(w_1^* | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta) \\ &\quad + \sum_{(w_1, w_2^*) \in W_2^+} \delta_1[\lambda'](w_1, w_2^*) \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2^* | a_{2\mathbf{e}}^\theta) \\ &\quad + \sum_{(w_1^*, w_2) \in W_1^+} \delta_2[\lambda'](w_1^*, w_2) \hat{\theta}_1^{\lambda'}(w_1^* | a_{1\mathbf{e}}^\theta) \theta_2(w_2 | a_{2\mathbf{e}}^\theta) \\ &\quad + \sum_{(w_1, w_2^*) \in W_2^+} \delta_2[\lambda'](w_1, w_2^*) \hat{\theta}_1^{\lambda'}(w_1 | a_{1\mathbf{e}}^\theta) \theta_2(w_2^* | a_{2\mathbf{e}}^\theta).\end{aligned}$$

By the balancedness of damages,

$$\begin{aligned}
D &= \sum_{(w_1^*, w_2) \in W_1^+} \delta_1[\lambda'](w_1^*, w_2) \theta_1(w_1^* | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta) \\
&\quad + \sum_{(w_1, w_2^*) \in W_2^+} \delta_1[\lambda'](w_1, w_2^*) \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2^* | a_{2\mathbf{e}}^\theta) \\
&\quad - \sum_{(w_1^*, w_2) \in W_1^+} \delta_1[\lambda'](w_1^*, w_2) \hat{\theta}_1^{\lambda'}(w_1^* | a_{1\mathbf{e}}^\theta) \theta_2(w_2 | a_{2\mathbf{e}}^\theta) \\
&\quad - \sum_{(w_1, w_2^*) \in W_2^+} \delta_1[\lambda'](w_1, w_2^*) \hat{\theta}_1^{\lambda'}(w_1 | a_{1\mathbf{e}}^\theta) \theta_2(w_2^* | a_{2\mathbf{e}}^\theta).
\end{aligned}$$

Combining,

$$\begin{aligned}
D &= \sum_{(w_1^*, w_2) \in W_1^+} \delta_1[\lambda'](w_1^*, w_2) \left( \theta_1(w_1^* | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta) - \hat{\theta}_1^{\lambda'}(w_1^* | a_{1\mathbf{e}}^\theta) \theta_2(w_2 | a_{2\mathbf{e}}^\theta) \right) \\
&\quad - \sum_{(w_1, w_2^*) \in W_2^+} \delta_1[\lambda'](w_1, w_2^*) \left( \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2^* | a_{2\mathbf{e}}^\theta) - \hat{\theta}_1^{\lambda'}(w_1 | a_{1\mathbf{e}}^\theta) \theta_2(w_2^* | a_{2\mathbf{e}}^\theta) \right).
\end{aligned}$$

By Condition 9,

$$\begin{aligned}
\left( \theta_1(w_1^* | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta) - \hat{\theta}_1^{\lambda'}(w_1^* | a_{1\mathbf{e}}^\theta) \theta_2(w_2 | a_{2\mathbf{e}}^\theta) \right) &\geq 0, \text{ and,} \\
\left( \theta_1(w_1 | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2^* | a_{2\mathbf{e}}^\theta) - \hat{\theta}_1^{\lambda'}(w_1 | a_{1\mathbf{e}}^\theta) \theta_2(w_2^* | a_{2\mathbf{e}}^\theta) \right) &\leq 0.
\end{aligned}$$

And, these inequalities are strict in at least one case. Therefore,  $D > 0$ .

