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RESEARCH ARTICLE

Information alliance in common agency

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Abstract
We study an agency model with two *independent* projects each of which is owned by a principal. Under exclusive agency, each principal uses a different agent, whereas under common agency, all principals use the same agent. A project's outcome depends on the agent's hidden effort. We show that, even in the absence of physical linkages between the projects, a principal benefits from *providing information* on her project outcome to the other principal under common agency (rather than benefiting from *receiving the information*), whereas no such benefits arise under exclusive agency. That is, under common agency, an information sharing principal can take advantage of the other principal's using the shared information. As a result, sharing information becomes each principal's dominant strategy, provided that the other principal uses the shared information in a Pareto-optimal way. We show that using a common agent is optimal when information can be shared.

Keywords Common agency · Exclusive Agency · Information Sharing · Moral Hazard

JEL Classification: D82 · D86 · L23

1 Introduction

It is frequently observed that different principals rely on a common agent. For instance, common suppliers are used by multiple firms, lawyers and lobbyists serve numerous clients, and retailers distribute products from multiple manufacturers. This type of arrangement takes place when synergies make it efficient for a single agent to handle multiple projects owned by different principals. While common agency is frequently adopted for physical synergies in related projects, such as economies of scale or scope,

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it may also be employed for strategic reasons, such as sharing information among the principals. The latter is particularly important when the agent's activities are not easily observable, making it crucial to design an incentive scheme that encourages optimal performance.[1]

In this paper, we analyze how multiple principals can benefit from using a common agent when no synergies or conflicts arise among principals for the use of the agent's resources or effort—the principals' projects are physically independent from each other. In such a setting, where the agent's use of resources for one project does not affect his use of resources for the other, using a common agent typically yields the same payoff for the principals as when they use exclusive agents. According to our results, the advantage of using a common agent stems from the principals' sharing information with each other.

An information alliance is formed when different organizations share their information. As Baron and Besanko (1999) note, an information alliance is not a full merger, and the players remain "separate entities." Thus, while the principals can have a binding agreement to share information in some environments, there may be no such methods available in others. In our paper, the principals cannot contract with each other, and thus "information alliance" must be formed non-cooperatively. We show the following. First, information alliance and common agency are complementary. Second, it is each principal's dominant strategy to share her information with the other principal under common agency, provided that the other principal uses the shared information in a Pareto-optimal way.

We compare two organizational structures—exclusive and common agency. Under exclusive agency, each principal uses an agent who works exclusively for her, whereas under common agency, the principals share a common agent. An agent's effort for a project is his hidden action. A principal's project output is realized after her agent's effort, and observed only by the principal and the agent of that project. Each principal can choose to share her information on her project output with the other players—information on a realized project output is "hard" in our model, and therefore the information can be withheld by the principal but cannot be manipulated.

Before we endogenize information sharing as a choice variable, we first analyze the optimal outcomes with two exogenous information structures, "information disassociation (no principal shares information)" and "information alliance (all principals share information)." As mentioned above, the principals' projects are independent from each other in our model—under common agency, the agent's effort for one project does not affect the other project's output. As such, with information disassociation, the principals' payoffs under exclusive and common agency are the same. With information alliance, the principals' payoffs under exclusive agency are the same as their payoffs with information disassociation. Under common agency, however, informa-

[1] Information sharing among multiple principals under common agency can be observed in real-world contexts. For example, Gustafson et al. (2021) report that multiple banks (principals) often jointly lend to a common borrower (agent), sharing information about the borrower's performance across distinct credit lines. Similarly, according to Steadman (2018), pharmaceutical companies (principals) frequently engage a common contract research organization (agent) to manage separate clinical trials and share relevant data among the sponsoring companies.

tion alliance can improve the principals' payoffs, even though the agent's effort for one project does not affect the other.

In other words, either information alliance or common agency alone do not enhance the principals' welfare—the informational and the organizational structure complement with each other according to our result. We show that, with information alliance, each principal under common agency can leverage on the other principal's transfers based on more information to reduce her own transfer payment to the agent. Simply put, information alliance and common agency together generate positive strategic effects between the principals, thereby allowing them to achieve a strictly higher expected payoffs.

We then endogenize each principal's choice of information sharing under common agency in a non-cooperative environment (under exclusive agency, the principals are indifferent to information sharing)—no mechanism between the principals is available for a binding agreement. We show that each principal in fact has an incentive to share information with the other principal and will choose to do so voluntarily. That is, a principal may have an incentive to share her information even if the other principal does not reciprocate the information provision. According to our analysis, the benefit of an information alliance stems from the "*sharing* " aspect rather than the "*being shared*" aspect. In other words, sharing information allows each principal to reduce her rent provision to the agent by leveraging the other principal's using the shared information.

To be more specific, a principal has an incentive to share her information with the other, regardless of the other principal's choice to share her information, as long as the shared information is used to Pareto-improve the equilibrium outcome. The reasoning is as follows. When a principal shares her information, the receiving principal's expected payoff is unaffected by whether or how she uses it—decomposing the transfer based on the received information does not change its expected value. In contrast, the sharing principal's expected payoff depends on how the receiving principal uses the shared information—the sharing principal adjusts her own transfer in response to the other principal's decomposition of her transfer. Thus, it is the sharing principal who can benefit from information sharing. As a result, provided the principals use the shared information in a Pareto-optimal manner, each principal shares her information, regardless of the other's choice of sharing.

Although our focus in this paper is not on antitrust issues, our results have policy implications for antitrust regulation. Information sharing among firms has been an important topic in antitrust policy and has received substantial attention in academic research. As Vives (2008) notes, firms may have incentives to share information for either efficiency-enhancing or purely strategic reasons.[2] In our setting, "non-cooperative" information alliance under common agency yields the same payoffs to the principals as a full merger—because the principals' objective functions are additively separable, and the same constraints apply as in the common agency with information alliance. This hints a possibility that firms can evade merger regulations simply by passing on information. Our result hence suggests that authorities may want to pay

[2] See also Jain and Sohoni (2015), Shamir (2017) and Do and Riquelme (2024) for this issue.

attention to not only formal mergers, but also to informal information sharing among firms.

The rest of the paper is organized as follows. We review the related literature in the next section. The model is presented in Section 3. In Section 4, we analyze and compare exclusive and common agency under information disassociation, followed by Section 5 where the two arrangements are analyzed and compared under information alliance. Section 6 endogenizes information alliance under common agency in a noncooperative game between the principals. We conclude with remarks in Section 7. All proofs are in the Appendix.

2 Review of Related Studies

Our paper contributes to and connects three strands of the literature. The first strand concerns the theory of common agency, pioneered by Bernheim and Whinston (1985, 1986a), and its comparison with exclusive dealing.[3] A key question in this line of work is whether principals prefer common or exclusive agency. Gal-Or (1991), Martimort (1996) and Mezzetti (1997) examine the trade-off under adverse selection, showing that common agency can worsen incentive problems, particularly when principals are asymmetric. They show that principals often prefer exclusive dealing because common agency exacerbates incentive problems in adverse selection settings, and they identify the benefit of production coordination as the main advantage of employing a common agent.[4] Using a moral hazard framework, our study offers new insights into the value of common agency. Unlike in previous contributions, our model yields no benefit from coordinating production. Instead, we show that principals may prefer common agency owing to the strategic effects of information sharing that arise when they employ the same agent.

The second strand of literature addresses communication of information between principals under common agency. Martimort and Moreira (2010) model indirect information transmission via contract design, where each principal strategically screens the common agent who has private information acquired from the other principal's offer. This logic extends to settings with unverifiable signals as in Galperti (2015) and is applied by Lima and Moreira (2014) and Lima et al. (2017), who study political and organizational contexts involving "soft" private information. Do and Riquelme (2024) further analyze how information is transmitted through contracts when direct communication between principals is restricted. Our contribution to this literature lies in optimality of providing information to the other principal, instead of learning the other principal's information. Unlike the previous contributions, our study permits direct information sharing between the principals (as information possessed by each principal is "hard" in our model), and shows that such "non-cooperative" formation of alliances can be Pareto-improving in equilibrium.

[3] See also Stole (1991) and Martimort (1992) for early contributions to the literature on common agency.

[4] Raff and Schmitt (2006) and Siqueira (2007) also compare common and exclusive agency, showing the benefits of common agency. While related to our study in theme, the former focuses on market welfare in oligopoly, and the latter examines the physical relationship between the principals' projects.

Relatedly, the study by Maier and Ottaviani (2009), like ours, shows that information sharing is beneficial under common agency.[5] There are, however, key differences between their and our study. In theirs, the principals benefit from information alliance mainly by receiving information, whereas in ours, the principals benefit from such alliance by providing information. This distinction stems from two differences in the model specifications. First, the output is a "public good" in their paper, and thus the agent makes only one effort for both principals.[6] In contrast, our model assumes independent projects, so the agent exerts separate efforts. Second, the agent is risk-averse in their paper, and thus risk-sharing is the incentive mechanism. In ours, the agent is risk-neutral, thus requiring rent provision for his effort. Also, their result requires that the principals' preferences and output observations are asymmetric, whereas ours does not rely on such assumption.[7]

Studies on information alliance or information sharing typically involves coordination between agents rather than between principals. For example, Baron and Besanko (1999) study cooperative information sharing among agents in a multi-agent setting, showing that such alliances can dominate centralized or decentralized structures. In their model, a third-party mechanism designer facilitates information aggregation through side contracts.[8] In contrast, our model involves a non-cooperative game between principals who strategically decide whether to share information with each other when contracting with a common agent.[9] Our setting thus shifts the focus from coordination among agents to coordination among principals, offering a different lens on the formation and value of information alliances.

Finally, the third strand of research to which our paper contributes is the literature on moral hazard and task bundling, particularly when limited liability constrains incentive design. Laux (2001) shows that assigning unrelated tasks to a single agent can help relax participation constraints by linking outcomes. Similarly, MacDonald and Marx (2001) show how task complementarities can be leveraged through payment schemes. Our paper adapts these insights to a multi-principal setting, where each principal's payoff is directly affected only by her own project while a common agent hired by the principals faces multiple projects to work on. In our model, using a common agent introduces cross-task informational spillovers that allow principals to relax incentive constraints, rather than participation constraints as in Laux (2001). This leads to reduced rent provision to the agent even though each project is owned by a different principal, as positive strategic effects can arise from sharing information in the decentralized environment we study. The fact that employing a common agent enables distinct organizations to benefit from information sharing distinguishes our

[5] See Piccolo and Pagnozz (2013) for an analysis on beneficial information sharing under exclusive agency.

