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IZA DP No. 1661

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July 2005

Forschungsinstitut
zur Zukunft der Arbeit
Institute for the Study
of Labor

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IZA Discussion Paper No. 1661
July 2005

ABSTRACT

From Team Spirit to Jealousy: The Pitfalls of Too Much Transparency*

Free riding in team production arises because individual effort is not perfectly observable. It seems natural to suppose that greater transparency would enhance incentives. Therefore, it is puzzling that team production often lacks transparency about individual contributions despite negligible costs for providing such information. We offer a rationale for this by demonstrating that transparency can actually hurt incentives. In the presence of career concerns information on the quality of task execution improves incentives while sustaining a cooperative team spirit. In contrast, making the identity of individual contributors observable induces sabotage behavior that looks like jealousy but arises purely from signal jamming by less successful team members. Our results rationalize the conspicuous lack of transparency in team settings with strong career concerns (e.g., co-authorship, architecture, and patent applications) and contribute to explaining the popularity of group incentive schemes in firms.

JEL Classification: D82, J30, L14

Keywords: teams, reputation, transparency, group incentives, sabotage

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* We thank Guido Friebel, Bob Gibbons, Francine Lafontaine, and Paul Oyer for helpful comments. Financial support from the Bonn Graduate School of Economics is gratefully acknowledged. The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the Federal Ministry of Finance.

The authors of [Hindriks and De Donder (2003)] regret that the 'order of authors' was incorrect in the original article.

Corrigendum reversing the ordering of the authors' names to create an alphabetical order. (De Donder and Hindriks 2004)

1 Introduction

It is a common practice in academics to obscure the ranking of individual authors' overall contributions to a co-authored paper by listing names in alphabetical order rather than in order of contribution.[1] In fact, virtually all co-authored papers do not even include readily available measures of specific individual contributions, e.g., in the form of footnotes that identify the originator of particular ideas among the authors. This is puzzling. It would seem natural to expect research teams to make use of such information to mitigate the free-rider problem that arises when individual inputs to the common endeavor are not perfectly observable (e.g., Holmström (1982)). Co-authorship[2] is just one example for the often observed lack of transparency about individual contributions in team production despite negligible costs for providing such additional information. Other domains characterized by powerful career concerns share this feature: information about individual contributions is often obscured in professions where creative human capital is prized (e.g., architecture[3]); partnerships in human capital intensive professional services (e.g., law firms) avoid publicly observable measures of individual performance by engaging in profit sharing.[4]; patent law prevents a public ranking of individual inventors' contributions.[5]

This paper sheds light on this phenomenon. We prove that the relation between transparency and effort incentives can actually be non-monotonic if the team production is characterized by

[1] This is especially pervasive in economics, where roughly 85 percent of co-authored papers use alphabetical listing (Engers, Gans, Grant, and King (1999) and van Praag and van Praag (2003)).

[2] Our analysis of team production is complementary to Engers, Gans, Grant, and King (1999), who focus exclusively on the prevalence of alphabetic ordering in co-authorship.

[3] "Architecture is a profession in which design capability is prized and intellectual property is the most common proof of worth, in terms of talent and of experience. It is the nature of contemporary practice to be a collaborative team effort." (AIA (2004)). Nevertheless, architecture firms often do not disclose individuals' contributions to projects (e.g., OAA (2000)).

[4] Profit sharing is the norm in law firms (e.g., Gilson and Mnookin (1985)) and these are also concerned with assuring "[...] that the client's perception of quality is associated with the firm rather than with one or a small number of lawyers." (Gilson and Mnookin (1985) p.362).

[5] In joint patent applications, by legal design, the order of the inventors' names has no significance (e.g., Eisenberg (2000)).

strong career concerns and if team members have the ability to adversely affect joint production. These two ingredients are nicely captured by the co-authorship example. Publication of a co-authored paper typically results in no or only small immediate pecuniary gains whereas the impact on future salaries can be substantial.[6] Clearly, the success of a paper depends not only on each co-author's individual effort but also on the team members' willingness to cooperate.

In the first part of the paper we analyze such self-governed teams. We show that some transparency enhances members' effort incentives without affecting the cooperative *team spirit*. The additional information alleviates the free rider problem by aligning an individual's share of direct material gains more closely with her contribution. However, since team production reveals information about its members' productive abilities, each individual's contribution affects her (and the team mates') future compensation in the labor market (*reputation*). If there is too much transparency about the production process (in a sense made more precise below), team members will try to influence their reputation by engaging in behavior that adversely affects the overall team performance. Such *sabotage* behavior looks like *jealousy* but arises purely from signal jamming by less successful team members.

The second part of the paper looks beyond self-governed teams to team incentives in firms. It is often argued that incentive contracts based on individual performance reduce worker morale and create conflict in teams. We demonstrate that indeed group incentives can be strictly more profitable than individual incentives because they lower the cost for the principal of inducing cooperation among team members. Thus, the possibility of information-induced sabotage that we highlight offers an additional rationale for the increasing popularity of low-powered group incentives in firms (e.g., Ichniowski and Shaw (2003)). In contrast to the existing literature, in our model sabotage is not a direct consequence of perceived inequalities in pay (e.g., Levine (1991) and Clark and Oswald (1996)) or of competition induced by relative performance evaluation or implicit tournaments (e.g., Lazear (1989) and Chen (2003)) but rather due to the informational externality that an agent can impose on the team.

Our basic argument can be summarized as follows. Consider two individuals working on a

[6]Estimates of expected salary increases in economics departments range from between 1.3 and 1.9 percent (Baser and Pema 2001) to 3.8 percent (Sauer (1988) who includes returns to citations) for ten article pages in the American Economic Review (AER) or 10.3 percent per AER-equivalent article (Ragan, Warren, and Bratsberg 1999). The first top finance journal publication has been estimated to have a present value of $ 20-30,000 (Swidler and Goldreyer 1998). In contrast to Sauer (1988) the study of Moore, Newman, and Turnbull (2001) suggests that economics departments do not appear to discount multi-authored papers. They report an impact of roughly 3 percent of a publication in one of the ten leading journals.

joint project for which the success probability depends on the kind of contribution that each team member provides in her task. There is a *routine* method that all types of players can apply. However, if an individual is talented and exerts effort, she can discover a *novel* approach to her task that –appropriately implemented– increases the project's success probability. A prerequisite for implementing such a novel method is coordination with the team mate. If a team member refuses to cooperate with her colleague (implicit *sabotage*) the novel method cannot be applied, and the team has to revert to the routine method. An incentive problem arises because effort to develop innovative approaches is unobservable and costly for team members.

We first consider a situation in which there are no direct material benefits from the project outcome and only the impact of team members' actions on their future compensation in the labor market matter. Our co-authorship example fits roughly into this category. Suppose that the market observes only whether a project has succeeded or failed. Then, success is a stronger signal about the presence of a talented individual in the team than lack of success: talented individuals may discover a novel approach that increases the project's success probability. All team members share the same reputation because market inference is based only on the project outcome. On the one hand, this leads to free riding on the team mate's effort, which is detrimental to incentives. On the other hand, no team member ever wants to engage in sabotage because this would only reduce the own expected reputation by lowering the probability of success.

Increasing transparency so that team members' contributions can be observed anonymously enhances incentives because the reputational impact of effort for a talented worker becomes stronger: the implementation of a novel approach now is directly visible and thus increases the team members' reputations even in the absence of success. As before, reputation is the same for all team members and no sabotage occurs. Free riding remains an issue because an individual who fails to come up with new ideas benefits from a team mate's innovation and the ensuing increase in the team's collective reputation.

In principle, free riding could be mitigated by increasing transparency further to make observable the specific contribution of each team member. Absent sabotage, if an individual discovers a novel method she is thereby identified as the source of the innovation and captures the full reputational credit instead of being put in the same pot with her –possibly less successful– team mate. However, failure to develop a new method can now be attributed as well. Therefore an unsuccessful individual has an incentive to sabotage her team mate. Specifically, if the market observes a team profile of routine approaches this might stem from failure of both team members to innovate or from one team member with a novel idea (who therefore must be talented) being prevented from implementing it. In contrast, being the sole unsuccessful contributor to the project sends a stronger negative message about talent: the possibility of sabotage can no longer serve as an excuse for failing to come up with new ideas. Thus, sabotage provides an unsuccessful team member with an opportunity to create a smokescreen of collective failure behind which to hide her individual failure. Because the market cannot distinguish her from her potentially more successful and able colleague, hiding behind this smokescreen enhances the reputation of the saboteur.

Sabotage looks like jealousy-inspired behavior because it occurs unless all team members successfully innovate. Since it weakens the incentives for talented individuals to exert effort in the first place, a non-monotonic relation between transparency and effort incentives arises. Transparency about the team's production process alleviates the free rider problem as long as reputation is not individually attributable. Increasing transparency further to create individual accountability induces sabotage behavior aimed at jamming the signal that the market receives about the saboteur. A team member can prevent the market from observing unfavorable information about her ability by undermining the team mate's contribution since this creates a correlation among bad performance signals that renders them less informative about each individual. This provides a rationale for restricting the degree of transparency on the identity of contributors in team production.

In our model, sabotage equilibria continue to exist even if there are direct material benefits from joint production. An example for such a setting where career concerns and material benefits both play important roles are teams of architects submitting proposals to a project competition.[7] Even though cooperative equilibria may also arise in such an environment, we show in an extension that these are not robust to slight changes in the information structure. As soon as there is a small probability that cooperation cannot only break down because of sabotage but also due to some exogenous event, e.g., team members do not 'get along', the presence of material benefits is not sufficient to prevent sabotage.

In several extensions of the base model we demonstrate that our main insights are robust to modelling choices. In particular, they are reinforced if the quality of contributions can only be observed in case of project success (as seems likely in our co-authorship example) or if team members start with different prior reputations. Moreover, we provide a detailed analysis of the welfare implications of enhanced transparency in team production.

[7] See footnote 3.

Related literature

Our work contributes to the literature on incentives in teams originated by Holmström (1982)'s seminal paper. As shown there, free riding cannot be entirely overcome if rewards from the common enterprise are fully shared among team members. In the presence of career concerns this problem persists (Jeon 1996). A natural conjecture is that greater transparency about team members' specific performances is a way out of this problem. Our results show that this intuition is wrong when there are career concerns and team members can affect each other's performances.

Our analysis of a principal - team of agents setting in the second part of the paper adds to a recent theoretical literature on group incentives (e.g., Itoh (1991) and Che and Yoo (2001)) and is most related to Auriol, Friebel, and Pechlivanos (2002). They derive optimal linear incentive schemes for teams under repeated interaction with a principal who has imperfect commitment power. In their model helping others enhances the perceived ability of all team members and leads to an increase in the collective component in the compensation scheme. A ratchet effect arises because of lacking commitment power by the principal. One implication of their analysis is that career concerns reduce cooperation only if the same agents remain teamed up during their productive life.[8] In contrast, in our setup sabotage arises even though there is no future interaction between team mates.

Our findings also contribute to the literature on conditions under which more information can hurt principals. Remaining ignorant about agents' abilities can serve as a commitment device to fire able agents who shirk (Crémer 1995). In the context of Holmström (1999)'s model of career concerns for individuals, Dewatripont, Jewitt, and Tirole (1999) show that reputational incentives can increase as the signal structure becomes coarser. Similar results obtain when explicit incentives interact with career concerns (Koch and Peyrache (2003, 2005)) or with ratchet effects (Meyer and Vickers 1997). In a model of expert career concerns, Prat (2005) shows that the incentive effects of transparency on consequences of actions can be very different from those of information on the actions themselves. Our model comes to a similar conclusion in the context of teams.