Finally,

$$\tilde{\mathbb{E}}_1^\theta[\lambda'](s) = \tilde{\mathbb{E}}_1^\theta[\lambda](s) + \sum_{w \in W} \delta_1[\lambda'](w) \theta_1(w | a_{1\mathbf{e}}^\theta) \hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta) + \epsilon_1.$$

where  $\epsilon_1 = 0$  if  $\hat{\theta}_2^{\lambda'}(w_2 | a_{2\mathbf{e}}^\theta)$  is also a minimizing type under  $\lambda$ , otherwise  $\epsilon_1 > 0$ . Pulling everything together,

$$\begin{aligned}
\tilde{\mathbb{S}}^\theta[\lambda'](s) &= \tilde{\mathbb{E}}_1^\theta[\lambda](s) + \tilde{\mathbb{E}}_2^\theta[\lambda](s) + D + \epsilon_1 + \epsilon_2, \\
&= \tilde{\mathbb{S}}^\theta[\lambda](s) + D + \epsilon_1 + \epsilon_2.
\end{aligned}$$

Since  $D + \epsilon_1 + \epsilon_2 > 0$ , the proof is complete.

## A.4 Proof of Proposition 4

For the next definition and the following proof, we make shorthand use of vector notation so that, e.g., rather than  $\sum_{w \in W} f^\theta(w|a)t(w)$ , we simply write  $f_a^\theta \cdot t$ . Recall that the “ $\sigma$ ” subscript denotes a suitor object.

**Condition 1** (Sufficient Dimensionality). *The type space  $\Theta$  is said to meet the sufficient dimensionality condition with respect to  $\theta \in \Theta$ , if there exist matrices  $\Lambda_+^\theta$ ,  $\Lambda_-^\theta$  and  $\Lambda^\theta$  with the following properties:*

1. *The set of rows of  $\Lambda_+^\theta$  are the union of the following probability vectors (columns correspond to deliverables):*
  - (a) *For all  $\theta' \in B_\tau^\theta \setminus \{\theta\}$ ,  $f_{a_e}^{\theta'}$ ;*
  - (b) *For all  $s'_\sigma \in S_\sigma$  such that  $s'_\sigma(\theta) \neq a_{\sigma e}^\theta$  and all  $s'_\tau \in S_\tau$ ,  $f_{(s'_\sigma(\theta), s'_\tau(\theta))}^\theta$ ;*
  - (c) *For each  $a \in A$  and a corresponding  $\theta' \in \Theta$ ,  $f_a^{\theta'}$ ;*
2. *The set of rows of  $\Lambda_-^\theta$  are the union of the following probability vectors: For each  $s'_\tau \in S_\tau$  such that  $s'_\tau(\theta) \neq a_{\tau e}$  and a corresponding  $\theta' \in B_\tau^\theta$ ,  $f_{(a_{\sigma e}^\theta, s'_\tau(\theta))}^{\theta'}$ ;*
3.  *$\Lambda^\theta$  consists of the rows of  $\Lambda_+^\theta$ , the rows of  $\Lambda_-^\theta$ , and a row corresponding to  $f_{a_e}^\theta$ ;*
4.  *$\Lambda^\theta$  has full row rank.*

**Comment** The sufficient dimensionality condition boils down to two requirements. The first, implicit, is that  $W$  be “large enough” relative to the number of relevant types and the set of relevant actions. In real world settings, we conjecture that this condition is not difficult to meet – if by no other means than intentionally elaborating a sufficiently refined set of deliverables outcomes. The second is that the types and actions be “informative enough” in the sense that changing types and/or actions results in distinguishable changes in the probabilities over deliverables. For example, action and type labels could refer to equivalence classes that have the feature: holding type constant and changing one firm’s action, or holding action constant and changing one firm’s type, results in a distinct probability distribution. It is worth noting that Condition 1 is less demanding than this in the sense that there may be redundant distributions in Items 1 and 2 (see, e.g., the extended example).