[6] In their paper, the information-sharing principal also benefits since the agent exerts a common effort.

[7] For simplicity, the principals are assumed to be symmetric. Our result remains intact without the symmetrical treatment between the principals.

[8] See Laffont and Martimort (1997) for an extensive analysis on the issue.

[9] Kirchsteiger et al. (2026) demonstrate positive effects of disclosure on cooperation among players.

contribution from standard bundling or cross-pledging mechanisms typically studied in single-principal or firm-level settings.[10]

3 Model

There are two principals who own one project each. A principal and her project are indexed by $i \in \{a, b\}$. Each project requires an agent's work who collects a transfer t^i for the project he works for. A project's outcome can be either success (*h*igh output) or failure (*l*ow output), denoted by π_j, where $j \in \{h, l\}$ and $\Delta\pi = \pi_h - \pi_l > 0$. A project's output can be contracted upon between the principal and the agent of the project.

The projects are independent from each other, and the likelihood of $j \in \{h, l\}$ in a project depends on the effort devoted to that project only. An effort level for each project is hidden action of the agent in charge, and denoted by $e^i \in \{0, 1\}$, where 0 and 1 indicate "shirking" and "working," respectively. The cost of effort for each project is given by $C(e^i) = ce^i$ where $c > 0$.[11] Depending on the effort levels, the probabilities of high output in a project are:

$$\Pr\left(j = h|e^i = 1\right) = z_1 \quad \text{and} \quad \Pr\left(j = h|e^i = 0\right) = z_0, \quad i \in \{a, b\}.$$

where $\Delta z = z_1 - z_0 > 0$.

In return for her agent's service, principal $i \in \{a, b\}$ pays a transfer, denoted by t^i, to the agent. Each principal's ex post payoff therefore is:

$$V^i \triangleq \pi - t^i,\ i \in \{a, b\},$$

and an agent's ex post payoff from project $i \in \{a, b\}$ is:

$$U^i \triangleq t^i - ce^i,\ i \in \{a, b\}.$$

Two different organizational structures are analyzed and compared—"exclusive" and "common" agency. Under exclusive agency, each principal uses a different agent, whereas under common agency, one agent is used for both principals. Therefore, when the principals use a common agent, his ex post payoff is $\sum_i U^i$, while a principal's ex post payoff is expressed as above independent of organizational structures.

[10] Diamond (1984) shows that bundling projects within a single firm can reduce monitoring costs and enhance efficiency through cross-pledging. Our mechanism does not rely on using additional information to cross-subsidize outcomes—it is the sharing of information that drives rent reduction in our setting.

[11] This assumption (rather than linking efforts via the cost function) allows us to focus on informational effects. Our main result—that common agency is advantageous to the principals over exclusive agency for informational reasons—can still hold when the projects are linked through the agent's efforts. For example, when $c(e^i, e^{-i})$ denotes the cost function under common agency, it entails a cost disadvantage (advantage) relative to exclusive agency if $c_{i,-i} > 0$ ($c_{i,-i} < 0$), where $c_{i,-i}$ is the cross-partial derivative. For $c_{i,-i} > 0$, the informational advantage of common agency dominates the cost disadvantage if $c_{i,-i}$ is not too large.

We consider the following information structures. When each project's realized output is observed only by the principal who owns the project and the agent in charge, we refer to the situation as "information disassociation." When each and every project's output is observed by all players, on the other hand, we refer to it as "information alliance." To ease our presentation, we first treat each information structure as a separate 'exogenous' environment in our analyses, and then will endogenize it as each principal's choice in the last step of our analyses.

Under information disassociation, each principal's contract offer is contingent only on her own project output, whereas under information alliance, each principal's contract offer is contingent both on her own project output and on the other principal's. Thus, the principal's contract offers in each information structure are written as:

$$t_j^i \text{ (information disassociation) and } t_{jk}^i \text{ (information alliance)}, \; j, k \in \{h, l\}.$$

As typical in common agency games, there are multiple equilibria. Following previous contributions, we restrict attention to symmetric equilibria.[12] A symmetric equilibrium in our paper is a Nash equilibrium that constitutes a fixed point of each principal's maximization problem, in which both principals make identical choices. That is, each principal chooses a transfer schedule to maximize her expected payoff, subject to the constraints she faces (to be elaborated in the subsequent section), while taking as given the transfer schedule and the induced effort level chosen by the other principal. We adopt Pareto-optimality (Pareto-dominance) as the refinement criterion for equilibrium selection. In particular, we focus on the Pareto-optimal outcome for the principals under common agency. In what follows, "the Pareto-optimality" refers to the Pareto-optimality for the principals, excluding the agent(s).

We summarize the timing of the game as follows.

1. Each principal offers the contract to the agent(s).[13]
2. The contracts are accepted or rejected by the agent(s).
3. The agent's effort levels for each projects are chosen.
4. The project outputs are realized and transfers are made.

We assume that the liability of the agent(s) is limited, such that transfers must exceed the cost of effort, c, to ensure the agent's payoff is non-negative in all cases. Alternatively, the limited liability may take the form of a requirement for a non-negative transfer from the principal—this does not affect our qualitative results. If the liability of the agent(s) is unlimited, the problem becomes trivial, as moral hazard is no longer an issue in that case. Lastly, we impose the following condition.

Condition 1 $\Delta\pi \gg z_1 c / (\Delta z)^2$.

The condition above ensures that it is optimal for each principal to induce the agent to exert $e^i = 1$ in any case throughout the paper.

We now turn to the analysis. First, we present each equilibrium outcome separately, based on the information and organizational structures described above. We then

[12] See, for example, Martimort and Moreira (2010).

[13] The "(s)" is for the two agents under exclusive agency.

compare the outcomes to conclude that information alliance between the principals and using a common agent are complementary, and any other combination of the information and the organizational structure does not improve the principals' expected payoffs.

4 Information Disassociation

In this section, we discuss the cases in which each principal keeps information on the project output between she and her agent. We analyze and compare exclusive and common agency to show that the two arrangements yield the same optimal outcome to the principals when they do not share information with each other.[14]

4.1 Exclusive Agency

Since two projects are independent from each other, each principal's problem boils down to a standard moral hazard problem. The contract from principal $i \in \{a, b\}$ must satisfy the following incentive constraint to induce the agent's effort ($e^i = 1$):

$$E\left[U_j^i | e^i = 1\right] \geq E\left[U_j^i | e^i = 0\right], \tag{1}$$

where $E[\cdot]$ is the expectation operator for $j \in \{h, l\}$ and $U_j^i = t_j^i - ce^i$.

A principal's offer must respect the agent's limited liability, and thus in the optimal contract:

$$U_j^i \geq 0, \;\; j \in \{h, l\}. \tag{2}$$

A principal chooses t_j^i to maximize the following objective function:

$$E\left[V_j^i | e^i = 1\right], \tag{3}$$

where $V_j^i = \pi_j - t_j^i$, subject to (1) and (2).

The solution to this problem is summarized in the following lemma.

Lemma 1 *With information disassociation, each principal's contract offer in equilibrium under exclusive agency, $\underline{t}_j^i$, $j \in \{h, l\}$, is characterized by:*[15]

$$\underline{t}_h^i = c + \frac{c}{\Delta z}, \;\; \underline{t}_l^i = c.$$

Each agent's expected payoff is $E\left[U_j^i | e^i = 1\right] = z_1 c / \Delta z$.

[14] The common agency game with information disassociation can be seen as a simplified version of Berheim and Whinston (1986) and Dixit et al. (1997), except that the projects are independent from each other here.

[15] We use the notation of underline (overline) for the equilibrium transfers in exclusive (common) agency.

The projects owned by each principal are independent from each other, and therefore the optimal outcome for each project is a well-known result in moral hazard problems. With his liability limited ($t^i_j - c \geq 0$), the agent has an incentive to shirk ($e^i = 0$), and thus the principal must provide a strictly positive rent to the agent to induce his effort ($e^i = 1$). As in standard moral hazard settings, the incentive constraint is binding as each agent has a shirking incentive, and the limited liability constraint for the low output is binding—that is, each agent receives rent only when the project output is high.

4.2 Common Agency

We now turn to the case where the principals use one common agent. Unlike in exclusive agency, the agent faces multiple possible ways to shirk a project under common agency. As mentioned earlier, we focus on parameter values such that each principal wants the agent to exert effort on her project (Condition 1). There are two types of possible deviations for the agent—he can shirk on one project while working on the other one, or he can shirk on both projects. The following 'local incentive constraint' prevents the agent from choosing $e^i = 0$, provided that he chooses $e^{-i} = 1$, where $i, -i \in \{a, b\}$ and $i \neq -i$:

$$\sum_i E\left[U^i_j | e^i = 1\right] \geq E\left[U^i_j | e^i = 0\right] + E\left[U^{-i}_j | e^{-i} = 1\right]. \tag{4}$$

The LHS of (4) is the common agent's expected payoff from making an effort for both projects, and the RHS is his expected payoff from shirking principal i's project, while making an effort for principal $-i$'s project.

Since the agent can shirk both projects, the following 'global incentive constraint' must be satisfied to ensure the agent's effort:

$$\sum_i E\left[U^i_j | e^i = 1\right] \geq \sum_i E\left[U^i_j | e^i = 0\right]. \tag{5}$$

Claim 1 *Suppose Condition 1 holds. Then (4) and/or (5) are the only potentially binding incentive constraints in equilibrium.*

Principal $i \in \{a, b\}$ chooses t^i_j to maximize her objective function in (3) subject to the local incentive constraint (4), the global incentive constraint (5) and the limited liability constraint (2), while taking as given the transfer schedule and the induced effort level chosen by the other principal.

The next lemma presents the optimal outcome under common agency with information disassociation.

Lemma 2 *With information disassociation, each principal's contract offer in equilibrium under common agency, $\bar{t}^i_j$, $j \in \{h, l\}$, is characterized by:*

$$\bar{t}^i_h = c + \frac{c}{\Delta z}, \; \bar{t}^i_l = c.$$

The agent's expected rent from each project is $E\left[U_j^i|e^i=1\right]=z_1c/\Delta z$.

The following proposition summarizes the results in this section by comparing the optimal contracts under the two organizations.