The paper is structured as follows. Section 2 presents the base model. Section 3 studies the case of pure career concerns. The interaction of career concerns and material benefits is analyzed in Section 4. Welfare implications of transparency are the focus of Sections 5 and 6. Section 7 studies the design of team compensation contracts by a principal. Section 8 presents

[8]When an agent leaves the firm or joins a different team, her future team mates' reputation and thus the collective pay component is not affected by help provided to current team mates.

several other extensions of the base model. Section 9 concludes.

2 Base model

Our setup considers two workers $i = 1, 2$ who join to form a team when they are young (period 1) and then move on to a competitive market for experienced labor where they pursue individual careers (period 2). Their outside options are normalized to zero. A worker can either be of 'ordinary' ability ($\theta_i = \underline{\theta}$) or 'talented' ($\theta_i = \bar{\theta}$), with $Pr(\theta = \bar{\theta}) = \lambda \leq \frac{1}{2}$.[9] Workers are wealth and credit constrained, risk neutral, and maximize their life-time income. For simplicity, the discount factor is normalized to one, and the initial wealth of each worker is normalized to zero.

Team production in period 1

Prior to learning about their work-related ability, both workers form a team to contribute to a project that can succeed or fail: $\tilde{y} \in \{0, 1\}$. The payoff of the project is zero in case of failure and π in case of success, i.e., it is given by $\tilde{y}\,\pi$. The production technology requires both team mates to perform specific tasks which are complex, and therefore make it impossible for an individual to do all of them alone. Hence, each worker in the team is assigned one task. Each of these tasks can be implemented by taking one of two approaches: a standard –*routine*– method (R) or an innovative –*novel*– method (N). Any worker is capable of taking the routine approach to her respective task. However, the novel method requires the development of new ideas which only talented workers are able to come up with. After learning their own type but not that of the colleague,[10] agents can engage in effort $e \in \{0, 1\}$ to develop ideas at unit cost c. If a talented worker exerts effort in generating ideas she discovers a novel approach ($\mathcal{I}_i = 1$) with probability η. With probability $(1 - \eta)$, she has no innovative ideas ($\mathcal{I}_i = 0$) and can only take the routine action. Absent effort or talent, workers never succeed in discovering innovative strategies, and are therefore restricted to execute their tasks according to routine practice:

$$Pr(\mathcal{I}_i = 1 \,|\, e_i = 1, \bar{\theta}) = \eta, \quad (1)$$

$$Pr(\mathcal{I}_i = 1 \,|\, e_i = 0, \bar{\theta}) = 0, \quad (2)$$

$$Pr(\mathcal{I}_i = 1 \,|\, e_i = 0, \underline{\theta}) = Pr(\mathcal{I}_i = 1 \,|\, e_i = 1, \underline{\theta}) = 0. \quad (3)$$

[9]That is, talent is relatively scarce. This restriction simplifies the exposition but does not affect the existence of the types of equilibria presented below.

[10]This simplifying assumption of *asymmetric learning* is dropped in Section 6.

As a convenient short hand, denote the ex ante probability of a worker who exerts effort to discover a novel approach as $\Lambda \equiv \lambda\eta$. A worker can choose what approach she intends to implement from the set of available approaches: her *intended* approach is

$$A_i \in \begin{cases} \{R\} & \text{if } \mathcal{I}_i = 0, \\ \{R, N\} & \text{if } \mathcal{I}_i = 1. \end{cases} \tag{4}$$

However, the *realized* contribution to a task may differ from that *intended* by a worker because implementing new ideas requires the team mate's cooperation. The team mates' tasks are interdependent and require some coordination to fit together. Absent collaboration on implementing ideas (*sabotage*), innovations cannot be put to productive use and workers are forced to implement the routine approach. We represent this interaction by a simple simultaneous choice of *intended* approaches A_i (in the action set determined by $\mathcal{I}_i$) and a decision of whether to sabotage or not the team mate, $S_i \in \{0, 1\}$ for $i = 1, 2$.[11] The profile of *realized* approaches $(\hat{A}_1, \hat{A}_2)$ is given by

$$(\hat{A}_1, \hat{A}_2) = \begin{cases} (A_1, A_2) & \text{if } S_1 = S_2 = 0, \\ (R, R) & \text{otherwise.} \end{cases} \tag{5}$$

For simplicity, we assume that players who are indifferent about whether to cooperate or not choose sabotage. Alternatively, we could introduce an arbitrarily small cost of coordination with the team mate.

Success depends on the quality of realized contributions and is most likely if both workers implement a novel approach and the least likely if both implement a routine approach:

$$Pr(\tilde{y} = 1 \,|\, \hat{A}_1, \hat{A}_2) = \begin{cases} p_{NN} & \text{if } \left(\hat{A}_1 = N, \hat{A}_2 = N\right), \\ p_N & \text{if } \left(\hat{A}_1 = N, \hat{A}_2 = R\right) \text{ or } \left(\hat{A}_1 = R, \hat{A}_2 = N\right), \\ p & \text{if } \left(\hat{A}_1 = R, \hat{A}_2 = R\right), \end{cases} \tag{6}$$

where $p_{NN} > p_N > p$.

Labor market for experienced workers in period 2

In period 2, both workers enter a competitive labor market for experienced workers. The value of an experienced 'ordinary' worker's labor services is assumed to be $\underline{k} > 0$ and that of an

[11] For simplicity, we assume here that only the outcome of the own idea generating process is learned. Our qualitative results obtain also under the following alternative modelling choices: 1. Workers can condition their decision to sabotage or not on the set of *both* worker's ideas. 2. Worker i can confine sabotage to player j's intended novel approach.

experienced 'talented' worker $\bar{k} = \underline{k} + \Delta k$, $\Delta k > 0$. Risk neutral firms compete in wage offers à la Bertrand for the services of a worker.[12]

Firms cannot observe workers' types or effort decisions directly. However, they can observe some aspects of the team production process. We compare three information regimes that reflect different degrees of transparency about the production process, $\mathcal{R} \in \{PR, TR, IR\}$:

1. **Performance Record (PR).** This is the regime with the least transparency. The labor market only observes the project's outcome: $\tilde{y} \in \{0, 1\}$.

2. **Team Record (TR).** Under this regime, the labor market can observe both team output and the *quality* of realized approaches without learning which approach a specific team member implemented. That is, firms observe an anonymous profile $\left(\hat{A}, \hat{A}; \tilde{y}\right)$.

3. **Individual Records (IR).** This is the regime with the greatest transparency. The labor market observes team output and *who* realized a specific approach in the production process: $\left(\hat{A}_1, \hat{A}_2; \tilde{y}\right)$.

Contracts

In the beginning of period 1, the workers meet and can agree to form a team and what contract to write to govern this relationship. We assume that bargaining power is symmetric. As is standard in career concerns models, team members are restricted to *spot* contracts that condition transfers among each other only on publicly observable variables and that respect limited liability. That is, the first period outcomes that can be contracted upon depend on the information regime $\mathcal{R} \in \{PR, TR, IR\}$, and transfers cannot condition on outcomes in the second period.

In period 2, firms can condition wages on any information about the first period that is available to them. The contract between the team members and the distributed profit shares are not part of this information set.[13] Due to its competitive nature, the labor market for experienced workers leads to wage offers equal to a worker's expected productivity, conditional on observable variables under the information regime $\mathcal{R}$. Denote this *market* information by

[12] This is a simple way of formalizing the idea that a worker's second period utility is increasing in expected ability. Section 6 provides an alternative interpretation in terms of sorting into different jobs in the second period.

[13] One reason for this modelling choice is that such agreements are typically secret in real life. Another is theoretical: it precludes the possibility of using contract terms as signals about the strategies that workers play. Such a model would not add much in terms of economic insight regarding the issue of transparency that we are interested in.

$m(\mathcal{R}) \in M(\mathcal{R})$, then the equilibrium market wage is equal to the belief about worker i's productivity:

$$b_i\left(m(\mathcal{R})\right) \;=\; \underline{k} + Pr\left(\theta_i = \bar{\theta} \,|\, m(\mathcal{R})\right) \Delta\, k. \tag{7}$$

Because of limited liability, first period contracts between the team members take a particularly simple form: they consist of a sharing rule $\alpha:\ M(\mathcal{R}) \rightarrow [0,1]$, fixing the share of first period profits $\tilde{y}\,\pi$ accruing to worker 1.[14] To conclude the description of the model, we summarize the sequence of events:

Period 1

1. Nature determines $\theta_i \in \{\underline{\theta}, \bar{\theta}\}$ where $Pr(\theta_i = \bar{\theta}) = \lambda$ for $i = 1, 2$.

2. Both workers decide on forming a team and on a contract to govern the team relationship.

3. Each worker observes her own ability θ_i, $i = 1, 2$.

4. Each worker chooses effort $e_i \in \{0, 1\}$, $i = 1, 2$.

5. Nature determines the quality of ideas $\mathcal{I}_i \in \{0, 1\}$, $i = 1, 2$.

6. Each worker chooses an *intended* approach

$$A_i \in \begin{cases} \{R\} & \text{if } \mathcal{I}_i = 0, \\ \{R, N\} & \text{if } \mathcal{I}_i = 1, \end{cases} \quad \text{and makes a sabotage decision } S_i \in \{0, 1\},\ i = 1, 2.$$

7. The profile of *realized* approaches is determined:

$$(\hat{A}_1, \hat{A}_2) = \begin{cases} (A_1, A_2) & \text{if } S_1 = S_2 = 0, \\ (R, R) & \text{otherwise.} \end{cases}$$

8. Nature determines project success $\tilde{y} \in \{0, 1\}$ and contract payoffs are realized.

Period 2

1. Firms observe information $m(\mathcal{R})$ and can make a wage offer to each worker.

2. Workers choose which offer, if any, to accept.

3. Payoffs are realized.

[14] Note that this assumes that there is no free disposal. It appears natural that the team members cannot commit to giving up part of the joint profit. Indeed, then they would always have an incentive to renegotiate the contract ex post to split up the part that was not supposed to be distributed under the original contract. This is similar to the setup in Holmström (1982).

3 Career concerns and accountability

In our benchmark case, there are no direct material benefits from a successful project, i.e., $\pi = 0$. Due to the restriction to spot contracts and because of limited liability this excludes (non-trivial) contingent contracts in period 1, and incentives for effort can only arise from the impact of the first period outcome on the second period wages.[15]

Strategies and solution concept

A strategy for a worker contains a decision of whether to team up with the other player or not, an effort decision $e : \{\underline{\theta}, \bar{\theta}\} \rightarrow \{0, 1\}$, a choice of intended approach to her task[16] $A_i : \{0, 1\} \rightarrow \{R, N\}$, and a decision whether or not to engage in sabotage $S_i : \{\underline{\theta}, \bar{\theta}\} \times \{0, 1\} \rightarrow \{0, 1\}$. The second period labor market is represented through a belief mapping $b : M(\mathcal{R}) \rightarrow [\underline{k}, \bar{k}]$. To analyze team production and effort incentives under the different information regimes, we use the concept of Perfect Bayesian Equilibrium.

Team formation and team equilibria

Prior to learning their types both workers meet and decide on forming a team. Our focus is only on 'team equilibria', where players always join forces. The following lemma provides a sufficient condition for workers' individual rationality constraints to be satisfied at the team formation stage:

Lemma 1

Both workers' individual rationality constraints are satisfied at the team formation stage if

$$\underline{k} + \lambda \, (\Delta \, k - c) \geq 0. \tag{8}$$

Proof.