**Proof** As stated in the premise, the focal type profile is  $\theta \in \Theta$ . The contract  $\lambda = (\bar{x}_\sigma, \bar{x}_\tau, 0)$  implements  $s = (s_2, s_\tau)$ . Under  $\lambda$  and  $s$ , the target  $\tau$  receives its maximum expected value from allying with Suitor 2 under a purely action- or deliverables-based contract:  $\tilde{\mathbb{E}}_\tau^\theta[\lambda](s)$ . By implication of the fact that  $s$  is implemented by  $\lambda$  between Suitor 2 and target  $\tau$ ,  $\tilde{\mathbb{E}}_\tau^\theta[\lambda](s) \geq 0$  and  $\tilde{\mathbb{E}}_2^\theta[\lambda](s) \geq 0$ .

Drop subscripts on  $t$  and simply take  $t > 0$  to be a positive transfer to  $\tau$ ; e.g.,  $t = t_\tau = -t_\sigma$ . For firm  $i$ , recall,  $\gamma_i(w) \equiv \frac{1}{2}v(w) - c_i(w)$ . Let  $L \equiv \mathbb{S}_e^\theta - \tilde{\mathbb{S}}^\theta[\lambda](s)$  ( $> 0$  by assumption). In what follows,  $\epsilon$  is arbitrary subject to:  $\frac{1}{2}L > \epsilon > 0$ . Let  $K$  be a number larger than the greatest absolute value of the expected unadjusted payoffs to suitors and the target. Specifically,

$$K \equiv 2 \max_{\substack{i \in \{\sigma, \tau\} \\ \theta \in \Theta \\ s \in S}} |f_{s(\theta)}^\theta \cdot \gamma_i| + L + \epsilon$$

We proceed by: (i) constructing a transfer scheme  $t$  that satisfies several conditions; (ii) showing that such  $t$  exist under the premise of the proposition; and, (iii) demonstrating that, under  $\lambda' = (\bar{x}_\sigma, \bar{x}_\tau, t)$ , the conclusions of the proposition hold.

**Part I** Pick an efficient action profile  $a_e^\theta$  and assume  $h$  is a solution to the following linear programming problem:

$$\min_{h \in \mathbb{R}^{|W|}} f_{a_e^\theta}^\theta \cdot h \tag{30}$$

subject to:

1.  $\tau$  values  $a_e^\theta$  using the true type: For all  $\theta' \in B_\tau^\theta \setminus \{\theta\}$ ,

$$f_{a_e^\theta}^{\theta'} \cdot h \geq K. \tag{31}$$

2.  $s'_1(\theta) = a_{1e}^\theta$  is a dominant strategy for Suitor 1: For all  $s''_1 \in S_1$  such that  $s''_1(\theta) \neq a_{1e}^\theta$  and all  $s''_\tau \in S_\tau$ ,

$$f_{(s''_1(\theta), s''_\tau(\theta))}^\theta \cdot (-h) \leq -K,$$

or,

$$f_{(s''_1(\theta), s''_\tau(\theta))}^\theta \cdot h \geq K, \tag{32}$$

3. *No-profit condition for Suitor 2*: For each  $a \in A$  and some corresponding  $\theta' \in \Theta$ ,

$$f_a^{\theta'} \cdot (-h) \leq -K,$$

or,

$$f_a^{\theta'} \cdot h \geq K. \quad (33)$$

4.  $s'_\tau(\theta) = a_{\tau\mathbf{e}}^\theta$  is a best reply to  $s'_1(\theta) = a_{1\mathbf{e}}^\theta$ : For all  $s''_\tau \in S_\tau$  such that  $s''_\tau(\theta) \neq a_{\tau\mathbf{e}}^\theta$  and, for each of these, a corresponding  $\theta' \in B_\tau^\theta$ ,

$$f_{(s'_1(\theta), s''_\tau(\theta))}^{\theta'} \cdot h \leq -K.$$

or,

$$-f_{(s'_1(\theta), s''_\tau(\theta))}^{\theta'} \cdot h \geq K. \quad (34)$$

5. *The transfer from Suitor 1 to  $\tau$  under  $a_{\mathbf{e}}^\theta$  is  $\frac{1}{2}L$  above  $\tilde{\mathbb{E}}_2^\theta[\lambda](s)$* :