Proposition 1 *With information disassociation, a principal's expected payoffs under common and exclusive agency are the same.*

When no information is shared, the optimal outcome is not sensitive to organization structures in our model. The reasoning behind the result is as follows. First, note that there are no (dis)economies of scope in the agent's effort decision under common agency—the cost of effort in each project is identical and independent across the projects. Therefore, the agent's expected payoffs from principal $-i$'s project on the LHS and the RHS of the local incentive constraint (4) are identical and cancel out with each other. The constraint then can be simplified to:

$$E\left[U_j^i|e^i=1\right]\geq E\left[U_j^i|e^i=0\right], \tag{6}$$

which is identical to (1), the incentive constraint under exclusive agency. Also, in a symmetric equilibrium, the global incentive constraint (5) is implied by (6)—that is, for each principal, the local incentive constraint is equivalent to the global incentive constraint, and thus both are binding to induce the agent's effort in equilibrium. Since the limited liability constraint for the low output is binding, it then implies that the constraints faced by the principals under common and exclusive agency are equivalent, resulting in the same optimal outcome for the two different organization structures.

We emphasize that, to isolate the informational effects, physical independency of each project is assumed in our model. Since the projects are independent from each other, using a common agent without sharing information yields the same expected payoffs to the principals as those under exclusive agency. As will be shown in the following section, this is no longer true if information is shared between the principals.

5 Information Alliance

We now move on to the cases where all project outputs are observed by all players. As aforementioned, a principal's contract with information alliance is contingent not only on her own project output but the other principal's as well.

5.1 Exclusive Agency

When each principal uses an exclusive agent, the principal of project $i\in\{a,b\}$ must satisfy the following incentive constraint for the agent's effort ($e^i=1$):

$$\mathbb{E}\left[U_{jk}^i|e^i=e^{-i}=1\right]\geq\mathbb{E}\left[U_{jk}^i|e^i=0\wedge e^{-i}=1\right], \tag{7}$$

where $\mathbb{E}[\cdot]$ is the expectation operator for $jk \in \{hh, hl, lh, ll\}$ and $U^i_{jk} = t^i_{jk} - ce^i$.[16]

The limited liability condition for the agent requires that:

$$U^i_{jk} \geq 0, \;\; j, k \in \{h, l\}. \tag{8}$$

With information alliance, a principal under exclusive agency maximizes her expected payoff:

$$\mathbb{E}\left[V^i_{jk} | e^i = e^{-i} = 1\right], \tag{9}$$

where $V^i_{jk} = \pi_j - t_{jk}$, subject to (7) and (8).

The next lemma presents the optimal outcome of a principal's problem.

Lemma 3 *With information alliance, each principal's contract offer in equilibrium under exclusive agency, $\underline{t}^i_{jk}$, $j, k \in \{h, l\}$, is characterized by:*

$$\underline{t}^i_{hh} = \underline{t}^i_{hl} = c + \frac{c}{\Delta z}, \;\; \underline{t}^i_{lh} = \underline{t}^i_{ll} = c.$$

Each agent's expected rent is $\mathbb{E}\left[U^i_{jk} | e^i = e^{-i} = 1\right] = z_1 c / \Delta z$.

Although each principal's transfer schedule is now decomposed based on the shared information, the set of binding constraints is identical to that under information disassociation—the incentive constraint and the limited liability constraints for the low output. And as long as the binding constraints are the same, a mere decomposition of the transfer schedule does not change the expected outcome. By comparing the result above with Lemma 1 (the result under exclusive agency with information disassociation), the following corollary is established.

Corollary 1 *Under exclusive agency, sharing information has no effect on the principals' expected payoffs.*

Under exclusive agency, each agent's payoff is not affected by the other project output even if information is shared by all parties. Suppose principal $i \in \{a, b\}$ conditions the transfers to her agent according to principal $-i$'s project output as well. It is equivalent to conditioning the transfers to the realization of an additional random event which is not affected by the agent in charge of project i. That is, the other project output simply introduces an additional uncertainty without adding benefit or cost to the principal-agent relationship. In expected value, therefore, the incentive constraint must still guarantee the same amount of rent to the agent.

We now proceed to the final case where the principals use the common agent with sharing information.

[16] That is, $\mathbb{E}[\cdot] \triangleq E[\boldsymbol{E}[\cdot]]$, where $E[\cdot]$ and $\boldsymbol{E}[\cdot]$ are the expectation operators for $j \in \{h, l\}$ and $k \in \{h, l\}$, respectively.

5.2 Common Agency

So far, a principal's expected payoffs were not sensitive to information or organization structures. We now analyze the final case where the principals use a common agent and share information on the project outputs. As will be shown below, information alliance under common agency generates strategic effects between the principals' choices, enabling them to leverage each other's choice in equilibrium. This, in turn, leads to partial extraction of the agent's rent in the optimal contracts.

With information alliance, the local incentive constraint for the common agent is:

$$\begin{aligned} &\sum_i \mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 1\right] \\ &\geqslant \mathbb{E}\left[U^i_{jk}|e^i = 0 \wedge e^{-i} = 1\right] + \mathbb{E}\left[U^{-i}_{jk}|e^i = 0 \wedge e^{-i} = 1\right], \end{aligned} \tag{10}$$

and the global incentive constraint is:

$$\sum_i \mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 1\right] \geq \sum_i \mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 0\right]. \tag{11}$$

Recall that, under information disassociation, the local and global incentive constraints are equivalent, each implying the other. This equivalence does not hold under information alliance—although the local incentive constraints are symmetrical but not identical, the global incentive constraint faced by each principal is both symmetrical and identical.[17]

Each principal maximizes her expected payoff in (9) subject to (10), (11) and the limited liability constraint (8), while taking as given the transfer schedule and the induced effort level chosen by the other principal.

The optimal outcome is presented in the lemma below.

Lemma 4 *With information alliance, each principal's contract offer in the Pareto-optimal equilibrium under common agency,* $\bar{t}^i_{jk}$*,* $j, k \in \{h, l\}$*, is characterized by:*

$$\bar{t}^i_{hh} = c + \frac{c}{(z_1 + z_0)\,\Delta z}, \quad \bar{t}^i_{hl} = \bar{t}^i_{lh} = \bar{t}^i_{ll} = c.$$

The agent's expected rent from each project is $\mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 1\right] = z_1^2 c / [(z_1 + z_0)\,\Delta z]$ $(< z_1 c/\Delta z)$.

According to Lemma 4, each principal under common agency pays a rent of less amount to the agent. The following proposition summarizes the central message in this section.

Proposition 2 *With information alliance, each principal's expected payoff in the Pareto-optimal equilibrium under common agency is strictly higher than her expected payoff under exclusive agency.*

[17] As in Claim 1, only (10) and (11) are the relevant incentive constraints in equilibrium. The third potential incentive constraint, $E\left[U^i_{jk}|e^i = 1\right] + E\left[U^{-i}_{jk}|e^{-i} = 0\right] \geq \sum_i E\left[U^i_{jk}|e^i = 0\right]$ is irrelevant.

Proposition 2 implies that, to take advantage of information alliance, the principals must use a common agent. To see the intuition behind this result, let us first revisit the case under exclusive agency. The incentive constraint (7) under exclusive agency, after a simple manipulation, can be written as:

$$z_1 \left[t_{hh}^i - t_{lh}^i\right] + (1 - z_1) \left[t_{hl}^i - t_{ll}^i\right] \geq \frac{c}{\Delta z}. \tag{12}$$

Notice from Lemma 3 that the RHS of the incentive constraint (12), $c/\Delta z$, is the ex post rent (when $j = h$) of an agent working for principal $i \in \{a, b\}$. Similarly, under common agency, the local incentive constraint (10) can be expressed as:

$$z_1 \left[t_{hh}^i - t_{lh}^i\right] + (1 - z_1) \left[t_{hl}^i - t_{ll}^i\right] \geq \frac{c}{\Delta z} - z_1 \left[t_{hh}^{-i} - t_{hl}^{-i}\right] - (1 - z_1) \left[t_{lh}^{-i} - t_{ll}^{-i}\right]. \tag{13}$$

Notice that the LHS of (12), the incentive constraint in exclusive agency, and (13), the local incentive constraint in common agency, are identical, whereas the RHS of (13) has extra terms linked to principal $-i$'s (the other principal's) transfers. That is, each principal's transfers to the agent have a strategic effect to the other principal's transfers under common agency with information alliance. The principals using a common agent can take advantage of the strategic effect, thereby (indirectly) coordinating their transfer schedules to their benefit—in equilibrium, the RHS of (13) has an extra negative term ($-z_1 \left[t_{hh}^{-i} - t_{hl}^{-i}\right] = -z_1 c / \left[\Delta z \left(z_1 + z_0\right)\right]$), which allows a principal to reduce the rent to the agent. We emphasize again that the agent makes two independent efforts—the strategic effects are rather "informational" than "physical."

Again, with information disassociation, the local and the global incentive constraint are equivalent and thus they are both binding in equilibrium. With information alliance, however, the local incentive constraint becomes relaxed and thus non-binding in the Pareto-optimal equilibrium. Although the game is played non-cooperatively between the principals, using a common agent with information sharing may allow them to effectively behave as if they were a single merged principal with multiple projects. That is, for a single principal facing the two projects, the optimal way to incentivize the agent coincides with the transfer schedule described in Lemma 4. This point is formally presented below.

Lemma 5 *With information alliance, each principal's contract offer in the Pareto-optimal equilibrium under common agency is the same as the optimal offer made by a single principal facing both projects.*

In fact, if a single principal faces two projects, the global incentive constraint is the only binding constraint and the local incentive constraint is slack. The same can be true under common agency with information alliance. In the Pareto-optimal equilibrium, the *global incentive constraint* (which applies to the principals not only symmetrically but also identically) is the only binding incentive constraint, rendering each principal's *local incentive constraint* (which applies symmetrically but not identically) slack. Since the set of binding limited liability constraints is identical across regimes, each principal's expected payoff in the Pareto-optimal equilibrium under common agency is higher than under exclusive agency.

We summarize the discussion thus far in the following corollary.

Corollary 2 *Information alliance and common agency are complementary to each other.*

Recall that, with information disassociation, using a common agent has no advantage over using an exclusive agent. As discussed in the previous section, without sharing information, although the incentive constraints (4) and (5) under common agency have the terms for the transfers from principal $-i$, the terms in the LHS and the RHS cancel each other. This is not true with information alliance, as shown in (13). And again, the principal cannot benefit from information alliance without using a common agent. Under common agency with sharing information, each principal's rent provision to the agent can be (non-cooperatively) coordinated with the other principal. Under exclusive agency, there is no such effect since each agent receives the transfer only from his own principal.