At the team formation stage information is symmetric. Equilibrium beliefs are a martingale and second period wages are equal to expected talent conditional on market information $m(\mathcal{R})$. Thus, given that there are no direct material benefits from team output, a team member's expected second period wage is equal to $\underline{k} + \lambda \, \Delta \, k$. Effort costs are at most c and can only incur if a worker is talented, which happens with probability λ. Combined with the value zero of the outside option of not belonging to a team, the result obtains. ■

[15]This corresponds to a *pure* career concerns setting (e.g., Holmström (1999) and Dewatripont, Jewitt, and Tirole (1999)).

[16]Without loss of generality, the dependence on the type θ is dropped because the action set depends only on the set of available ideas $\mathcal{I}_i$.

In the following, we assume that the parameters satisfy condition (8) so that team formation is always part of an equilibrium. We further confine our analysis to the most interesting case of 'high effort equilibria', in which talented agents always exert effort. Since no worker would engage in futile effort or sabotage herself, in any candidate equilibrium where effort is exerted ($e_i(\bar{\theta}) = 1$) novel approaches are always implemented ($A_i(\mathcal{I}_i = 1) = N$) and a successful innovator does not engage in sabotage ($S_i(\cdot, 1) = 0$).

3.1 Performance Record

Under the *Performance Record* (PR) regime, firms in the second period labor market only learn whether the team's project in period 1 was successful or not: $m(PR) = \tilde{y} \in \{0, 1\}$. Since $\tilde{y}$ does not contain any information about what approaches a particular worker implemented, the market's beliefs about both workers' abilities are identical. Consider now the candidate equilibrium in which agents always exert effort and workers never engage in sabotage, with the corresponding market beliefs. Straightforward but tedious calculations show that second period wages following success are

$$b(1) \quad = \quad Pr(\bar{\theta}, \bar{\theta}\,|\,1)\,\bar{k} + Pr(\underline{\theta}, \underline{\theta}\,|\,1)\,\underline{k} + Pr(\underline{\theta}, \bar{\theta}\,|\,1)\,\frac{\underline{k} + \bar{k}}{2} = \underline{k} + \frac{NUM}{Pr(1)}\,\Delta\,k, \tag{9}$$

where

$$NUM \equiv \Lambda\,\left[\Lambda\,p_{NN} + (1 - \Lambda)\,p_N\right] + \lambda\,\left[\Lambda\,p_N + (1 - \Lambda)\,p\right], \tag{10}$$

and the unconditional success probability is given by

$$Pr(1) \quad = \quad \Lambda^2\,p_{NN} + 2\,\Lambda(1 - \Lambda)\,p_N + (1 - \Lambda)^2\,p. \tag{11}$$

Similarly, second period wages following failure are

$$b(0) = \underline{k} + \frac{\lambda - NUM}{1 - Pr(1)}\,\Delta\,k. \tag{12}$$

Given the other team mate's equilibrium strategy and the market beliefs, it never pays off for a worker to deviate from the candidate equilibrium strategy and engage in sabotage. The second period wage is larger following success than following failure: $b(1) > b(0)$. Hence, engaging in sabotage, a worker i would strictly reduce the success probability:[17] team mate j discovers a novel idea with probability Λ, and thus sabotage would reduce the success probability from $\Lambda\,p_{NN} + (1 - \Lambda)\,p_N$ to p (if $\mathcal{I} = 1$ and worker i could implement a novel approach) or from $\Lambda\,p_N + (1 - \Lambda)\,p$ to p (if $\mathcal{I} = 0$ and worker i implements a routine approach).

[17] This is also true if the market beliefs are that sabotage occurs whenever a worker fails to generate novel ideas, preventing the existence of a high-effort sabotage equilibrium.

What remains to be determined are the conditions under which both workers indeed exert effort if they are talented. The incentive constraint for a talented worker i is given by

$$\begin{aligned} -c + \{\eta\, [\Lambda\, p_{NN} + (1-\Lambda)\, p_N] + (1-\eta)\, [\Lambda\, p_N + (1-\Lambda)\, p]\, \}\; b(1) \\ + \{\eta\, [\Lambda\, (1-p_{NN}) + (1-\Lambda)\, (1-p_N)] + (1-\eta)\, [\Lambda\, (1-p_N) + (1-\Lambda)\, (1-p)]\, \}\; b(0) \\ \geq \quad \{\Lambda\, p_N + (1-\Lambda)\, p\}\; b(1) + \{\Lambda\, (1-p_N) + (1-\Lambda)\, (1-p)\}\; b(0) \\ \Leftrightarrow \qquad c_0^{PR} \equiv \frac{\eta\, \Lambda\, (1-\lambda)\, [\Lambda\, (p_{NN}-p_N) + (1-\Lambda)\, (p_N-p)]^2}{Pr(1)\, (1-Pr(1))}\, \Delta\, k \geq c. \end{aligned} \tag{13}$$

This leads to the following result.

Lemma 2

Under information regime PR, all high-effort equilibria involve no sabotage. Such a high-effort equilibrium $e_1(\bar{\theta}) = e_2(\bar{\theta}) = 1$; $S_1(\cdot,\cdot) = S_2(\cdot,\cdot) = 0$ exists whenever

$$\begin{aligned} c \leq c_0^{PR} \quad &\equiv \quad \frac{\eta\, \Lambda\, (1-\lambda)\; [\Lambda\, (p_{NN}-p_N) + (1-\Lambda)\, (p_N-p)]^2}{Pr(1)\; (1-Pr(1))}\, \Delta\, k, \\ Pr(1) \quad &= \quad \Lambda^2\, p_{NN} + 2\, \Lambda(1-\Lambda)\, p_N + (1-\Lambda)^2\, p. \end{aligned}$$

3.2 Team Record

Under the *Team Record* (TR) regime, firms in the second period labor market observe the team's performance $\tilde{y} \in \{0,1\}$ and what types of approaches were used in the production process. However, outsiders cannot distinguish which team member made a specific contribution. The additional information comes in the form of an anonymous profile of realized approaches $(\hat{A}, \hat{A}) \in \{N, R\}^2$, where anonymity is expressed by the lack of indices. Ability and effort affect success or failure of the project only by determining the approaches available to the team. Therefore, on the equilibrium path, the profile of realized approaches $(\hat{A}, \hat{A})$ is a sufficient statistic for $m(TR) = (\hat{A}, \hat{A}; \tilde{y})$ with respect to workers' abilities.

Again, we consider candidate equilibria in which talented agents exert effort and there is no sabotage. Upon observing team production and outcomes, firms pay the following second period wages

$$b(\hat{N}, \hat{N}; \cdot) \quad = \quad \bar{k} \tag{14}$$

$$b(\hat{R}, \hat{N}; \cdot) \quad = \quad \underline{k} + \left[Pr(\bar{\theta}, \bar{\theta} \,|\, \hat{R}, \hat{N}) + \frac{Pr(\underline{\theta}, \bar{\theta} \,|\, \hat{R}, \hat{N})}{2} \right] \Delta\, k = \underline{k} + \frac{1}{2} \left[1 + \frac{\lambda - \Lambda}{1-\Lambda} \right] \Delta\, k, \tag{15}$$

$$b(\hat{R}, \hat{R}; \cdot) \quad = \quad \underline{k} + \left[Pr(\bar{\theta}, \bar{\theta} \,|\, \hat{R}, \hat{R}) + \frac{Pr(\underline{\theta}, \bar{\theta} \,|\, \hat{R}, \hat{R})}{2} \right] \Delta\, k = \underline{k} + \frac{\lambda - \Lambda}{1-\Lambda}\, \Delta\, k. \tag{16}$$

As under the PR-regime, given the other players' equilibrium strategies and beliefs, it never pays off for a worker to deviate from the candidate equilibrium strategy and to engage in sabotage. After all, the second period wage is identical for both workers and increases whenever any of the workers realizes a novel approach instead of a routine one.

The incentive constraint for a talented worker i is given by

$$-c + \eta \left[\Lambda\, b(\hat{N}, \hat{N}; \cdot) + (1-\Lambda)\, b(\hat{R}, \hat{N}; \cdot)\right] + (1-\eta) \left[\Lambda\, b(\hat{R}, \hat{N}; \cdot) + (1-\Lambda)\, b(\hat{R}, \hat{R}; \cdot)\right]$$
$$\geq \quad \Lambda\, b(\hat{R}, \hat{N}; \cdot) + (1-\Lambda)\, b(\hat{R}, \hat{R}; \cdot)$$
$$\Leftrightarrow \quad c_0^{TR} \equiv \tfrac{\eta\,(1-\lambda)}{2\,(1-\Lambda)}\, \Delta\, k \geq c. \tag{17}$$

Again, it can be shown that high-effort sabotage equilibria cannot exist (see appendix), leading to the following result.

Lemma 3

Under information regime TR, all high-effort equilibria involve no sabotage. Such a high-effort equilibrium $e_1(\bar{\theta}) = e_2(\bar{\theta}) = 1$; $S_1(\cdot,\cdot) = S_2(\cdot,\cdot) = 0$ exists whenever

$$c \leq c_0^{TR} \equiv \frac{\eta\,(1-\lambda)}{2\,(1-\Lambda)}\, \Delta\, k.$$

3.3 Individual Records

Under the *Individual Records* (IR) regime, firms in the second period labor market observe the realization of $\tilde{y}$ and the different realized approaches are fully attributable to individual team members: $(\hat{A}_1, \hat{A}_2) \in \{R, N\}^2$. The transparency on individual contributions allows firms to form separate judgements of each individual worker. However, the lack of symmetry in beliefs (and consequently in payoffs) across team mates has a serious downside: cooperation cannot be part of an equilibrium. Suppose that the market forms beliefs under the presumption that sabotage never occurs. Then, a worker i who fails to come up with an innovative idea is indifferent between cooperation or sabotage since $b_i(\hat{R}_i, \hat{N}_j; \cdot) = b_i(\hat{R}_i, \hat{R}_j; \cdot)$. Therefore, given our tie-breaking assumption/the cost of coordination, in equilibrium a player i will always choose to sabotage the team mate if she herself lacks the capability to implement a novel approach.[18]

Taking this into consideration leads to the following equilibrium beliefs. On the equilibrium path only homogeneous profiles of realized approaches are observed: $(\hat{N}_1, \hat{N}_2)$ or $(\hat{R}_1, \hat{R}_2)$. If a realized novel approach is observed for a worker i, this reveals her talent (given the candidate equilibrium strategies, this occurs if and only if $\mathcal{I}_i = \mathcal{I}_j = 1$):

$$b_i(\hat{N}_i, \cdot; \cdot) = \bar{k}, \quad i = 1, 2. \tag{18}$$

[18] Our result obtains without this indifference assumption whenever there are exogenous sources of conflict or contributions are only observable in case of success $\tilde{y} = 1$ (see Section 8).