$$f_{a_{\mathbf{e}}^\theta}^\theta \cdot (-h) = \tilde{\mathbb{E}}_2^\theta[\lambda](s) + \frac{1}{2}L - f_{a_{\mathbf{e}}^\theta}^\theta \cdot \gamma_1,$$

or,

$$-f_{a_{\mathbf{e}}^\theta}^\theta \cdot h \geq \tilde{\mathbb{E}}_2^\theta[\lambda](s) + \frac{1}{2}L - f_{a_{\mathbf{e}}^\theta}^\theta \cdot \gamma_1, \text{ and} \quad (35)$$

$$f_{a_{\mathbf{e}}^\theta}^\theta \cdot h \geq - \left( \tilde{\mathbb{E}}_2^\theta[\lambda](s) + \frac{1}{2}L - f_{a_{\mathbf{e}}^\theta}^\theta \cdot \gamma_1 \right), \quad (36)$$

Construct  $t : W \rightarrow \mathbb{R}$  as follows. First, define:

$$h'(w) = \begin{cases} 0, & \text{if } h(w) \neq 0; \\ \epsilon, & \text{otherwise} \end{cases}. \quad (37)$$

Then,  $t \equiv h + h'$ .

**Part II** A solution exists to the LP in Part I if a collection of distributions exist that render constraints (31) through (36) consistent. The existence of this collection is assured by Condition 1.

Note that the rows of  $\Lambda_+^\theta$  correspond to the distributions in (31)-(33) and those of  $\Lambda_-^\theta$  correspond to (34).  $\Lambda^\theta$  contains all the rows of  $\Lambda_+^\theta$  and  $\Lambda_-^\theta$  and  $f_{a_e}^\theta$  (35)-(36). The construction of  $\Lambda^\theta$  ensures that the sets of distributions associated each of the three types of constraint have empty intersections.

Let  $c$  be the vector of values taken from the RHS of (31)-(36) corresponding to the rows of  $\Lambda^\theta$ . Then, either the preceding LP has a solution or the following equations have a nonnegative solution  $x$ :<sup>21</sup>

$$\begin{aligned} x\Lambda^\theta &= \mathbf{0} \\ xc &= 1 \end{aligned}$$

By Condition 1,  $\Lambda^\theta$  has full row rank. Therefore, failure of  $x\Lambda^\theta = \mathbf{0}$  is immediate for any  $x$  other than  $x' = \mathbf{0}$ , the trivial solution. Of course, the trivial solution fails the second equation.

**Part III** By the addition of the  $\epsilon$  elements,  $t$  is strictly nonzero. Therefore, under  $\lambda' = (\bar{x}_\sigma, \bar{x}_\tau, t)$ , for all  $i, \theta, w$  and  $a$ :  $\delta_i^\theta[\lambda'](w|a) = 0$ . Note that, for any probability distribution  $f$ ,  $\epsilon \geq (t-h)f \geq 0$ ; i.e., the transfer scheme  $t$  always transfers an expected amount between 0 and  $\epsilon$  to target  $\tau$  above and beyond a transfer scheme  $h$  as computed in Part I.

By (35) and (36), the objective expected value of a strategy  $s'$  such that  $s'(\theta) = a_e^\theta$  to Suitor 1 is:

$$\begin{aligned} \mathbb{E}_1^\theta[\lambda'](s') &= f_{a_e}^\theta (\gamma_1 - t) \\ &= f_{a_e}^\theta (\gamma_1 - h - h') \\ &= f_{a_e}^\theta (\gamma_1 - h') + \tilde{\mathbb{E}}_2^\theta[\lambda](s) + \frac{1}{2}L - f_{a_e}^\theta \cdot \gamma_1 \\ &= \tilde{\mathbb{E}}_2^\theta[\lambda](s) + \frac{1}{2}L - f_{a_e}^\theta \cdot h'. \end{aligned}$$

Therefore,

$$\mathbb{E}_1^\theta[\lambda'](s') \in [V - \epsilon, V],$$

where  $V \equiv \tilde{\mathbb{E}}_2^\theta[\lambda](s) + \frac{1}{2}L$ . Because Suitor 1 has full information,

$$\tilde{\mathbb{E}}_1^\theta[\lambda'](s') = \mathbb{E}_1^\theta[\lambda'](s'). \tag{38}$$

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<sup>21</sup>See, e.g., Rockafeller (1970, Theorem 22.1, p. 198) or Gale (1989, Theorem 2.7, p. 46).