It is worth noting that, while we focus on the Pareto-optimal equilibrium for our result under common agency, there also exists the 'Pareto-inefficient' equilibrium, in which the principals are worse off than under exclusive agency or information disassociation. Again, in the Pareto-optimal equilibrium, each principal sets t^i_{hl} at the lowest possible level ($t^i_{hl} = c$), thereby relaxing the local incentive constraint faced by the other principal and rendering it slack. By contrast, in the Pareto-inefficient equilibrium, each principal sets t^i_{hh} at the lowest level ($t^i_{hh} = c$) instead of t^i_{hl}. This results in $t^i_{hh} < t^i_{hl}$, which raises the RHS of the local incentive constraint faced by the other principal, thereby tightening the constraint compared to the case under exclusive agency or information disassociation.[18]

6 Endogenous Information Alliance in Common Agency

Up until this point, we have taken an information structure as an "exogenously" given. In practice, however, whether or not to share the output information is rather a choice of the project owner. Although we know from the previous section that information alliance allows the principals to save on their rent provisions to the agent (and thus higher payoffs), it is yet to be shown that each principal will in fact choose to disclose the information on her project output to the other principal under a non-cooperative environment.

We now allow the principals to make a choice on sharing information. In particular, each principal can *commit* at the outset whether or not to let the other principal observe the contract and the realized project output via the common agent.[19] We note that each

[18] In the Pareto-inefficient equilibrium, the outcome is as follows. If $z_1 < 1/2$, then $t^i_{hh} = t^i_{lh} = t^i_{ll} = c$, $t^i_{hl} = c + c/[\Delta z(1 - 2z_1)]$, and the agent's expected rent from each project is $2z_1(1 - z_1)c/[\Delta z(1 - 2z_1)]$ ($> z_1 c/\Delta z$). If $z_1 \geq 1/2$, then the outcome in the Pareto-inefficient equilibrium is identical to that under exclusive agency or information disassociation.

[19] As aforementioned, shared information is "hard" in our model, i.e., each project output can be publicly verifiable. As such, each principal can choose not to disclose it, but cannot manipulate it.

principal makes this decision independently, without explicitly coordinating with the other principal. Our aim here is to demonstrate that, under common agency, it is each principal's dominant strategy to share information with the other principal, provided that the other principal uses the shared information in a Pareto-optimal way—we refer to it as "*Pareto-Optimal Dominant Strategy*." As will be shown below, sharing information is each principal's *Pareto-Optimal Dominant Strategy*, and thus a principal will share information even if the other does not—provided the other uses the shared information in a Pareto-optimal manner.[20]

Since a principal's decision on sharing information is made at the point of her contract offer to the agent, the principals can anticipate what information will be available to them when the project outputs are realized. Thus, if principal a has chosen to share information, for example, principal b can make her transfers conditional on principal a's project output and vice versa—each principal can condition the transfers based on additional information only if the other principal chose to share information.

The contract offer by principal $i \in \{a, b\}$ is contingent on the following: (i) her decision on sharing information, (ii) her project outcome, (iii) principal $-i$'s decision on sharing her information, and (iv) principal $-i$'s project outcome if that information is shared. Therefore, principal i's contract offer is expressed as:

$$\Phi^i \triangleq \left(s^i;\ t^i_{j\mathbf{k}(s^{-i})}\right),$$

where $s^i \in \{1 \text{ (information sharing)}, 0 \text{ (no information sharing)}\}$ and:

$$\mathbf{k}(s^{-i}) = \begin{cases} k \in \{h, l\} & \text{if } s^{-i} = 1 \\ \varnothing & \text{if } s^{-i} = 0 \end{cases}.$$

We denote by $\varnothing$ the "null" message, and thus if $s^{-i} = 0$, then $t^i_{j\varnothing} = t^i_j$. So, for example, if principal i decides not to share her information ($s^i = 0$) whereas principal $-i$ decides to share her information ($s^{-i} = 1$), then $\Phi^i = \left(s^i = 0;\ t^i_{hh}, t^i_{hl}, t^i_{lh}, t^i_{ll}\right)$ and $\Phi^{-i} = \left(s^{-i} = 1;\ t^{-i}_h, t^{-i}_l\right)$. In this example, if principal i commits to use principal $-i$'s information, then $hh \neq hl$ and/or $lh \neq ll$. If she commits not to use the shared information, then $hh = hl$ and $lh = ll$.

The timing of the game is as follows.

1. Each principal offers the contract, Φ^i, to the agent.
2. The contracts are observed by all players.
3. The contracts are accepted or rejected by the agent.
4. The agent's effort levels for each projects are chosen.
5. Each project output is realized, and observed depending on s^i.
6. Transfer from each principal is made contingent on $j\mathbf{k}(s^{-i})$.

If both principals choose not to share their output information, then we are in the setting for common agency with information disassociation in the previous section

[20] Under exclusive agency, each principal is always indifferent to sharing information.

(the optimal contract presented in Lemma 2). If, on the other hand, both of them choose to share their information and use the shared information in a Pareto-optimal way, then they are playing a common agency game with information alliance (the optimal contract presented in Lemma 4).

To identify the principal's strategies in equilibrium for sharing information, the remaining task therefore is to compute the payoffs from the asymmetric subgame, where one of the principals choose to share information while the other decides not to do so. Suppose principal $i \in \{a, b\}$ chooses not to share the output information with principal $-i$ ($\neq i$), whereas principal $-i$ chooses to share that information with principal i. That is, principal i can condition her transfer payments to the agent on both projects i's and $-i$'s outputs, while principal $-i$ can condition her transfers on project $-i$'s output.

As before, each principal faces two incentive constraints, local and global, in her utility maximization problem. The principals' problems, however, are not symmetric, and thus the constraints they face are written differently. The local incentive constraint faced by principal i is:

$$\begin{aligned} &\mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 1\right] + E\left[U^{-i}_k|e^{-i} = 1\right] \\ &\geqslant \mathbb{E}\left[U^i_{jk}|e^i = 0 \wedge e^{-i} = 1\right] + E\left[U^{-i}_k|e^{-i} = 1\right], \end{aligned} \tag{14}$$

which is reduced to:

$$\mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 1\right] \geqslant \mathbb{E}\left[U^i_{jk}|e^i = 0 \wedge e^{-i} = 1\right], \tag{15}$$

because the agent's payoffs linked to principal $-i$ cancel out—principal $-i$'s transfers have no effect on the local incentive constraint for principal i.

In this asymmetric subgame, the incentive constraints satisfied by principal $-i$'s contract are different from principal i's. The local incentive constraints faced by principal $-i$ is:

$$\begin{aligned} &\mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 1\right] + E\left[U^{-i}_k|e^{-i} = 1\right] \\ &\geqslant \mathbb{E}\left[U^i_{jk}|e^i = 1 \wedge e^{-i} = 0\right] + E\left[U^{-i}_k|e^{-i} = 0\right]. \end{aligned} \tag{16}$$

Notice that, unlike in (14), the agent's payoffs linked to the other principal (principal i) do not cancel out in the local incentive constraint for principal $-i$.

For both principals, the global incentive constraints are the same and:

$$\begin{aligned} &\mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 1\right] + E\left[U^{-i}_k|e^{-i} = 1\right] \\ &\geqslant \mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 0\right] + E\left[U^{-i}_k|e^{-i} = 0\right]. \end{aligned} \tag{17}$$

In this subgame, principal i chooses t^i_{jk}, $jk \in \{hh, hl, lh, ll\}$, to maximize her objective function in (9) subject to (15), (17) and the limited liability constraint (8).

Principal $-i$ chooses t_k^{-i}, $k \in \{h, l\}$, to maximize her objective function in (3) subject to (16), (17) and the limited liability constraint (2).

In the previous section, we implicitly assumed that each principal under information alliance chooses to use the extra information from the other principal in the Pareto-optimal way. Since we are endogenizing information alliance, we need to also examine whether or not a principal who received information from the other principal uses the information. The next lemma shows that there exists a set of equilibria in which principal i uses principal $-i$'s information ($hh \neq hl$ and/or $lh \neq ll$), which Pareto-dominates the equilibrium in which she does not ($hh = hl$ and $lh = ll$), and characterizes the outcome for each principal.

Lemma 6 *Suppose $s^i = 0$ and $s^{-i} = 1$. Then, there exists a set of equilibrium contracts in which principal i uses the information shared by principal $-i$ in a Pareto-dominant way, that is, these contracts Pareto-dominate the equilibrium contracts in which principal i does not use such information. An equilibrium in which principal i uses the shared information in a Pareto-dominant way is characterized by:*

$$\widetilde{t}_{hh}^{i} = c + \frac{c}{\Delta z} + \varepsilon,\ \widetilde{t}_{hl}^{i} = c + \frac{c}{\Delta z} - \frac{z_1}{1-z_1}\varepsilon,\ \widetilde{t}_{lh}^{i} = \widetilde{t}_{ll}^{i} = c;$$
$$\widetilde{t}_{h}^{-i} = c + \frac{c}{\Delta z} - \frac{z_0}{1-z_1}\varepsilon,\ \widetilde{t}_{l}^{-i} = c, \quad \textit{where } \varepsilon \in \left(0,\ \frac{1-z_1}{z_1 \Delta z}c\right].$$

The agent's expected rent from project i is $\mathbb{E}\left[U_{jk}^{i}|e^i = e^{-i} = 1\right] = z_1 c/\Delta z$, and his expected rent from project $-i$ is $E\left[U_k^{-i}|e^{-i} = 1\right] = z_1 c/\Delta z - z_0 z_1 \varepsilon/[1-z_1] < z_1 c/\Delta z$.

Lemma 6 characterizes the set of equilibria indexed by $\varepsilon > 0$ when only one principal shares information with the other who uses the shared information in a Pareto-dominant way. Notice that as ε increases $\widetilde{t}_{hh}^{i}$ increases while $\widetilde{t}_{hl}^{i}$ decreases. The case with $\varepsilon = 0$ corresponds to the equilibrium in which principal i does not use the shared information from principal $-i$. When $\varepsilon = 0$ (i.e., $t_{hh}^i = t_{hl}^i$), the agent receives an expected rent of $z_1 c/\Delta z$ from each project—recall from Lemma 2 in the previous section that this is the same amount of rent when neither principal shares information (information disassociation).