If both workers fail to implement a novel approach, given the candidate equilibrium strategies, each worker might be of average ability (I), talented and unlucky in the search for innovative ideas (II), or talented and stopped from realizing a novel approach by sabotage (III):

$$Pr(\hat{R}_i) = 1 - Pr(\mathcal{I}_i = \mathcal{I}_j = 1) = \underbrace{1-\lambda}_{(I)} + \underbrace{\lambda\,(1-\eta)}_{(II)} + \underbrace{\Lambda\,(1-\Lambda)}_{(III)} = 1 - \Lambda^2. \tag{19}$$

This leads to the second period wage

$$b_i(\hat{R}_i, \hat{R}_j; \cdot) = \underline{k} + \frac{\lambda - \Lambda^2}{1-\Lambda^2}\,\Delta\, k. \tag{20}$$

A deviation by worker i to a cooperative strategy with $S_i(\cdot,\cdot) = 0$ would lead to the off the equilibrium path profile of realized approaches $(\hat{R}_i, \hat{N}_j)$ with some probability. Upon observing realized approaches $(\hat{R}_i, \hat{N}_j)$, it is clear that worker j is talented and exerted effort. The worst belief about worker i that is consistent with the technology is constructed as follows: the worker is assumed to have provided effort if she was talented and not to have been stopped from implementing a potentially discovered novel approach by sabotage. Then, not observing a novel approach for worker i is a bad signal and her expected ability is

$$b_i^{min}(\hat{R}_i, \hat{N}_j; \cdot) = \underline{k} + \frac{\lambda - \Lambda}{1-\Lambda}\,\Delta\, k. \tag{21}$$

The best possible belief arises if the market assumes that she exerted no effort:

$$b_i^{max}(\hat{R}_i, \hat{N}_j; \cdot) = \underline{k} + \lambda\,\Delta\, k. \tag{22}$$

Hence, consistent beliefs lead to second period wages

$$b_i(\hat{R}_i, \hat{N}_j; \cdot) \in \left[b_i^{min}(\hat{R}_i, \hat{N}_j; \cdot), b_i^{max}(\hat{R}_i, \hat{N}_j; \cdot)\right]. \tag{23}$$

Since $b_i^{max}(\hat{R}_i, \hat{N}_j; \cdot) > b_i(\hat{R}_i, \hat{R}_j; \cdot)$, the equilibrium exists if and only if off the equilibrium path beliefs satisfy the following condition[19]

$$b_i(\hat{R}_i, \hat{N}_j; \cdot) \in \left[b_i^{min}(\hat{R}_i, \hat{N}_j; \cdot), b_i(\hat{R}_i, \hat{R}_j; \cdot)\right]. \tag{24}$$

Given equilibrium beliefs that satisfy condition (24), the effort incentive constraint for a talented worker i is given by

$$\eta\Lambda\, b_i(\hat{N}_i, \cdot; \cdot) + (1-\eta\Lambda)\, b_i(\hat{R}_i, \hat{R}_j; \cdot) - c \geq b_i(\hat{R}_i, \hat{R}_j; \cdot),$$

$$\Leftrightarrow \quad c_0^{IR} \equiv \tfrac{\eta\Lambda - \Lambda^2}{1-\Lambda^2}\,\Delta\, k \geq c. \tag{25}$$

This leads to the following result.

[19]Note, an arbitrarily small error probability in the sabotage decision suffices to put $b_i(\hat{R}_i, \hat{N}_j; \cdot) = b_i^{min}(\hat{R}_i, \hat{N}_j; \cdot)$ on the equilibrium path.

Lemma 4

Under information regime IR, all high-effort equilibria involve sabotage. Such a high-effort equilibrium $e_1(\bar{\theta}) = e_2(\bar{\theta}) = 1$; $S_i(\cdot, 0) = 1$, $S_i(\cdot, 1) = 0$, $i = 1, 2$ exists if and only if beliefs satisfy condition (24) and

$$c \leq c_0^{IR} \equiv \frac{\eta\Lambda - \Lambda^2}{1 - \Lambda^2}\,\Delta\, k.$$

3.4 Comparison of information regimes

A comparison of the thresholds from Lemmas 2- 4 (see appendix) yields the following result:

Proposition 1

The range of parameter values for which a high-effort equilibrium exists is non-monotonic in the degree of transparency:

$$c_0^{TR} > c_0^{PR} \quad \textit{and} \quad c_0^{TR} > c_0^{IR}.$$

High-effort equilibria under information regimes PR and TR are always cooperative. All high-effort equilibria under the IR-regime involve sabotage.

Moving from the PR-regime to the more transparent TR-regime increases the range of effort cost values for which a high-effort equilibrium exists. Moreover, in these equilibria sabotage does not occur and all innovations in the team are actually realized. Effort incentives under the TR-regime improve because the visibility of the team's realized approaches makes more finely tuned market beliefs possible. By exerting effort and implementing innovative ideas, talented players can increase the market's belief about the team members' average ability. Because the market only has access to anonymous information a cooperative *team spirit* is preserved: both team mates benefit from innovations and refrain from sabotage.

In spite of the additional incentives, the TR-regime still suffers from free riding among the team mates: because performance information is anonymous, the reputational benefits from exerting effort to discover a novel approach are shared across the team and do not fully accrue to the innovator.

The PR- and TR-regimes suffer from free riding: the reputational benefits from exerting effort to discover a novel approach are shared across the team and do not fully accrue to the innovator. Thus, the individual accountability under the IR-regime could potentially boost incentives so that high-effort equilibria arise for an even greater range of cost parameters: each worker could then reap all the reputational benefits from realizing a novel approach instead of only getting a reputation premium that is lower because of the 'averaging' over the team members' reputations under the PR- and TR-regimes. However, as a consequence of the individual accountability induced by the IR-regime, players no longer care about their team mate's achievements. This undermines cooperation and leads to behavior that looks like *jealousy* since team members engage in sabotage if they themselves fail to produce an innovation.

The possibility of sabotage provides a player with the means to jam the signal on her ability that her failure to realize an innovative approach sends to the market. To see how this smokescreen works, suppose that sabotage was not possible. In this case, it reflects badly on a worker if she is only able to realize a routine approach. The market's judgement is that she is either talented and failed to discover new ideas (I) or untalented (II):

$$b_i^{NS}(\hat{R}_i, \cdot; \cdot) = \underline{k} + \frac{\overbrace{\lambda - \Lambda}^{(I)}}{\underbrace{1 - \Lambda}_{(I)+(II)}} \Delta k. \tag{26}$$

The opportunity to engage in sabotage, changes this picture: a worker i who fails to realize a novel approach is thought to be either talented and to have failed to discover new ideas (I), to be untalented (II), or to be talented and to have been stopped from realizing a novel approach by sabotage (III):

$$b_i(\hat{R}_i, \hat{R}_j; \cdot) \quad = \quad \underline{k} + \frac{\overbrace{\lambda - \Lambda^2}^{(I)+(II)}}{\underbrace{1 - \Lambda^2}_{(I)+(II)+(III)}} \Delta k. \tag{27}$$

Since $b_i(\hat{R}_i, \hat{R}_j; \cdot) > b_i^{NS}(\hat{R}_i, \cdot; \cdot)$, sabotage provides a way of jamming the performance signal that the market receives – effectively hiding behind a smokescreen of common failure – so that individual failure to innovate does not look as bad as it would if team mates always cooperated. Due to these sabotage activities, the additional transparency under the IR-regime actually reduces overall incentives compared to the TR-regime.

The comparison between information regimes PR and IR is less clear cut. If a high-effort equilibrium exists under both regimes, then innovations are always realized under PR while some innovations fall prey to sabotage under IR. However, the threshold value c_0^{PR} may be either larger or smaller than c_0^{IR}, depending on the values of p, p_N, and p_{NN}, i.e., on how informative $\tilde{y} = y$ is about the use of innovative approaches. For example, consider the case in which $\tilde{y} = y$ is an extremely powerful signal for innovative ideas: $p_{NN}, p_N \to 1$ and $p \to 0$. Then, $c_0^{PR} - c_0^{IR}$ converges to the following expression:

$$\frac{\eta\,(1-\lambda)}{2\,(1-\Lambda)} - \frac{\eta\,\Lambda\,(1-\lambda)}{1-\Lambda\eta} = \frac{\eta\,(1-\lambda)}{2\,(1+\Lambda)}\Delta\,k > 0. \tag{28}$$

In this case $c_0^{TR} > c_0^{PR} > c_0^{IR}$.

4 The case of material benefits

In this section, we introduce direct monetary gains from successful project outcomes ($\pi > 0$), the distribution of which team members can regulate in a contract. Such a contingent sharing rule can be used to influence (i) the division of surplus ex ante;[20] (ii) effort incentives at the idea generating stage; and (iii) cooperation/sabotage at the production stage.

4.1 Performance Record

If talented workers exert effort and there is no sabotage, firms' beliefs are as in Section 3.1. Sabotage cannot be part of a such an equilibrium since the market has identical beliefs about both workers' abilities. Both current period profits and second period wages following success are strictly larger than those following failure. Thus, direct material benefits and contracts only influence the conditions under which a high-effort equilibrium exists. Given the symmetry in beliefs, a contract with equal profit shares, $\alpha(\cdot) = 1/2$, maximizes both workers' effort incentives and thus the range of equilibria. The only difference to the incentive constraint in Section 3.1 is that in case of a successful project outcome each team member earns $\pi/2$ in addition to the second period wage equal to $b(1)$. Since there are direct material benefits from team production, a forteriori condition (8) guarantees that players form a team. The remaining step is to show that at the team formation/contracting stage (before learning their own type) team members, given the above market beliefs, prefer to write a contract that satisfies both workers' incentive constraints instead of setting other contract terms (see appendix). This leads to the following result:

Lemma 5

With material benefit π, under information regime PR, all high-effort equilibria involve no sabotage. Such a high-effort equilibrium $e_1(\bar{\theta}) = e_2(\bar{\theta}) = 1$; $S_1(\cdot,\cdot) = S_2(\cdot,\cdot) = 0$ exists if and only if

$$c \leq c_+^{PR} \equiv \eta \left[\Lambda \left(p_{NN} - p_N\right) + \left(1 - \Lambda\right)\left(p_N - p\right)\right] \pi/2 + c_0^{PR}.$$

Not surprisingly, reputational incentives are not affected by direct payoffs from a successful project. The material incentives simply add on to reputational incentives.

[20] Our assumption of symmetric bargaining power implies that the contract has to maximize ex ante expected team surplus.

4.2 Team Record

As under the PR-regime, material benefits and contracts only influence the conditions under which a high-effort equilibrium exists.

Lemma 6

With material benefit π, under information regime PR, all high-effort equilibria involve no sabotage. Such a high-effort equilibrium $e_1(\bar{\theta}) = e_2(\bar{\theta}) = 1$; $S_1(\cdot,\cdot) = S_2(\cdot,\cdot) = 0$ exists if and only if

$$c \leq c_+^{TR} \equiv \eta\, \left[\Lambda\,(p_{NN} - p_N) + (1-\Lambda)\,(p_N - p)\right]\, \pi/2 + c_0^{TR}.$$

4.3 Individual Records

Direct material benefits and contracts have the biggest impact on the conditions under which high-effort equilibria exist under the IR-regime: as a consequence of these benefits high-effort equilibria with and without sabotage can arise.

High-effort equilibria with sabotage

Candidate equilibrium.

Suppose that the market believes that talented agents exert effort and workers without an innovation engage in sabotage. Then, as in Section 3.3 $b_i(\hat{N}_i, \cdot; \cdot) = \bar{k}$, $i = 1, 2$ and $b_i(\hat{R}_i, \hat{R}_j; \cdot) = \underline{k} + \frac{\lambda - \Lambda^2}{1-\Lambda^2}\, \Delta\, k$.