Recall,  $\tilde{\mathbb{E}}_1^\theta[\lambda](s) + \tilde{\mathbb{E}}_\tau^\theta[\lambda](s) = \tilde{\mathbb{S}}^\theta[\lambda](s)$ ,  $\mathbb{E}_2^\theta[\lambda'](s') + \mathbb{E}_\tau^\theta[\lambda'](s') = \mathbb{S}_e^\theta$  and  $L = \mathbb{S}_e^\theta - \tilde{\mathbb{S}}^\theta[\lambda](s)$ .

Therefore,

$$\mathbb{E}_\tau^\theta[\lambda'](s') \in [V', V' + \epsilon],$$

where  $V' \equiv \tilde{\mathbb{E}}_\tau^\theta[\lambda](s) + \frac{1}{2}L$ . For  $\tau$ ,

$$\tilde{\mathbb{E}}_\tau^\theta[\lambda'](s') = \min_{\theta' \in B_\tau^\theta} \mathbb{E}_\tau^{\theta'}[\lambda'](s').$$

If  $s'(\theta') = a_{\mathbf{e}}^\theta$ , then  $\mathbb{E}_\tau^{\theta'}[\lambda'](s') \in [V', V' + \epsilon]$  by our previous calculation. Consider  $\theta'$  such that  $s'(\theta') \neq a_{\mathbf{e}}^\theta$ . By (31),

$$\begin{aligned} \mathbb{E}_\tau^{\theta'}[\lambda'](s') &= f_{s'(\theta')}(\gamma_\tau + h + h') \\ &\geq f_{s'(\theta')}(\gamma_\tau + h') + K, \\ &\geq V' + \epsilon. \end{aligned}$$

The last inequality is due to the definition of  $K$ . Therefore,

$$\tilde{\mathbb{E}}_\tau^\theta[\lambda'](s') = \mathbb{E}_\tau^\theta[\lambda'](s'). \quad (39)$$

Since  $\frac{1}{2}L > \epsilon > 0$ , both (38) and (39) are strictly positive.

Now, suppose  $s'$  is an implementable strategy such that  $s'(\theta) \neq a_{\mathbf{e}}^\theta$ . By Condition (32), it must be the case that  $s'_1(\theta) = a_{\mathbf{1e}}^\theta$  because  $t$  makes this a dominant strategy for Suitor 1. Therefore, it must be the case that  $s'_\tau(\theta) \neq a_{\tau\mathbf{e}}^\theta$ . This, however, is impossible due to Condition (34) which makes  $a_{\tau\mathbf{e}}^\theta$  the best reply to  $a_{\mathbf{1e}}^\theta$ . Therefore,  $s'(\theta) \neq a_{\mathbf{e}}^\theta$  is a contradiction. This implies that under any implementable strategy, expected payoffs to Suitor 1 and Target  $\tau$  are (38) and (39), respectively. This proves conclusions P3.1 and P3.2.

Because  $B_2^\theta = \Theta$ , Condition (33) ensures that, for every action profile  $a$  there exists a type  $\theta' \neq \theta$  such that  $\mathbb{E}_2^{\theta'}[\lambda'](s(\theta') = a) < 0$ . Therefore, regardless of the strategy  $s$ ,  $\tilde{\mathbb{E}}_2^\theta[\lambda'](s) < 0$ . This proves conclusion P3.3.

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