According to Lemma 6, principal i (who does not share information) still ends up providing an expected rent of $z_1 c/\Delta z$ to the agent. Without sharing her information, therefore, a principal's expected payoff does not change, even if she has additional information from the other principal. By contrast, principal $-i$ (who shares information) provides an expected rent of lower amount ($z_1 c/\Delta z - z_0 z_1 \varepsilon/[1-z_1] < z_1 c/\Delta z$) to the agent. Since the agent's rent from project i is independent of ε, while his rent from project $-i$ is decreasing in ε, an equilibrium that dominates the one in which principal i does not use the shared information requires that $\varepsilon > 0$. And the Pareto-optimal equilibrium in this subgame is when ε takes its maximum value, $\varepsilon = (1-z_1)c/[z_1 \Delta z]$.

Lemma 6 therefore implies that, *the one who shares her information can benefit* (*not the one who will have more information*) when only one of the principals choose to share information. This can be seen from the local incentive constraints (15) and (16) that principal i's and $-i$'s offers must satisfy respectively. The incentive constraint faced by principal i who uses principal $-i$'s information (without sharing her information with principal $-i$) can be expressed as:

$$z_1 t^i_{hh} + (1 - z_1) t^i_{hl} - \left[z_1 t^i_{lh} + (1 - z_1) t^i_{ll} \right] \geq \frac{c}{\Delta z}. \tag{18}$$

As noted above, in principal i's constraint, no transfer from principal $-i$ appears. That is, while using additional information from principal $-i$, there is no strategic effect that the principal i can take advantage of in incentivizing the agent. On the other hand, the incentive constraint faced by principal $-i$ who shares her information with principal i (without receiving principal i's information) can be expressed as:

$$t^{-i}_h - t^{-i}_l \geq \frac{c}{\Delta z} - z_1 \left[t^i_{hh} - t^i_{hl} \right] - (1 - z_1) \left[t^i_{lh} - t^i_{ll} \right]. \tag{19}$$

The extra terms in the RHS of the constraint shows that principal i's transfers can positively affect principal $-i$'s rent provision to the agent. Although using less information than principal i, principal $-i$ can benefit from sharing her information by taking advantage of the strategic effect arising from principal i's use of the shared information.

To be more specific, principal i is indifferent between t^i_{hh} and t^i_{hl} (there is a degree of freedom in setting these transfers as long as $z_1 t^i_{hh} + (1 - z_1) t^i_{hl}$ is the right value) to incentivize the agent, as can be seen from the LHS of (18). By setting $t^i_{hh} > t^i_{hl}$, however, principal i decreases the RHS of (19), the incentive constraint faced by principal $-i$, thereby allowing her to decrease t^{-i}_h. That is, in a Pareto-dominating equilibrium given $s^i = 0$ and $s^{-i} = 1$, it is principal $-i$ who benefits from principal i's using the shared information.

Together with the result in Lemma 6, we have the following corollary.

Corollary 3 *Under common agency, a principal who shares information benefits if the shared information is used in a Pareto-dominant way by the other principal.*

It is noteworthy again at this point that "*sharing* " (instead of "*being shared* ") information is the source of receiving the benefit under common agency. By *providing* (instead of *receiving*) information to the other principal, a principal can leverage her rent provision to the agent on the other principal's using additional information. This '*taking by giving*' strategy by each principal is the key result in forming information alliance (non-cooperatively) between the principals.

We now proceed to the last point to be made. Recall from Lemma 4 in the previous section that principal i with information alliance provides an expected rent of $z_1^2 c / [(z_1 + z_0)\,\Delta z]$ ($< z_1 c/\Delta z$). This implies that, when principal $-i$ shares information, it is in principal i's interest to reciprocate the information provision, provided that both principals will use the shared information. The following lemma shows that, given $s^i = s^{-i} = 1$, using the shared information is indeed the Pareto-dominating equilibrium.

Lemma 7 *Suppose* $s^i = s^{-i} = 1$. *Then there exists a set of equilibria in which both principals use the shared information in a manner that Pareto-dominates the equilibrium in which they do not use it.*

Summarizing the result from Lemma 6, Corollary 3 and Lemma 7, we can now combine each principal's expected payoffs from any outcome, based on both their own and the other principal's decision to share or not share information. Recall that sharing information is a principal's "*Pareto-Optimal Dominant Strategy*" if that choice is her dominant strategy, assuming the other principal uses the shared information in a Pareto-optimal manner. The following proposition presents the central point of this section.

Proposition 3 *Sharing information is the Pareto-Optimal Dominant Strategy for each principal under common agency, and thus* $s^i = s^{-i} = 1$ *in equilibrium.*

Revisiting the previous sections where the different structures are compared, if possible, each principal will choose to form an "information alliance." What has been identified here is that no binding contract between the principals may not be required to form such an alliance. Each principal has an incentive to disclose her information to the other, regardless of the other principal's choice regarding information disclosure—as long as the other principal uses the shared information to Pareto-improve the equilibrium outcome.

As mentioned above, when a principal shares her information, the expected payoff of the other principal is independent of whether or how she uses the shared information—because decomposing the transfer using the shared information does not alter its expected value. By contrast, the expected payoff of the information-sharing principal depends on whether or how the other principal uses the shared information, because she can adjust the expected values of her transfer by leveraging the other principal's transfer schedule. Hence, provided that the principals use the shared information in the Pareto-optimal way, each principal shares her information regardless of the other principal's choice to share information.

7 Conclusion and Remarks

In this paper, we have provided a novel rationale for using a common agent for multiple projects. In our model, there are no physical linkages between the projects—that is, the projects are physically independent from each other. According to our analyses, without sharing information, the principals' expected payoffs are not sensitive to organizational structures, and hence the principals are indifferent between exclusive and common agency. When sharing information is possible, using exclusive agents does not improve the principals payoffs—additional information to each principals does not contribute to their payoffs when an agent receives a transfer only from one principal. Using a common agent, on the other hand, can generate positive strategic effects between the principals' choices, thereby allowing them to reduce rent provision to the agent.[21] *Information sharing* between the principals and the use of a *common agent*, therefore, *complement* each other.

We have also identified that the benefit of additional information under common agency is not from "*receiving* " it, but from "*providing* " it. By sharing her output information, a principal can leverage her rent provision to the agent on the other principal's transfer payments conditioned on the larger information set—and when information is shared by only one principal, there exists a set of equilibria in which the shared information is used in a Pareto-dominant way. As a result, provided that the other principal uses the shared information in a Pareto-dominant manner when setting the transfer schedule, sharing information is the dominant strategy for each principal under common agency.

In closing, we offer a brief discussion of the following points as remarks and extensions.

Equilibrium Refinements

Throughout the paper, we have adopted Pareto-optimality as the refinement criterion for equilibrium selection. As pointed out by Chiesa and Denicolò (2009), two of the most commonly employed refinement concepts in common agency games with moral hazard are Pareto-optimality and "truthful equilibrium."[22] The latter requires each principal to reward the agent according to his marginal contribution in all possible outcome realizations for her own project. In our setting, however, where the project outputs are independent and all players' payoffs are linear combinations of the potential transfers, no equilibrium is singled out by this refinement, as the truthful equilibrium is not unique.[23]

That is, principal i cares only about whether his project succeeds in our model (as opposed to, for example, a public-output environment). From principal i's perspective, t^i_{hh} and t^i_{hl} are therefore payoff-equivalent in truthful equilibria. A truthful equilibrium therefore pins down only the conditional expected payment when project i yields π_h, not the split between t^i_{hh} and t^i_{hl}. Any allocation of the conditional payment between the two transfers, with $z_1 t^i_{hh} + (1 - z_1)\, t^i_{hl}$ satisfying the global incentive constraint and the limited liability constraints, equally fulfills the truthful equilibrium condition for the principal. Therefore, in both subgames with $s^i = s^{-i} = 1$ (Lemma 4) and $s^i = 0$ and $s^{-i} = 1$ (Lemma 6), adopting the truthful equilibrium yields a continuum of equilibria, whereas the Pareto-optimality criterion selects a unique one—as in Lemma 4, and in Lemma 6 when ε takes its maximum value. In other words, the Pareto-optimal equilibrium in our setting is also a truthful equilibrium, but the converse does not hold.[24]

[21] Thus our study explains why individual players should ever join groups under common agency instead of acting as separate principals on their own, a question raised by Mallard (2014).

[22] See Bernheim and Whinston (1986b) and Dixit et al. (1997).

[23] In a common agency game with complementary inputs, Laussel and Resende (2020) show that there is a unique Pareto-undominated Nash equilibrium.

[24] In general, as noted by Chiesa and Denicolò (2009), a Pareto-optimal equilibrium and a truthful equilibrium do not necessarily coincide.

Correlation between the Project Outputs

We have assumed that the probability distributions of potential outputs for each project are independent. While this assumption is reasonable when each project belongs to a different entity, there may be situations in which the outputs are correlated. In particular, if the projects use similar technologies, their outputs may be positively correlated. In multi-agent settings with moral hazard, relative-performance evaluation is optimal when the agents' outputs are positively correlated. With positive correlation, high effort by other agents increases the likelihood of high outputs overall, making it easier for an individual agent to achieve a high output with lower effort. For this reason, an agent's high output is rewarded more when the outputs from other tasks are low. This insight applies to our settings with information alliance.[25]

In our context, under positive correlation and exclusive agency, the optimal transfers for the high output will be $t^i_{hh} = c$ while $t^i_{hl} > c$ (recall that under independence, $t^i_{hh} = t^i_{hl} > c$), allowing the principals to improve their payoffs. Under common agency, however, positive correlation creates a trade-off for the principals. As shown, with no correlation, $t^i_{hh} > c$ and $t^i_{hl} = c$ under common agency—the equilibrium is Pareto-improved by widening the gap $t^i_{hh} - t^i_{hl}$. This benefit remains with positive correlation, but the relative-performance logic discussed above now calls for $t^i_{hh} = c$ and $t^i_{hl} > c$, the opposite pattern of transfers. Nevertheless, when the correlation is not too strong, the Pareto-improvement effect dominates the relative-performance effect, and our main result continues to hold.