Before checking that team mates have no incentive to deviate from $S(\cdot, 0) = 1$ to $S(\cdot, 0) = 0$, we write down the incentive constraint for worker 1 given the candidate equilibrium strategies,

$$\eta\, \Lambda\, \left[\alpha(\hat{N}_1, \hat{N}_2; 1)\, p_{NN} - \alpha(\hat{R}_1, \hat{R}_2; 1)\, p\right]\, \pi + c_0^{IR} \geq c. \qquad (29)$$

Similarly, the incentive constraint for worker 2 is

$$\eta\, \Lambda\, \left[(1 - \alpha(\hat{N}_1, \hat{N}_2; 1))\, p_{NN} - (1 - \alpha(\hat{R}_1, \hat{R}_2; 1))\, p\right]\, \pi + c_0^{IR} \geq c. \qquad (30)$$

Thus, a necessary condition for the existence of a sabotage equilibrium is that contract terms $\alpha(\hat{N}_1, \hat{N}_2; 1)$ and $\alpha(\hat{R}_1, \hat{R}_2; 1)$ as well as cost parameter c satisfy inequalities (29) and (30). It remains to be shown under which conditions team mates do not deviate to cooperation.

Conditions for no profitable deviation to cooperation.

A deviation by worker i, who failed to innovate, to cooperation now impacts both her expected second period wage and her expected share of team profits under the team's contract. Given the other player's equilibrium strategy, cooperation moves her expected second period wage from $b_i(\hat{R}_i, \hat{R}_j; \cdot)$ to $\Lambda\, b_i(\hat{R}_i, \hat{N}_j; \cdot) + (1 - \Lambda)\, b_i(\hat{R}_i, \hat{R}_j; \cdot)$. Thus, the maximum expected loss in terms of reputation from such a deviation is

$$\Lambda \left[b(\hat{R}_i, \hat{R}_j; \cdot) - b_i^{min}(\hat{R}_i, \hat{N}_j; \cdot) \right] = \frac{\Lambda^2 (1 - \lambda)}{1 - \Lambda^2} \Delta k, \tag{31}$$

where $b_i^{min}(\hat{R}_i, \hat{N}_j; \cdot)$ is the worst consistent belief about worker i (see equation (21)). Contracts can be designed to help induce cooperation at the interim stage by allocating a larger share of the material benefit to a team member who is the only one to have failed to innovate. Without loss of generality, deviation to cooperation for a player who did not innovate can be induced at the interim stage 2 if there exists an $\alpha(\hat{R}_1, \hat{N}_2; 1) \in (0, 1)$ such that for team member 1 the expected gain in direct project profits outweighs the expected reputation loss:[21]

$$\begin{aligned} &\Lambda \left[\alpha(\hat{R}_1, \hat{N}_2; 1)\, p_N - \alpha(\hat{R}_1, \hat{R}_2; 1)\, p \right] \pi > \tfrac{\Lambda^2 (1-\lambda)}{1-\Lambda^2} \Delta k, \\ \Leftrightarrow \quad &\alpha(\hat{R}_1, \hat{N}_2; 1) > \alpha^{IR} + \alpha(\hat{R}_1, \hat{R}_2; 1)\, \tfrac{p}{p_N}, \end{aligned} \tag{32}$$

where

$$\alpha^{IR} \equiv \frac{\Lambda (1 - \lambda)}{1 - \Lambda^2} \frac{\Delta k}{p_N \pi}. \tag{33}$$

However, since transfers among team members must balance ex post, sabotage cannot be prevented by reallocating profit shares if $\alpha^{IR} \geq 1$, which is equivalent to $\pi \leq \frac{\Lambda (1-\lambda)}{(1-\Lambda^2)\, p_N} \Delta k$. Then the possible reputation loss exceeds the benefits from project success. This already provides a sufficient condition for the existence of a sabotage equilibrium. Even if $\alpha^{IR} < 1$, a contract that induces cooperation may still not be profitable at the contracting stage. The team must also worry that setting contract terms to satisfy inequality (32) may induce an agent with a novel idea to refrain from implementing it or even engage in sabotage. For example, if $\alpha(\hat{R}_1, \hat{N}_2; 1)$ is large then worker 2 might find it profitable to reduce the success probability by not innovating and thus guaranteeing herself a better share of profits of $1 - \alpha(\hat{N}_1, \hat{R}_2; 1)$ or $1 - \alpha(\hat{R}_1, \hat{R}_2; 1)$. Should worker 2 anticipate that she will not implement an innovation at the interim stage, she has clearly no incentives to engage in effort herself. Therefore, even if a contract induces cooperation at the interim stage, it may not satisfy both workers' incentive constraints for effort at the previous stage.

As before, the maximum value of the cost parameter c for which a sabotage equilibrium may exist can be found by setting $\alpha(\hat{N}_1, \hat{N}_2; 1) = \alpha(\hat{R}_1, \hat{R}_2; 1) = 1/2$. The final step of verifying that a contract inducing high-effort will indeed be chosen is relegated to the appendix, and we directly state the following result:

[21] The case for player 2 is symmetric, setting $\alpha(\hat{N}_1, \hat{R}_2; 1) = 1 - \alpha(\hat{R}_1, \hat{N}_2; 1)$.

Lemma 7

Under the IR-regime,

$$c \leq c^{IR}_{(+,S)} \equiv \eta\,\Lambda\,(p_{NN} - p)\,\pi/2 + c^{IR}_0,$$

is a necessary condition and

$$\alpha^{IR} \equiv \frac{\Lambda\,(1-\lambda)}{1-\Lambda^2}\,\frac{\Delta\,k}{p_N\,\pi} \geq 1.$$

is a sufficient condition for high-effort equilibria with sabotage to exist.

Cooperative high-effort equilibria

Now suppose that the market believes that talented workers innovate and there is no sabotage. Hence, each worker who produces new ideas can realize her novel approach. Since both team mates' idea generating processes are independent, a worker's second period wage only depends on her own realized approach. Thus, following an innovation a worker reveals her talent and $b_i(\hat{N}_i, \cdot; \cdot) = \bar{k}$, $i = 1, 2$. If a worker fails to implement a novel approach she might be of average ability or talented and unlucky in the search for innovative ideas, leading to second period wage:

$$b_i(\hat{R}_i, \cdot; \cdot) \quad = \quad \underline{k} + \frac{\lambda - \Lambda}{1 - \Lambda}\,\Delta\,k. \tag{34}$$

As in Section 3.3, a worker who is capable of implementing a novel approach would reduce her second period wage by deviating from the equilibrium strategy to sabotage. Any deviation to sabotage by a worker who failed to innovate would strictly lower the success probability of the project. In contrast to Section 3.3, the project outcome now matters because of the material benefit π that the team mates share. Thus, a contract $\alpha(\cdot, \cdot; \cdot) = 1/2$ ensures that a worker i strictly prefers to cooperate regardless of her innovation success and that workers' effort incentives are maximized. In the proof of the following result we show that, given the above beliefs, such a contract indeed will be chosen at the contracting stage.

Lemma 8

Under information regime IR, cooperative high-effort equilibria exist if and only if

$$c \leq c^{IR}_{(+,C)} \equiv \eta\,\left[\Lambda\,(p_{NN} - p_N) + (1-\Lambda)\,(p_N - p)\right]\,\frac{\pi}{2} + 2\,c^{TR}_0. \tag{35}$$

In Section 3, we showed that absent direct material payoffs from production individual records always induce sabotage. With such material payoffs sabotage becomes more costly for a worker because she forfeits potential material gains by lowering the chances of a successful project outcome. Moreover, the possibility to write a contract that allocates these gains depending on the individual contributions to the project helps avoid sabotage. Nevertheless, if potential reputational gains from signal jamming are sufficiently large, high-effort equilibria with sabotage can still arise. Additionally, there now exist cooperative high-effort equilibria, in which innovations are always implemented.

4.4 Comparison of information regimes

The above results and the comparisons in Proposition 1 lead to the following result:

Proposition 2
With material benefits $\pi > 0$, the range of parameter values for which a high-effort equilibrium exists is monotonic in the degree of transparency. Nevertheless, increasing transparency from the TR- to the IR-regime can induce a less productive high-effort equilibrium with sabotage:

$$c_+^{TR} > c_+^{PR} \quad \textit{and} \quad c_{(+,C)}^{IR} > c_+^{TR} > c_{(+,S)}^{IR}.$$

With material benefits, the range of parameter values for which cooperative high-effort equilibria exist increases with the degree of transparency. An increase in transparency by moving from the PR- to the TR-regime unambiguously enhances incentives. However, switching from the TR to the IR-regime can either enhance or decrease incentives, depending on which equilibrium realizes under the IR-regime. On the one hand, individual records permit workers to receive rewards for their individual contributions and thus potentially alleviate the free riding problem. On the other hand, individual accountability can also induce sabotage. As in Section 3, this signal jamming leads to a better reputation for a worker who fails to innovate if she is part of a team which has a profile of routine approaches than if the team mate realizes an innovative approach. Since under the IR-regime high-effort equilibria with cooperation or sabotage may arise, greater transparency is not always better for incentives even with material benefits. In fact, as Section 8.1 demonstrates, under the IR-regime, cooperative high-effort equilibria are less stable than sabotage equilibria.

5 Welfare implications

The preceding discussion focused on the strength of incentives under the different information regimes. To derive the implications for welfare, we first determine the efficient effort levels for a given cost parameter c (see appendix):

Lemma 9

Regardless of the information regime, it is efficient that

- *all workers exert effort if talented if and only if* $c \leq \min\left[c_{00}^{11}, c_{10}^{11}\right]$ *, where*

$$c_{00}^{11} \equiv \eta\left[\Lambda\left(p_{NN}-p_{N}\right)+(2-\Lambda)(p_{N}-p)\right]\pi/2,$$
$$c_{10}^{11} \equiv \eta\left[\Lambda\left(p_{NN}-p_{N}\right)+(1-\Lambda)(p_{N}-p)\right]\pi;$$

- *only one worker exerts effort if talented if and only if* $c_{10}^{11} < c \leq c_{00}^{10}$*, where*

$$c_{00}^{10} \equiv \eta\left(p_{N}-p\right)\pi;$$

- *no effort effort is exerted otherwise.*

Consider first the efficiency of effort decisions for a given degree of transparency. Under any information regime, effort incentives may be inefficiently low if reputational incentives are sufficiently low. As shown in the previous section, effort incentives are maximal under the IR-regime with cooperation. Nevertheless, high-effort equilibria may not exist even though high-effort is efficient, e.g. if $c_{(+,C)}^{IR} < c \leq \min\left[c_{00}^{11}, c_{10}^{11}\right]$.[22] Thus, if workers are mainly motivated by the material benefit π derived from the team output, free riding among team member can kill off incentives. This corresponds to the logic underlying the classical model of Holmström (1982), which studies the limiting case $\Delta k = 0$. In contrast, if career concerns are sufficiently strong, effort incentives can be inefficiently large. This is seen most easily for the case when there are no material benefits ($\pi = 0$). Here, any effort is wasteful but for some range of values of the cost parameter c, high-effort equilibria exist under any information regime.