Continuous Effort Levels

An agent effort level for a project is binary in our model, that is, $e^i \in \{0, 1\}$. Our result will remain valid when an effort level is continuous. To see this, consider, for example, $\Pr\left(j = h|e^i\right) = e^i \in [0, 1)$ and thus $\Pr\left(j = l|e^i\right) = 1 - e^i$ with the cost of effort given by $C(e^i) = c\left(e^i\right)^2/2$. Under exclusive agency with information alliance, each agent's choice of his effort is:

$$\underline{e}^i \in \arg\max_{e^i} e^i\left[e^{-i}t^i_{hh} + (1 - e^{-i})t^i_{hl}\right] + (1 - e^i)\left[e^{-i}t^i_{lh} + (1 - e^{-i})t^i_{ll}\right] - \frac{c\left(e^i\right)^2}{2},$$

and the first-order condition can be expressed as:

$$e^{-i}\left[t^i_{hh} - t^i_{lh}\right] + (1 - e^{-i})\left[t^i_{hl} - t^i_{ll}\right] = c\underline{e}^i. \tag{20}$$

Under common agency with information alliance, the agent's effort for a project is:

$$\overline{e}^i \in \arg\max_{e^i}\left\{\begin{array}{c} e^i e^{-i}\left[t^i_{hh} + t^{-i}_{hh}\right] + e^i(1 - e^{-i})\left[t^i_{hl} + t^{-i}_{lh}\right] + (1 - e^i)e^{-i}\left[t^i_{lh} + t^{-i}_{hl}\right] \\ +(1 - e^i)(1 - e^{-i})\left[t^i_{ll} + t^{-i}_{ll}\right] - \frac{c\left(e^i\right)^2}{2} - \frac{c\left(e^{-i}\right)^2}{2} \end{array}\right\},$$

[25] With information disassociation, the equilibrium outcomes are not affected by the correlation.

and the first-order condition gives:

$$e^{-i}\left[t^i_{hh}-t^i_{lh}\right]+(1-e^{-i})\left[t^i_{hl}-t^i_{ll}\right]=c\overline{e}^i-e^{-i}\left[t^{-i}_{hh}-t^{-i}_{hl}\right]-(1-e^{-i})\left[t^{-i}_{lh}-t^{-i}_{ll}\right]. \tag{21}$$

Conditions (20) and (21) are the incentive constraints under exclusive and common agency, respectively. Under exclusive agency, additional information available to the principals does not affect incentive provision to their agents. In (20), principal i simply uses t^i_{hh} and t^i_{hl} as the incentive devices, while setting t^i_{lh} and t^i_{ll} as low as possible—a principal's transfers to incentivize her agent are not affected by the other principal's transfers. In (21), by contrast, a principal's transfer schedule is affected by the other principal's transfers based on the shared information—as the gap $t^{-i}_{hh}-t^{-i}_{hl}$ set by principal $-i$ becomes larger, it decreases the RHS of the constraint, thereby allowing principal i to reduce her transfers (on the LHS) to the common agent. Also implied by (21) is that, $\overline{e}^i$, the agent's optimal effort level for project i increases in the gap $t^{-i}_{hh}-t^{-i}_{hl}$. Notice that with information disassociation, $t^i_{hh}=t^i_{hl}=t^i_h$ and $t^i_{lh}=t^i_{ll}=t^i_l$, $i\in\{a,b\}$, and thus (20) and (21) become identical.

Continuous Project Outputs

The binary project output levels, $\pi_j,\ j\in\{h,l\}$, can be extended to a continuum—for example, $\pi_j\in\pi=\left[\underline{\pi},\overline{\pi}\right]$, with distribution function $F(\pi_j|e^i)$ where $dF(\pi_j|e^i)=f(\pi_j|e^i)d\pi_j$, and the expected π_j is better with $e^i=1$ in that $\Delta F_j\equiv F(\pi_j|e^i=1)-F(\pi_j|e^i=0)<0$ for $\pi_j\in(\underline{\pi},\overline{\pi})$. We reiterate the same point made in the case of continuous effort levels discussed above. Under exclusive agency with information alliance, the incentive constraint for an agent's effort is:

$$\int\int_{\pi}t^i(\pi_j,\pi_k)\Delta f\left(\pi_j\right)f(\pi_k|e^{-i}=1)d\pi_j d\pi_k\geq c, \tag{22}$$

where $\Delta f\left(\pi_j\right)\equiv f(\pi_j|e^i=1)-f(\pi_j|e^i=0)$. As can be seen from (22), while principal i uses information shared by principal $-i$, her transfer schedule is not affected by principal $-i$'s transfer.

Under common agency with information alliance, the local incentive constraint satisfied by principal i's contract is:

$$\int\int_{\pi}t^i(\pi_j,\pi_k)\Delta f\left(\pi_j\right)f(\pi_k|e^{-i}=1)d\pi_j d\pi_k$$
$$\geq c-\int\int_{\pi}t^{-i}(\pi_j,\pi_k)\Delta f\left(\pi_j\right)f(\pi|e^{-i}=1)d\pi_j d\pi_k, \tag{23}$$

where the transfer schedule set by principal $-i$ to the common agent decreases the RHS, thus the constraint is relaxed compared to (22).

With information disassociation, (22) becomes:

$$\int_{\pi}t^i(\pi_j)\Delta f\left(\pi_j\right)d\pi_j\geq c, \tag{24}$$

and (23) becomes:

$$\sum_i \int_\pi t^i(\pi_j) f(\pi_j|e^i = 1) d\pi_j - 2c \geq \int_\pi t^i(\pi_j) f(\pi_j|e^i = 0) d\pi_j$$
$$+ \int_\pi t^{-i}(\pi_k) f(\pi|e^{-i} = 1) d\pi_k - c$$
$$\iff \int_\pi t^i(\pi_j) \Delta f\left(\pi_j\right) d\pi_j \geq c, \tag{25}$$

which also implies the global incentive constraint. Since (24) and (25) are identical, it is implied that information disassociation makes each principal's optimization problem under exclusive agency equivalent to her problem under common agency.

Appendix

Proof of Lemma 1

The incentive constraint (1) can be rewritten as:

$$\Delta z(t_h^i - t_l^i) \geq c. \tag{26}$$

From (26), and the principal's objective function, t_l^i is set optimally at its minimum value, $\underline{t}_l^i = c$. Replacing for t_l in (26), we have: $\Delta z\left(t_h^i - c\right) \geq c$, which must be binding with the optimal t_h^i. The binding constraint gives: $\underline{t}_h^i = c + \frac{c}{\Delta z}$. An agent's expected payoff is obtained from $z_h^i \underline{t}_h^i + z_l^i \underline{t}_l^i - c$. ■

Proof of Claim 1

There can only be three possibilities for principal $i \in \{a, b\}$ in inducing the agent's effort for her project, represented by the local incentive constraint (4), the global incentive constraint (5), and the following incentive constraint:

$$E\left[U_j^i|e^i = 1\right] + E\left[U_j^{-i}|e^{-i} = 0\right] \geq \sum_i E\left[U_j^i|e^i = 0\right].$$

With (4) and (5) satisfied, the constraint expressed above, however, is automatically satisfied in equilibrium. By Condition 1, each principal wants to induce the agent's effort for her project. Thus, by the local constraint (4), principal $-i$ will induce $e^{-i} = 1$ in equilibrium given that $e^i = 1$. In addition, the constraint above boils down to:

$$E\left[U_j^i|e^i = 1\right] \geq E\left[U_j^i|e^i = 0\right],$$

since $E\left[U_j^{-i}|e^{-i} = 0\right]$ on the LHS and the RHS cancel each other. The simplified inequality, however, is implied by the global incentive constraint (5) since the agent's payoff is additively separable across the two projects. ■

Proof of Lemma 2

The local incentive constraint (4) is rewritten as:

$$\begin{aligned} & z_1^2\left[t_h^i+t_h^{-i}\right]+z_1(1-z_1)\left[t_h^i+t_l^{-i}+t_l^i+t_h^{-i}\right]+(1-z_1)^2\left[t_l^i+t_l^{-i}\right]-2c \\ & \quad \geq z_0 z_1\left[t_h^i+t_h^{-i}\right]+z_0(1-z_1)\left[t_h^i+t_l^{-i}\right] \\ & \qquad +(1-z_0) z_1\left[t_l^i+t_h^{-i}\right]+(1-z_0)(1-z_1)\left[t_l^i+t_l^{-i}\right]-c, \end{aligned}$$

where t_j^{-i}, $j \in \{h, l\}$, on the LHS and the RHS cancel each other out. The constraint is simplified to:

$$\Delta z(t_h^i - t_l^i) \geq c. \tag{27}$$

The global incentive constraint (5) is rewritten as:

$$\begin{aligned} & z_1^2\left[t_h^i+t_h^{-i}\right]+z_1(1-z_1)\left[t_h^i+t_l^{-i}+t_l^i+t_h^{-i}\right]+(1-z_1)^2\left[t_l^i+t_l^{-i}\right]-2c \\ & \geq z_0^2\left[t_h^i+t_h^{-i}\right]+z_0(1-z_0)\left[t_h^i+t_l^{-i}+t_l^i+t_h^{-i}\right]+(1-z_0)^2\left[t_l^i+t_l^{-i}\right], \end{aligned}$$

which is simplified to:

$$\Delta z(t_h^i - t_l^i) + \Delta z(t_h^{-i} - t_l^{-i}) \geq 2c. \tag{28}$$

In a symmetric equilibrium where both principals are subject to the local incentive constraint (27), the global incentive constraint (28) is implied by (27). Together with the limited liability constraint for the agent in (2), each principal's problem then becomes identical to the one under exclusive dealing, and hence the optimal outcome: $\bar{t}_h^i = c + \frac{c}{\Delta z}$ and $\bar{t}_l^i = c$, $i \in \{h, l\}$, and an agent's expected payoff is obtained from $z_1\bar{t}_h^i + z_0\bar{t}_l^i - c$. ■

Proof of Proposition 1

The proof follows from Lemmas 1 and 2. ■

Proof of Lemma 3

The incentive constraint for each agent (7) is rewritten as:

$$\begin{aligned} & z_1^2 t_{hh}^i+z_1(1-z_1)\left[t_{hl}^i+t_{lh}^i\right]+(1-z_1)^2 t_{ll}^i-c \\ & \geq z_0 z_1 t_{hh}^i+z_0(1-z_1) t_{hl}^i+(1-z_0) z_1 t_{lh}^i+(1-z_0)(1-z_1) t_{ll}^i, \end{aligned}$$

which can be reduced to:

$$z_1\left[t_{hh}^i - t_{lh}^i\right] + (1-z_1)\left[t_{hl}^i - t_{ll}^i\right] \geq \frac{c}{\Delta z}. \tag{29}$$

Since t^i_{lh} and t^i_{ll} make (29) harder to be satisfied, the optimal contract reduces them to the minimum value according to the limited liability constraint (8): $\widehat{t^i_{lh}} = \widehat{t^i_{ll}} = c$. In the optimal contract, t^i_{hh} and t^i_{hl} are reduced to the levels such that (29) is binding. The binding constraint, with $t^i_{lh} = t^i_{ll} = c$, becomes:

$$z_1 t^i_{hh} + (1 - z_1) t^i_{hl} = c + \frac{c}{\Delta z}. \tag{30}$$

There is a degree of freedom in choosing t^i_{hh} and t^i_{hl} as all players are risk-neutral. Any combination of t^i_{hh} and t^i_{hl} that satisfies (30) and (8) induces the agent's effort. Thus, without loss of generality, we can set $t^i_{hh} = t^i_{hl}$ and (30) gives: $\underline{t}^i_{hh} = \underline{t}^i_{hl} = c + \frac{c}{\Delta z}$. An agent's expected payoff is obtained from $z_1^2 \underline{t}^i_{hh} + z_1(1 - z_1)\left[\underline{t}^i_{hl} + \underline{t}^i_{lh}\right] + (1 - z_1)^2 \underline{t}^i_{ll} - c$. ■

Proof of Corollary 1

The proof follows from Lemmas 1 and 3. ■

Proof of Lemma 4

We first solve a principal's problem subject to (11) and (8), and then show that (10) is automatically satisfied by the solution without it. After simplifying (11), the Lagrangian of the problem is:

$$\begin{aligned}
\mathcal{L} = {} & z_1 \pi_h + (1 - z_1)\pi_l - z_1^2 t^i_{hh} - z_1 (1 - z_1)\left[t^i_{hl} + t^i_{lh}\right] - (1 - z_1)^2 t^i_{ll} \\
& + \gamma_{hh}\left[t^i_{hh} - c\right] + \gamma_{hl}\left[t^i_{hl} - c\right] + \gamma_{lh}\left[t^i_{lh} - c\right] + \gamma_{ll}\left[t^i_{ll} - c\right] \\
& + \mu \Delta z \left[(z_1 + z_0)\left(t^i_{hh} + t^{-i}_{hh}\right) + (1 - z_1 - z_0)\left(t^i_{hl} + t^{-i}_{lh} + t^i_{lh} + t^{-i}_{hl}\right)\right. \\
& \left. + (z_1 + z_0 - 2)\left(t^i_{ll} + t^{-i}_{ll}\right)\right],
\end{aligned}$$

where γ_{jk} and μ are the Lagrange multipliers for (8) and (11) respectively. The first-order conditions for the optimization problem are:

$$\frac{\partial \mathcal{L}}{\partial t^i_{hh}} = -z_1^2 + \gamma_{hh} + \mu \Delta z (z_1 + z_0) \leq 0, \;\; t^i_{hh} \geq c,$$

$$\text{with } \left(t^i_{hh} - c\right)\left[-z_1^2 + \gamma_{hh} + \mu \Delta z (z_1 + z_0)\right] = 0;$$

$$\frac{\partial \mathcal{L}}{\partial t^i_{hl}} = -z_1 (1 - z_1) + \gamma_{hl} + \mu \Delta z (1 - z_1 - z_0) \leq 0, \;\; t^i_{hl} \geq c,$$

$$\text{with } \left(t^i_{hl} - c\right)\left[-z_1 (1 - z_1) + \gamma_{hl} + \mu \Delta z (1 - z_1 - z_0)\right] = 0;$$

$$\frac{\partial \mathcal{L}}{\partial t^i_{lh}} = -z_1 (1 - z_1) + \gamma_{lh} + \mu \Delta z (1 - z_1 - z_0) \leq 0, \ t^i_{lh} \geq c,$$

$$\text{with } \left(t^i_{lh} - c\right) \left[-z_1 (1 - z_1) + \gamma_{lh} + \mu \Delta z (1 - z_1 - z_0)\right] = 0;$$

$$\frac{\partial \mathcal{L}}{\partial t^i_{ll}} = -(1 - z_1)^2 + \gamma_{ll} + \mu \Delta z (z_1 + z_0 - 2) \leq 0, \ t^i_{ll} \geq c,$$

$$\text{with } \left(t^i_{ll} - c\right) \left[-(1 - z_1)^2 + \gamma_{ll} + \mu \Delta z (z_1 + z_0 - 2)\right] = 0;$$

Finding a value of μ such that $\gamma_{hh} = 0$ and $t^i_{hh} \geq c$, we have:

$$\mu = \frac{z_1^2}{\Delta z (z_1 + z_0)}.$$

By replacing μ with its value in the first-order conditions for t^i_{hl}, t^i_{lh} and t^i_{ll}, it must be that $\gamma_{hl} > 0$, $\gamma_{lh} > 0$ and $\gamma_{ll} > 0$, implying that: $\bar{t}^i_{hl} = \bar{t}^i_{lh} = \bar{t}^i_{ll} = c$. Substituting for $\bar{t}^i_{hl}$, $\bar{t}^i_{lh}$ and $\bar{t}^i_{ll}$ in binding (11), we have:

$$\bar{t}^i_{hh} = c + \frac{c}{(z_1 + z_0) \Delta z}.$$

The agent's expected rent from each project is obtained from $z_1^2 \bar{t}^i_{hh} + z_1(1 - z_1) \left[\bar{t}^i_{hl} + \bar{t}^i_{lh}\right] + (1 - z_1)^2 \bar{t}^i_{ll} - c$. To show that (10) is satisfied by the solution, we replace the transfers with their values in (10) to have:

$$\frac{2z_1^2}{\Delta z (z_1 + z_0)} - 1 \geq \frac{2z_1 z_0}{\Delta z (z_1 + z_0)} \iff (z_1 - z_0)^2 \geq 0,$$

which is satisfied with a strict inequality. To see that the transfer schedules constitute a Pareto-optimal equilibrium, suppose the principals were merged into a single entity—that is, the case become identical to one principal with two projects. The merged principals then maximize the following joint payoff:

$$2 [z_1 \pi_h + (1 - z_1) \pi_l] - z_1^2 \left[t^i_{hh} + t^{-i}_{hh}\right] - z_1 (1 - z_1) \left[t^i_{hl} + t^i_{lh} + t^{-i}_{hl} + t^{-i}_{lh}\right]$$
$$- (1 - z_1)^2 \left[t^i_{ll} + t^{-i}_{ll}\right],$$

subject to (11) and the limited liability constraints. It is straight forward to see that the optimal outcome in this problem is the same as the one in Lemma 4. ■

Proof of Proposition 2

The proof follows from Lemmas 3 and 4. ■

Proof of Lemma 5

Since the single principal uses all information available in designing the transfer schedule must satisfy the same local and global incentive constraints, (10) and (11), and the limited liability constraint (8). The principal maximizes the expected join payoff from the projects:

$$\sum_i \left[z_1\pi_h + (1-z_1)\pi_l - z_1^2 t_{hh}^i - z_1(1-z_1)\left[t_{hl}^i + t_{lh}^i\right] - (1-z_1)^2 t_{ll}^i\right]$$

subject to (8), (10) and (11). We can solve the principal's problem subject to (11) and (8), and then show that (10) is satisfied by the solution without it. After simplifying (11), the Lagrangian of the problem is:

$$\begin{aligned}\mathcal{L} = &\sum_i \left[z_1\pi_h + (1-z_1)\pi_l - z_1^2 t_{hh}^i - z_1(1-z_1)\left[t_{hl}^i + t_{lh}^i\right] - (1-z_1)^2 t_{ll}^i\right]\\ &+ \sum_i \left[\gamma_{hh}^i\left(t_{hh}^i - c\right)\right] + \sum_i \left[\gamma_{hl}^i\left(t_{hl}^i - c\right)\right] + \sum_i \gamma_{lh}^i\left[\left(t_{lh}^i - c\right)\right]\\ &+ \sum_i \left[\gamma_{ll}^i\left(t_{ll}^i - c\right)\right]\\ &+ \mu\Delta z\left[(z_1+z_0)\left(t_{hh}^i + t_{hh}^{-i}\right) + (1-z_1-z_0)\left(t_{hl}^i + t_{lh}^{-i} + t_{lh}^i + t_{hl}^{-i}\right)\right.\\ &\left.+(z_1+z_0-2)\left(t_{ll}^i + t_{ll}^{-i}\right)\right],\end{aligned}$$

Since the objective function and the limited liability constraints are additively separable across the two projects, and the global incentive constraint is identical to the one under common agency, the solution to this problem is the same as in Lemma 4. ∎

Proof of Corollary 2

The proof follows from Propositions 1 and 2, and Corollary 1. ∎

Proof of Lemma 6

The objective functions of principal i and $-i$ are respectively:

$$z_1\pi_h + (1-z_1)\pi_l - z_1^2 t_{hh}^i - z_1(1-z_1)\left[t_{hl}^i + t_{lh}^i\right] - (1-z_1)^2 t_{ll}^i \text{ and}$$

$$z_1\pi_h + (1-z_1)\pi_l - z_1 t_h^{-i} - (1-z_1)\,t_l^{-i}.$$

The local incentive constraints faced by principal i and $-i$, (15) and (16), can be simplified and rewritten as:

$$\Delta z\left[z_1\left(t_{hh}^i - t_{lh}^i\right) + (1-z_1)\left(t_{hl}^i - t_{ll}^i\right)\right] \geq c, \tag{31}$$

$$\Delta z\left[\left(t_h^{-i} - t_l^{-i}\right) + z_1\left(t_{hh}^i - t_{hl}^i\right) + (1-z_1)\left(t_{lh}^i - t_{ll}^i\right)\right] \geq c, \tag{32}$$

and the global incentive constraint faced by both principal can be rewritten as:

$$\Delta z\left[(z_1+z_0)t^i_{hh}+(1-z_1-z_0)\left[t^i_{hl}-t^i_{lh}\right]-(2-z_1-z_0)t^i_{ll}+t^{-i}_h-t^{-i}_l\right]\geq 2c. \tag{33}$$

From these expression we notice, t^i_{lh}, t^i_{ll} and t^{-i}_l make it harder to satisfy the constraints while lowering the principals' expected payoffs. Therefore, we must have $t^i_{lh}=t^i_{ll}=t^{-i}_l=c$ in equilibrium. With these transfer values, (31), (32) and (33) are rewritten respectively as:

$$z_1 t^i_{hh}+(1-z_1)t^i_{hl}\geq c+\frac{c}{\Delta z}, \tag{34}$$

$$t^{-i}_h+z_1\left(t^i_{hh}-t^i_{hl}\right)\geq c+\frac{c}{\Delta z}, \tag{35}$$

$$(z_1+z_0)t^i_{hh}+(1-z_1-z_0)t^i_{hl}+t^{-i}_h\geq 2\left(c+\frac{c}{\Delta z}\right). \tag{36}$$

Since principal $-i$'s transfer does not enter in (34), it is implied that (34) is binding in principal i's offer. There are two potential cases in equilibrium.