What are the implications of more transparency for efficiency? The preceding discussion showed that, because of career concerns, increasing effort incentives is not always efficient, and therefore welfare does not necessarily increase with more transparency. Consider again the case $\pi = 0$ in which any effort is wasteful and parameter values for which $\max\left[c_0^{PR}, c_0^{IR}\right] < c \leq c_0^{TR}$. Then, moving to the TR-regime, for which a high-effort equilibrium without sabotage exists, increases effort incentives but clearly decreases welfare. In this example, welfare is non-monotonic in the degree of transparency, decreasing when moving from the least transparent information regime, PR, to the more transparent TR-regime, and increasing again when moving to the most transparent information regime, IR. However, incentives and welfare can also be aligned

[22]This situation may arise since $c_{(+,C)}^{IR} = 2\,c_0^{TR} + c_{00}^{11} - \eta(p_N - p)\,\pi/2 = 2\,c_0^{TR} + c_{10}^{11}/2$ and $c_0^{TR} \to 0$ as $\Delta k \to 0$.

as the following example for the situation with $\pi > 0$ shows. High effort is efficient whenever $c \leq \min\left[c_{00}^{11}, c_{10}^{11}\right]$. This condition implies that

$$\min\left\{(p_N - p), (\Lambda\,(p_{NN} - p_N) + (1-\Lambda)\,(p_N - p))\right\} \frac{1-\lambda}{1-\Lambda} \geq \frac{\Delta\,k}{\pi}, \tag{36}$$

and, therefore, is more likely to be satisfied when the heterogeneity of experienced workers' productivities, $\Delta\,k$, is low. Now, if high effort is efficient and $c_{+}^{PR} < c_{+}^{TR} < c \leq c_{(+,C)}^{IR}$ then both effort incentives and welfare increase with the added transparency of the IR-regime if cooperation ensues. The following result summarizes the above discussion.

Proposition 3

For a given information regime, effort incentives are inefficiently low (high) if $\Delta\,k$ is relatively small (large). Moreover, welfare can either increase or decrease with transparency and does not necessarily move in the same direction as effort incentives.

One should be careful to point out that the above analysis neglects potential other sources of welfare gains. First, it may be that the material benefit of the project outcome for the team members, π, is less than the social value of the project outcome. One example is that the project is a public good that creates additional social welfare W in case of success. Thus, $W+\pi$ matters for the efficiency of effort, while effort incentives are influenced by π only. A second possibility is that the development of new ideas per se improves the efficiency of production for other teams through technological spill-overs. A third reason could be that innovations provide signals that improve sorting in the second period. The next section explores this last possibility.

6 Reputation based job assignments

This section illustrates the additional welfare implications that may arise from reputation based job assignments in the labor market. It also demonstrates that our main insights do not rely on the assumption of asymmetric learning about ability. To this end we drop the assumption that a worker learns her ability parameter θ. This corresponds to the classical Holmström (1999) context, in which information about talent is symmetric (*symmetric learning*).[23]

For simplicity, consider a situation in which $\pi = 0$ (i.e., effort is purely wasteful) but in which there are gains from improved sorting of experienced workers. We introduce these gains by

[23] What would happen if we made this assumption in the base model with $\pi = 0$? There, second period wages are linear in expected talent. If workers take the effort decision without knowing their type, the martingale property of Bayesian beliefs implies that the reputational payoffs offset each other and there are no effort incentives at all (cf. also Lemma 1).

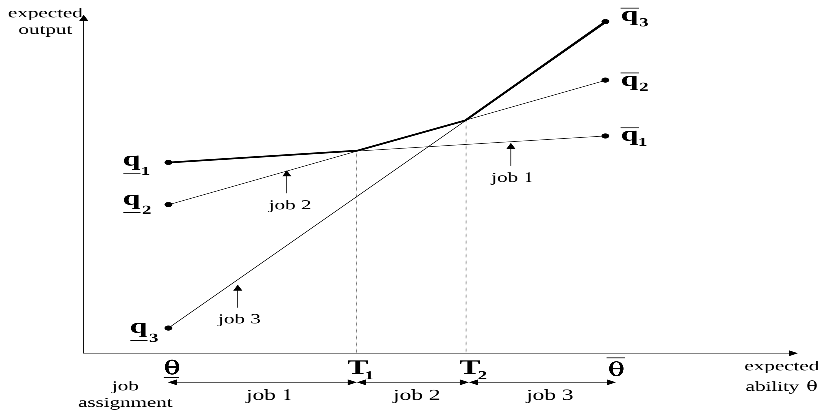

Figure 1: Jobs for experienced workers

allowing for various types of jobs for experienced workers with different sensitivities to human capital. Specifically, in period 2, firms can place a worker in one of three different types of jobs $J = 1, 2, 3$. Assigned to job J, a worker of normal ability $\underline{\theta}$ produces $\underline{q}_J$ and a worker of high ability $\bar{\theta}$ produces $\bar{q}_J \equiv \underline{q}_J + \Delta\, q_J$ (where $\Delta\, q_J > 0$). Figure 1 graphs expected productivity as a function of expected ability. A worker who is expected to be of low ability ($E[\theta|m(\mathcal{R})] < T_1]$) should be assigned to job 1, a worker of intermediate ability ($T_1 \leq E[\theta|m(\mathcal{R})] < T_2]$) to job 2, and a worker of high ability ($E[\theta|m(\mathcal{R})] \geq T_2]$) to job 3.[24]

We will focus on the parameter constellations where $T_1 > \underline{\theta} + \lambda\,\Delta\,\theta$ and $T_2 > \underline{\theta} + \frac{1}{2}\left(1 + \frac{\lambda - \Lambda}{1 - \Lambda}\right)\Delta\,\theta$. Then, it is straightforward to show that the possible high-effort equilibria under the different information regimes have the same structure as in Section 2. Faced with the prior distribution of talent it is efficient to assign a worker to job 1. The threshold for assignment to job 3 requires that $Pr(\theta_i = \bar{\theta}\,|\,m(\mathcal{R})) > Pr(\theta_i = \bar{\theta}\,|\,\hat{R}, \hat{N}; \cdot) = \frac{1}{2}\left(1 + \frac{\lambda - \Lambda}{1 - \Lambda}\right)$. Hence, job assignments as a function of the profile of realized approaches and the project outcome are as in Table 1. Under the regimes PR and TR high-effort equilibria exist (and always involve cooperation) if c is smaller than the respective threshold c^{PR}_{sym} or c^{TR}_{sym} given in the appendix. For the IR-regime high-effort equilibria exist (and always involve sabotage) if $c \leq c^{IR}_{sym}$.

As a benchmark, we consider the full information case where effort and the idea generating process are publicly observable. Then, effort is efficient if the signal provided by innovations improves job assignment sufficiently to outweigh its cost. If no effort is implemented, only the

[24]This is similar to the setups in Waldman (1984), Bernhardt (1995), and Gibbons and Waldman (1999). For example, this reduced form could result from increasing returns to talent in different levels of a hierarchy (see Rosen (1982)).

job assignment	information regime PR	TR	IR
1	$\tilde{y}=0$	$(\hat{R},\hat{R})$	$\hat{R}_i$
2	$\tilde{y}=1$	$(\hat{R},\hat{N})$	–
3	–	$(\hat{N},\hat{N})$	$\hat{N}_i$

Table 1: Job assignments

Parameter values					
$\lambda=1/2$	$\eta=1/2$	$p_{NN}=1$	$p_N=1/2$	$p=1/4$	
Job J		***1***	***2***	***3***	
$\underline{q}_J$		6	5	0	
$\bar{q}_J$		7	9	15	
Cost thresholds for the efficiency of high-effort equilibria					
first best		$\mathbf{c^{PR}_{sym}}$	$\mathbf{c^{TR}_{sym}}$	$\mathbf{c^{IR}_{sym}}$	
2		0.08	0.71	0.53	
Welfare from high effort ($\mathbf{c=0}$)					
first best	**full info**	$\mathbf{c^{PR}_{sym}}$	$\mathbf{c^{TR}_{sym}}$	$\mathbf{c^{IR}_{sym}}$	
16.5	14.51	12.66	13.88	13.5	

Table 2: Numerical example

prior distribution of talent is known and a worker will always be assigned to job 1. If effort is implemented a worker who succeeds in discovering a novel approach ($\mathcal{I}_i = 1$) will be assigned to job 3 and otherwise will be assigned to job 1. Thus, it is efficient to have both agents exert effort if and only if $c \leq \Lambda\left(\bar{q}_3 - \bar{q}_1\right)$.

Equipped with the above results, we illustrate the potential welfare implications arising from reputation based job assignments using the numerical example given in Table 2. High effort is efficient if c is less than 2. As in the base model, the threshold values for c, below which high-effort equilibria exist, vary non-monotonically in the degree of transparency. However, even if c is such that high effort arises under any regime (e.g., $c = 0$), welfare is affected through the efficiency of job assignments. Moving from the PR to the TR-regime improves job assignments because it becomes possible to perfectly identify an individual's ideas if both team mates have the same outcome of the idea generating process. Still, more transparency could be beneficial since then ideas could be individually attributed even in the mixed outcome case leading to realized profile $(\hat{R}, \hat{N})$ under the TR-regime. In the full information outcome, instead of being assigned job 2, the worker with $\hat{R}$ $(\hat{N})$ is moved to job 1 (3), leading to a welfare gain of $2\,\Lambda\,(1-\Lambda)\left[\bar{q}_3 - \bar{q}_2 + \underline{q}_1 - \underline{q}_2\right] = 0.63$. However, because a high-effort equilibrium under the IR-regime always involves sabotage, in the mixed outcome case the realized profile under the IR-regime would be $(\hat{R}, \hat{R})$ and both workers would be assigned to job 1. Thus, a move from the TR- to the IR- regime entails a drop in welfare of $2\,\Lambda\,(1-\Lambda)\left[\bar{q}_1 - \bar{q}_2 + \underline{q}_1 - \underline{q}_2\right] = 0.38$. Thus, even though more transparency could improve job assignments, sabotage leads to a welfare loss when moving from the TR to the IR regime.

7 Team with a budget balancing principal

In the base model with self-governed teams more transparency can hurt incentives. Does this carry over to team production in firms as well? Human resource managers often argue that compensation based on individual performance rather than group performance reduces worker morale and creates conflict. We will now explore this proposition in our setup.

One reason why the presence of a principal could change the picture is that the principal can serve as a budget balancer, eliminating the limited liability restriction of the base model.[25] Self-governed teams have some scope to prevent sabotage in the IR-regime by allocating an unsuccessful individual with a larger share of the material benefit to compensate for the reputation loss associated with being the only one to have failed to innovate (see Section 4.3). However, the restriction that transfers among team members must balance ex post means that sabotage cannot be prevented in situations where the possible reputation loss exceeds the material benefits that can be distributed in case of project success.

Consider now the situation where team members are agents for a principal to whom project benefits $\tilde{y}\,\pi$ accrue and who is not constrained to balancing the budget ex post. Assume that the principal can choose the information regime and that the market observes this choice and the contract offered to the team members. As before, parties are restricted to spot contracts. Thus, the principal can only offer incentive schemes that condition wages on the observable outcome of the team production. If the principal wanted to implement effort, and had to choose between the TR-regime and an IR-regime that always induces sabotage, the TR-regime would always be preferred: under such an IR-regime reputational incentives are smaller and

[25] In the standard team setting of Holmström (1982) such a budget balancing principal can restore efficient incentives.

the project success probability lower than under the TR-regime. However, the principal can set transfers in such a way that cooperation is always guaranteed under the IR-regime, thus influencing market beliefs to sustain this outcome. What remains to be shown is under what conditions the principal might prefer the TR-regime to the more transparent IR regime if cooperation is induced through appropriately designed contracts.