Case (i): The case where (35) is binding, while (36) is automatically satisfied by the solution without it. With binding (34) and (35), it must be that (36) is satisfied with equality with $t^i_{hh}=t^i_{hl}$ to avoid a contradiction. With $t^i_{hh}=t^i_{hl}$, binding (34) gives:

$$t^i_{hh}=t^i_{hl}=c+\frac{c}{\Delta z},$$

and (35) in turn gives:

$$t^{-i}_h=c+\frac{c}{\Delta z}.$$

With these transfers, (36) is in fact satisfied, and hence a set of contracts $\{\widehat{\Phi}^i,\widehat{\Phi}^{-i}\}$,

$$\begin{aligned}\text{where } \widehat{\Phi}^i&=\left(s^i=0;\ \widehat{t^i_{hk}}=c+\frac{c}{\Delta z},\ \widehat{t^i_{lk}}=c\right),k\in\{h,l\},\\ \text{and } \widehat{\Phi}^{-i}&=\left(s^{-i}=1;\ \widehat{t^{-i}_h}=c+\frac{c}{\Delta z},\ \widehat{t^{-i}_l}=c\right),\end{aligned}$$

is an equilibrium provided that $s^i=0$ and $s^{-i}=1$. This is the equilibrium in which principal i does not use the information shared by principal $-i$. The agent's rent from each project in this equilibrium is:

$$\mathbb{E}\left[U^i_{jk}|e^i=e^{-i}=1\right]=E\left[U^{-i}_k|e^{-i}=1\right]=z_1c/\Delta z. \tag{37}$$

Case (ii): The case where (36) is binding while (35) is satisfied by the solution without it. Binding (34) and (36) together imply that:

$$z_0\left(t^i_{hh}-t^i_{hl}\right)+t^{-i}_h=c+\frac{c}{\Delta z}. \tag{38}$$

Substituting for $z_1 t^i_{hh} + (1 - z_1) t^i_{hl} = c + \frac{c}{\Delta z}$ from binding (34) and $t^i_{lh} = t^i_{ll} = t^{-i}_l = c$ in principal i's objective function, her problem is rewritten as follows:

$$\mathcal{P}^i : \max z_1 \pi_h + (1 - z_1)\, \pi_l - \left(1 + \frac{z_1}{\Delta z}\right) c, \quad \text{s.t.} \quad t^i_{hh} \geq c,\ t^i_{hl} \geq c \text{ and } (38).$$

With $t^{-i}_l = c$, principal $-i$'s problem is rewritten as:

$$\mathcal{P}^{-i} : \max z_1 \pi_h + (1 - z_1)\, \pi_l - z_1 t^{-i}_h - (1 - z_1)\, c, \quad \text{s.t.} \quad t^{-i}_h \geq c \text{ and } (38).$$

In $\mathcal{P}^i$, for any $t^{-i}_h \geq c$, principal i is indifferent between t^i_{hh} and t^i_{hl} subject to (38), $t^i_{hh} \geq c$ and $t^i_{hl} \geq c$. Thus, we have a continuum of equilibrium candidates in this subgame. The transfers in *Case i*, $t^i_{hh} = t^i_{hl} = c + \frac{c}{\Delta z}$ and $t^{-i}_h = c + \frac{c}{\Delta z}$, satisfy these condition, and also satisfy (35) with equality, hence an equilibrium. Another equilibrium candidate within the continuum is:

$$t^i_{hh} = c + \frac{c}{\Delta z} + \varepsilon_{hh} \text{ and } t^i_{hl} = c + \frac{c}{\Delta z} - \varepsilon_{hl}, \tag{39}$$

$$\text{where } \varepsilon_{hh} > 0,\ \varepsilon_{hh} \approx 0 \text{ and } \varepsilon_{hl} = \frac{z_1}{1 - z_1} \varepsilon_{hh}.$$

That $\varepsilon_{hl} = [z_1/(1 - z_1)]\, \varepsilon_{hh}$ is obtained from (34). For notational simplicity, we let $\varepsilon = \varepsilon_{hh}$. Then, from (38), we have:

$$\text{and } t^{-i}_h = c + \frac{c}{\Delta z} - \frac{z_0}{1 - z_1} \varepsilon. \tag{40}$$

With these transfers in (39) and (40), the constraint (35) is satisfied by strict inequality as the constraint becomes after substituting for the transfer values:

$$\frac{\Delta z}{1 - z_1} > 0.$$

From $\mathcal{P}^i$ and $\mathcal{P}^{-i}$, since principal i is indifferent between t^i_{hh} and t^i_{hl} as long as subject to (38), $t^i_{hh} \geq c$ and $t^i_{hl} \geq c$, but principal $-i$'s payoff increases in the gap between t^i_{hh} and t^i_{hl} for $t^i_{hh} > t^i_{hl}$. Since $t^i_{hl} = c$ is the lower-limit, the upper-limit of t^i_{hh} from (34) is: $t^i_{hh} = c + c/[z_1 \Delta z]$, which in turn gives the upper-limit of ε:

$$\varepsilon = \frac{1 - z_1}{z_1 \Delta z} c.$$

Thus, a set of contract $\{\widetilde{\Phi}^i, \widetilde{\Phi}^{-i}\}$,

$$\text{where } \widetilde{\Phi}^i = \left(s^i = 0;\ \widetilde{t}^i_{hh} = c + \frac{c}{\Delta z} + \varepsilon,\ \widetilde{t}^i_{hl} = c + \frac{c}{\Delta z} - \frac{z_1}{1-z_1}\varepsilon,\ \widetilde{t}^i_{lh} = \widetilde{t}^i_{ll} = c\right),$$
$$\widetilde{\Phi}^{-i} = \left(s^{-i} = 1;\ c + \frac{c}{\Delta z} - \frac{z_0}{1-z_1}\varepsilon,\ \widetilde{t}^{-i}_l = c\right),\ \text{and } \varepsilon \in \left(0, \frac{1-z_1}{z_1 \Delta z}c\right]$$

is an equilibrium, provided that $s^i = 0$ and $s^{-i} = 1$, in which principal i uses the information shared by principal $-i$ since $\widetilde{t}^i_{hh} \neq \widetilde{t}^i_{hl}$. The agent's rent from each project in this equilibrium is:

$$\mathbb{E}\left[U^i_{jk}|e^i = e^{-i} = 1\right] = z_1 c/\Delta z \quad \text{and} \quad E\left[U^{-i}_k|e^{-i} = 1\right] = \frac{z_1 c}{\Delta z} - \frac{z_1 z_0}{1-z_1}\varepsilon < \frac{z_1 c}{\Delta z}. \tag{41}$$

It follows from (37) and (41) that $\{\widetilde{\Phi}^i, \widetilde{\Phi}^{-i}\}$ Pareto-dominates $\{\widehat{\Phi}^i, \widehat{\Phi}^{-i}\}$. ■

Proof of Corollary 3

The proof follows from the discussion. ■

Proof of Lemma 7

Given that $s^i = s^{-i} = 1$, The local incentive constraint (10) and the global incentive constraint (11) for principal i, after substituting for the optimal values for $t^i_{lh} = t^i_{ll} = t^{-i}_{lh} = t^{-i}_{ll} = c$, can be rewritten respectively as:

$$z_1 t^i_{hh} + (1-z_1)t^i_{hl} \geq c + \frac{c}{\Delta z} - z_1 \Delta_t, \text{ and} \tag{42}$$

$$t^i_{hl} + t^{-i}_{hl} = 2\left(c + \frac{c}{\Delta z}\right) - 2(z_1 + z_0)\Delta_t, \tag{43}$$

where $\Delta_t = t^i_{hh} - t^i_{hl} = t^{-i}_{hh} - t^{-i}_{hl}$ in a symmetric equilibrium. Since t^i_{hl} and t^{-i}_{hl} have the lower bound at $t^i_{hl} = t^{-i}_{hl} = c$, from Lemma 4 implies that Δ_t has the maximum value:

$$\Delta^{\max}_t = \frac{c}{(z_1 + z_0)\,\Delta z},$$

if the principals use the shared information in the Pareto-optimal way. If the principals do not use information, then $\Delta_t = 0$, in which case (42) and (43) become identical and the principal's expected payoffs are the same as when they do not share information. Thus, given that $s^i = s^{-i} = 1$, a set of equilibria with $\Delta_t \in (0, \Delta^{\max}_t)$ such that using the shared information Pareto-dominates the equilibrium in which they do not use the information. ■

Proof of Proposition 3

As shown in Lemmas 6 and 7, given that information is shared (by one or both principals), there exists a set of equilibria in which the shared information is used in a Pareto-dominant way. Then, given that principal i chooses $s^i = 0$, the agent's expected rent from principal $-i$'s offer is $z_1 c/\Delta z$ if $s^{-i} = 0$ from Lemma 2, and $z_1 c/\Delta z - z_0 z_1 \varepsilon/[1 - z_1] = c$ $(< z_1 c/\Delta z)$ if $s^{-i} = 1$ from Lemma 6, where $\varepsilon = (1 - z_1)\, c/(z_1 \Delta z)$ is the Pareto-optimal value. Also, given that principal i chooses $s^i = 1$, the agent's expected rent from principal $-i$'s offer is $z_1 c/\Delta z$ if $s^{-i} = 0$ from Lemma 6, and $z_1^2 c/\,[(z_1 + z_0)\, \Delta z]$ $(< z_1 c/\Delta z)$ if $s^{-i} = 1$ from Lemma 4. Thus, regardless of $s^i \in \{0, 1\}$, principal $-i$ chooses $s^{-i} = 1$. By symmetry, regardless of $s^{-i} \in \{0, 1\}$, principal i chooses $s^i = 1$, and hence $s^i = s^{-i} = 1$ is the equilibrium in Pareto-Optimal Dominant Strategy. ■

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