Suppose that the market holds the belief that under the IR-regime sabotage arises unless the contract stipulates that an agent i who is not successful is fully compensated for the reputation loss associated with cooperation through a wage payment $w_i^{IR}(\hat{R}_i, \hat{N}_j) = \frac{\Lambda^2\,(1-\lambda)}{1-\Lambda^2}\,\Delta\,k$. In addition, to induce effort by talented workers the principal's contract needs to satisfy the effort incentive constraint. Because agents are risk-neutral it is without loss of generality to concentrate possible additional wage payments in the outcome state $(\hat{N}_i, \hat{N}_j)$ by setting $w_i^{IR}(\hat{N}_i, \hat{N}_j) = \max\left[\frac{c-2\,c_0^{TR}}{\Lambda\,\eta}\,\Delta\,k, 0\right]$. Hence, the expected cost of implementing effort and cooperation under the IR-regime is $2\,\Lambda^2\,w_i^{IR}(\hat{N}_i, \hat{N}_j) + 2\,\Lambda\,(1-\Lambda)\,w_i^{IR}(\hat{R}_i, \hat{N}_j)$. In contrast, under the TR-regime cooperation is always guaranteed and the principal needs to offer $w_i^{TR}(\hat{N}, \hat{N}) = \max\left[\frac{c-c_0^{TR}}{\Lambda\,\eta}\,\Delta\,k, 0\right]$ to induce effort.

It is useful to distinguish the following three cases:

1. If $c \geq 2\,c_0^{TR}$, monetary incentives are needed under both information regimes to induce effort. The difference in profits for the principal then becomes[26]

$$\begin{aligned}\Pi^{TR} - \Pi^{IR} &= 2\,\Lambda\,(1-\Lambda)\,w_i^{IR}(\hat{R}_i, \hat{N}_j) + 2\,\Lambda^2\,\Big[w_i^{IR}(\hat{N}_i, \hat{N}_j) - w_i^{TR}(\hat{N}, \hat{N})\Big] \\ &= \frac{\Lambda\,(1-\lambda)}{1-\Lambda^2}\,\left[2\,\Lambda^2(1-\Lambda) - (1+\Lambda)\right]\,\Delta\,k < 0. \end{aligned} \tag{37}$$

   In this situation the principal always prefers the more transparent IR-regime.

2. If $c_0^{TR} < c < 2\,c_0^{TR}$, monetary incentives are needed under the TR-regime to induce effort while under the IR-regime monetary payments $w_i^{IR}(\hat{R}_i, \hat{N}_j)$ are only required to sustain cooperation. Then,

$$\begin{aligned}\Pi^{TR} - \Pi^{IR} &= 2\,\Lambda\,(1-\Lambda)\,w_i^{IR}(\hat{R}_i, \hat{N}_j) - 2\,\Lambda^2\,w_i^{TR}(\hat{N}, \hat{N}) \\ &= \frac{2\,\Lambda}{\eta}\,\Big[\underbrace{\frac{(1-\lambda)\,\eta\,\left[1+\Lambda+2\,\Lambda^2\,(1-\Lambda)\right]}{2(1-\Lambda^2)}\,\Delta\,k}_{\equiv\tilde{c}} - c\Big]. \end{aligned} \tag{38}$$

   It is straightforward to show that $c_0^{TR} < \tilde{c} < 2\,c_0^{TR}$. Thus, the less transparent TR-regime is more profitable if $c_0^{TR} < c < \tilde{c}$.

[26]Note that $\Lambda \leq 1/2$ and thus $2\,\Lambda^2(1-\Lambda) \leq 1/4$.

3. Finally, if $c \leq c_0^{TR}$ the TR-regime is always optimal: it guarantees cooperation and requires no monetary transfers since career concerns provide sufficient effort incentives, whereas monetary transfers $w_i^{IR}(\hat{R}_i, \hat{N}_j)$ are still necessary under the IR-regime to sustain cooperation.

This yields the following result:

Proposition 4

Suppose that the market holds the belief that under the IR-regime sabotage arises unless the team's contract includes wages $w_i^{IR}(\hat{R}_i, \hat{N}_j) = \frac{\Lambda^2 (1-\lambda)}{1-\Lambda^2} \Delta k$, $i, j = 1, 2$, $i \neq j$. Then a principal strictly prefers the less transparent TR-regime over the IR-regime if and only if

$$c < \tilde{c} \equiv \frac{(1-\lambda)\,\eta\,\left[1 + \Lambda + 2\,\Lambda^2\,(1-\Lambda)\right]}{2(1-\Lambda^2)}\,\Delta\,k.$$

A corollary of this result is that, for $c < \tilde{c}$ the equilibrium monetary compensation is *identical* for all team members since the principal cannot discriminate agents' contributions under the TR-regime. In other words, a principal might strictly prefer to implement group incentives instead of individual ones, even though this contract form performs less well when one focuses only on the direct monetary incentives. Key for this result is the fact that a compensation scheme may adversely affect reputational incentives because of the information that it makes available.[27] Pay equity emerges because incentive schemes based on individual performance provide signals to the market that are vulnerable to manipulation by disruptive behavior of team members. This corresponds to the widespread notion that incentive contracts based on each individual's performance separately might reduce worker morale and create conflict in teams because of resulting pay inequality. For example, Levine (1991) suggests that wage dispersion reduces productivity because it lowers group cohesiveness. Moreover, there is evidence that relative pay affects job satisfaction (Clark and Oswald 1996). However, in contrast to the existing literature, in our model sabotage is not a direct consequence of perceived inequalities in pay but rather due to the informational externality that an agent can impose on the team. Because of reputational incentives from team members' career concerns the explicit incentive scheme can be rather low-powered. The possibility of information-induced sabotage that we highlight offers an additional element for explaining the increasing popularity of low-powered group incentives (e.g., Ichniowski and Shaw (2003)).

[27] Koch and Peyrache (2003, 2005) show that a similar trade-off between 'good' monetary incentives and reputational incentives can emerge in a different setup as well.

8 Other extensions of the base model

8.1 Exogenous sources of conflict

In this section, we demonstrate that, under the IR-regime, high-effort equilibria with cooperation are more fragile than those with sabotage. Consider the following modification of the base model. The realization of novel approaches is only feasible within an *harmonious* team relationship, which requires both mutual compatibility of team members and their willingness to cooperate. *Conflict* arises if team members are not compatible, which occurs with probability x, regardless of the workers' actions, or if at least one of the workers engages in sabotage. We proceed to show that, under these assumptions, high-effort equilibria may always involve sabotage under the IR-regime, while cooperation can be sustained as an equilibrium outcome with performance and team records.

Performance and Team Record. Consider first the PR-regime. The logic from the base model remains intact: given previous effort, cooperation is an equilibrium outcome since $b(1) > b(0)$ (as can easily be shown). Hence, it is optimal for talented workers to exert effort if effort costs are not too high.

Under the TR-regime the realization of at least one novel approach indicates the absence of conflict. Thus, in the candidate high-effort equilibrium with cooperation, $b(\hat{N}, \hat{N}; \cdot)$ and $b(\hat{R}, \hat{N}; \cdot)$ are as in the base model. When no innovations are realized, firms cannot be sure whether this is due to lack of talent/luck or lack of compatibility of team members, i.e.,

$$b(\hat{R}, \hat{R}; \cdot) \quad = \quad \underline{k} + \frac{x\lambda + (1-x)(\lambda - \Lambda)(1-\Lambda)}{x + (1-x)(1-\Lambda)^2}\,\Delta\, k. \tag{39}$$

Note that the possibility of conflict for exogenous reasons increases the market's evaluation compared to the base model (where $x = 0$). However, given that workers exert effort, cooperation is still optimal since $b(\hat{N}, \hat{N}; \cdot) > b(\hat{R}, \hat{N}; \cdot) > b(\hat{R}, \hat{R}; \cdot)$. Hence, both the material and the reputational gains are increasing in implemented innovations and the cooperative outcome obtains. It is straightforward to show that sabotage cannot arise with either PR or TR

Individual Records. As in the base model, realizing a novel approach signals talent: $b_i(\hat{N}_i, \cdot) = \bar{k}$. What is different now are the beliefs about a worker i who fails to innovate. Suppose first that the market's beliefs are that workers exert effort if talented and do not sabotage each other. If both workers fail to realize innovations, possible causes are lack of talent/luck or conflict arising from incompatibility of team members, i.e.,

$$b_i(\hat{R}_i, \hat{R}_j; \cdot) \quad = \quad \underline{k} + \frac{x\lambda + (1-x)(\lambda - \Lambda)(1-\Lambda)}{x + (1-x)(1-\Lambda)^2}\,\Delta\, k. \tag{40}$$

In contrast, the realization of at least one novel approach indicates the absence of conflict:

$$b_i(\hat{R}_i, \hat{N}_j; \cdot) = \underline{k} + \frac{\lambda - \Lambda}{1 - \Lambda} \Delta k. \tag{41}$$

This is worse news about worker i's talent: $b_i(\hat{R}_i, \hat{N}_j; \cdot) < b_i(\hat{R}_i, \hat{R}_j; \cdot)$. As in Section 4.3, to prevent sabotage contract terms can be set to give a worker who fails to innovate a larger share of the material benefit in case of success. A sufficient condition for this not to be feasible is

$$\breve{\alpha}_C \equiv \frac{x \Lambda (1-\lambda)}{(1-\Lambda)[x + (1-x)(1-\Lambda)^2]} \frac{\Delta k}{p_N \pi} \geq 1. \tag{42}$$

Following the steps of our analysis of the sabotage equilibrium in Section 4.3, we obtain the following result.

Proposition 5

With exogenous sources of conflict, under the IR-regime all high-effort equilibria involve sabotage if the following sufficient conditions are met:

$$c \leq \eta (1-x) \Lambda \left[(p_{NN} - p) \frac{\pi}{2} + \frac{1-\lambda}{x + (1-x)(1-\Lambda^2)} \Delta k \right]$$

$$\textit{and} \quad \breve{\alpha}_C \equiv \frac{x \Lambda (1-\lambda)}{(1-\Lambda)[x + (1-x)(1-\Lambda)^2]} \frac{\Delta k}{p_N \pi} \geq 1.$$

It is straightforward to show that the implications of transparency for efficiency and effort incentives are analogous to the ones in Section 4.

8.2 Limited observability of contributions

In some cases, it may be natural to assume that individual approaches can only be observed if the project has been successful. For example, academic contributions are usually more visible if they have been published in a widely disseminated journal ($\tilde{y} = 1$). In this section, focus again on the base case $\pi = 0$ and assume that information regarding realized approaches can potentially be observed – depending on the information regime – only if the project has succeeded. In case of a project failure the market observes the signal $\tilde{y} = 0$ under *all* information regimes. As it turns out, this information structure only reinforces our main insights.

Performance and Team Record. Again we consider candidate high-effort equilibria without sabotage. Then, under any information regime, the observation $\tilde{y} = 0$ induces market beliefs $b(0)$ derived in Section 3.1 (see equation (12)). Under the PR-regime project success induces the same market beliefs $b(1)$ as in Section 3.1 (see equation (9)). Hence, nothing changes relative to the base model: high-effort equilibria never involve sabotage and exist if and only if $c \leq c_0^{PR}$. Under the TR-regime, project success and the observed team contribution profile now induce the wages $b(\hat{N}, \hat{N}; 1)$, $b(\hat{N}, \hat{R}; 1)$, and $b(\hat{R}, \hat{R}; 1)$ from Section 3.2. Again, it is straightforward to show that high-effort equilibria never involve sabotage and exist if and only if

$$\begin{aligned} c \;\leq\; c_L^{TR} \;&\equiv\; \eta \left\{ \Lambda \left[p_{NN} \left(b(\hat{N}, \hat{N}; 1) - b(0) \right) + p_N \left(b(0) - b(\hat{N}, \hat{R}; 1) \right) \right] \right. \\ &+\; \left. (1 - \Lambda) \left[p_N \left(b(\hat{N}, \hat{R}; 1) - b(0) \right) + p \left(b(0) - b(\hat{R}, \hat{R}; 1) \right) \right] \right\}. \end{aligned} \tag{43}$$

Individual Records. As in the base model, cooperative high-effort equilibria do not exist. To see this, consider a candidate high-effort equilibrium without sabotage. As under the other information regimes, ensuing project failure the second period wage is $b(0)$. In case of project success, the market observes realized approaches and forms the following beliefs: $b_i(\hat{N}_i, \cdot; 1) = \bar{k}$ and $b_i(\hat{R}_i, \cdot; 1) = \underline{k} + \frac{\lambda - \Lambda}{1 - \Lambda} \Delta k$. It is easy to check that $b(0) > b_i(\hat{R}_i, \cdot; 1)$. Therefore, given these market beliefs, a player who fails in generating novel ideas will always engage in sabotage to guarantee herself a wage of $b(0)$. Note that this deviation from cooperation does not require the tie-breaking assumption made in the base setup. To prove that high-effort equilibria with sabotage exist, we proceed as in Section 3.3. In such a candidate equilibrium, following success market beliefs on the equilibrium path are exactly as in the base model: $b_i(\hat{N}_i, \cdot; 1) = \bar{k}$ and $b_i(\hat{R}_i, \hat{R}_j; 1) = \underline{k} + \frac{\lambda - \Lambda^2}{1 - \Lambda^2} \Delta k$. Off the equilibrium path (or introducing an arbitrarily small error probability in the sabotage decision) we can again find a belief $b_i^{min}(\hat{R}_i, \hat{N}_j; 1) = \underline{k} + \frac{\lambda - \Lambda}{1 - \Lambda} \Delta k$. Project failure now induces market belief

$$\begin{aligned} b_{i,S}(0) \;&=\; \underline{k} + \frac{\Lambda^2 (1 - p_{NN}) + (\lambda - \Lambda^2)(1 - p)}{\Lambda^2 (1 - p_{NN}) + (1 - \Lambda^2)(1 - p)} \Delta k \\ &>\; b_i(\hat{R}_i, \hat{R}_j; 1) > b_i(\hat{R}_i, \hat{N}_j; 1). \end{aligned} \tag{44}$$

Therefore, an unsuccessful worker will always engage in sabotage. High-effort equilibria involving sabotage exist whenever

$$c \leq c_L^{IR} \;\equiv\; \eta \, \Lambda \left\{ p_{NN} \left[b_i(\hat{N}_i, \hat{N}_j; 1) - b_{i,S}(0) \right] + p \left[b_{i,S}(0) - b_i(\hat{R}_i, \hat{R}_j; 1) \right] \right\}. \tag{45}$$

As in the base model, $c_L^{TR} > c_0^{PR}$ and $c_L^{TR} > c_L^{IR}$, providing a corollary to Proposition 1.

8.3 Asymmetric priors

Often a team member will have a better or worse prior reputation than the other one, i.e., $\lambda_1 \neq \lambda_2$. Possibly, because this individual is older and there is more information available for the market to form a prior. Following the same steps as in Sections 3.1 to 3.3, we obtain again the result that all high-effort equilibria under regimes PR and TR are cooperative, whereas they always involve sabotage under the IR-regime. A high-effort equilibrium under the information regime $\mathcal{R} \in \{PR, TR\}$ exists if and only if $c \leq \min[c^{\mathcal{R}}_{1,A}, c^{\mathcal{R}}_{2,A}]$, for the thresholds given in the appendix.

9 Conclusion

Free riding is a pervasive problem in team production when there is no budget balancing principal (Holmström 1982). Therefore, it is puzzling that many real-life team settings involve limited disclosure of individual contributions despite negligible costs for doing so. We provide a rationale for this by showing that creating more individual accountability through greater transparency about individuals' contributions to team production does not necessarily improve incentives. In the presence of strong career concerns the possibility of a non-monotonic relationship between transparency and effort incentives arises.

In our team setting, information on the *quality* of individual inputs always improves incentives while sustaining a cooperative *team spirit*. In contrast, making the *identity* of individual contributors observable as well may induce sabotage behavior that looks like *jealousy* but arises purely from signal jamming by less successful team members. Put simply, this means that in the presence of career concerns too much information may 'hurt' incentives. This argument is robust to a number of different modelling choices, such as the inclusion of direct material benefits and the possibility of contingent contracts among team members.

The welfare implications of increased transparency are ambiguous. It is shown that reputational incentives may be inefficiently strong. Stronger incentives tend to be welfare enhancing when the social value generated by project success is large or if the information generated about team members' abilities during the first period production process leads to significant gains from improved future job assignments. In these latter cases, welfare can be non-monotonic in the degree of transparency as well.

In our setup sabotage emerges because of the informational externality that an agent can impose on the team when information about individual contributions is made available for the purpose of compensation. This is consistent with the notion that incentive contracts based explicitly on individuals' performances might reduce worker morale and create conflict in teams. This interpretation is supported by the principal-agent version of the model, where group incentives can be strictly more profitable than individual incentives. The result offers a new explanation for the increasing popularity of such schemes.

A Proof of Lemma 3

Consider the candidate equilibrium where sabotage occurs whenever a worker fails to generate novel ideas, with the corresponding market beliefs. On the equilibrium path beliefs are $b(\hat{N},\hat{N};\cdot) = \bar{k}$ and $b(\hat{R},\hat{R};\cdot) = \underline{k} + \frac{\lambda-\Lambda^2}{1-\Lambda^2}\,\Delta\,k$. (see the derivation of equation (20)). Off the equilibrium path, the only restriction on beliefs is that they are consistent with the production technology. Upon observing realized approaches $(\hat{R},\hat{N})$, it is clear that no sabotage occurred and that at least one worker is talented. The worst belief consistent with the technology about the other worker arises if the market assumes that she provided effort if she was talented and failed to generate novel ideas:

$$b^{min}(\hat{R},\hat{N};\cdot) = \underline{k} + \frac{1}{2}\left[1 + \frac{\lambda-\Lambda}{1-\Lambda}\right]\Delta\,k. \tag{46}$$

Thus, if at least one novel approach is implemented, consistent beliefs lead to second period wages greater or equal to $b^{min}(\hat{R},\hat{N};\cdot)$. Since

$$b^{min}(\hat{R},\hat{N};\cdot) - b(\hat{R},\hat{R};\cdot) = \frac{1-\lambda}{2\,(1+\Lambda)} > 0, \tag{47}$$

it always pays off to deviate to cooperation, leading to a contradiction.

B Proof of Proposition 1

$$\begin{aligned}
\frac{c_0^{TR}-c_0^{PR}}{\Delta\,k} &= \frac{\eta\,(1-\lambda)}{2\,(1-\Lambda)} - \frac{\eta\,\Lambda\,(1-\lambda)\left[\Lambda\,(p_{NN}-p_N)+(1-\Lambda)\,(p_N-p)\right]^2}{\Lambda^2\,p_{NN}+2\,\Lambda\,(1-\Lambda)\,p_N+(1-\Lambda)^2\,p} \\
= \quad & \frac{(1-\lambda)\,\eta}{DEN}\Big\{(1-\Lambda)^2\,p\,\left[\Lambda^2\,[2\,(p_{NN}-p_N)+1-p_N]+(1-\Lambda^2)\,(1-p)\right] \\
& + 2\,\Lambda\,(1-\Lambda)\,p_N\,\left[2\,\Lambda\,(1-\Lambda)\,(1-p_{NN})+(1-2\,\Lambda\,(1-\Lambda))\,(1-p_N)\right] \\
& + 2\,\Lambda^3\,(1-\Lambda)\,p_{NN}\,(1-p_{NN})+\Lambda^2\,(1-\Lambda)^2\,(p_{NN}-p\,p_N)\Big\} > 0,
\end{aligned} \tag{48}$$

$$DEN = 2\,(1-\Lambda)\left[\Lambda^2\,p_{NN}+2\,\Lambda\,(1-\Lambda)\,p_N+(1-\Lambda)^2\,p\right]. \tag{49}$$

C Proof of Lemma 5

Given market beliefs $b(1)$ and $b(0)$ of a high-effort equilibrium, the ex ante expected team utilities for the situations where all talented workers exert effort (V_{11}^{PR}), only one worker

$i = 1, 2$ exerts effort if talented (V_{10}^{PR}), or no worker exerts effort (V_{00}^{PR}) are:

$$\begin{aligned} V_{11}^{PR} &= \left[\Lambda^2\, p_{NN} + 2\,\Lambda\,(1-\Lambda)\,p_N + (1-\Lambda)^2\, p\right]\,(\pi + 2\,b(1)) \qquad (50)\\ &\quad + \left[\Lambda^2\,(1-p_{NN}) + 2\,\Lambda\,(1-\Lambda)\,(1-p_N) + (1-\Lambda)^2\,(1-p)\right]\,2\,b(0) - 2\,\lambda\,c,\\ V_{10}^{PR} &= \left[\Lambda\, p_N + (1-\Lambda)\,p\right]\,(\pi + 2\,b(1)) \qquad (51)\\ &\quad + \left[\Lambda\,(1-p_N) + (1-\Lambda)\,(1-p)\right]\,2\,b(0) - \lambda\,c,\\ V_{00}^{PR} &= p\,(\pi + 2\,b(1)) + (1-p)\,2\,b(0). \qquad (52) \end{aligned}$$

$$\begin{aligned} V_{11}^{PR} - V_{10}^{PR} &= \Lambda\,\left[\Lambda\,(p_{NN} - p_N) + (1-\Lambda)\,(p_N - p)\right]\,\left[\pi + 2\,(b(1) - b(0))\right] - \lambda\,c\\ &= \lambda\,\left(2\,c_+^{PR} - c\right), \qquad (53)\\ V_{11}^{PR} - V_{00}^{PR} &= \Lambda\,\left[\Lambda\,(p_{NN} - p_N) + (2-\Lambda)\,(p_N - p)\right]\,\left[\pi + 2\,(b(1) - b(0))\right] - 2\,\lambda\,c\\ &> 2\,\lambda\,\left(c_+^{PR} - c\right). \qquad (54) \end{aligned}$$

If $c \leq c_+^{PR}$ ex ante team utility is maximized with a contract that implements high effort.

D Proof of Lemma 6

Given market beliefs $b(\hat{N}, \hat{N}; \cdot)$, $b(\hat{R}, \hat{N}; \cdot)$, and $b(\hat{R}, \hat{R}; \cdot)$ of a high-effort equilibrium, the ex ante expected team utilities for the situations where all talented workers exert effort (V_{11}^{TR}), only one worker $i = 1, 2$ exerts effort if talented (V_{10}^{TR}), or no worker exerts effort (V_{00}^{TR}) are:

$$\begin{aligned} V_{11}^{TR} &= \left[\Lambda^2\, p_{NN} + 2\,\Lambda\,(1-\Lambda)\,p_N + (1-\Lambda)^2\, p\right]\,\pi \qquad (55)\\ &\quad + 2\,\Lambda^2\, b(\hat{N}, \hat{N}; \cdot) + 4\,\Lambda\,(1-\Lambda)\,b(\hat{R}, \hat{N}; \cdot) + 2\,(1-\Lambda)^2\, b(\hat{R}, \hat{R}; \cdot) - 2\,\lambda\,c,\\ V_{10}^{TR} &= \left[\Lambda\, p_N + (1-\Lambda)\,p\right]\,\pi + 2\,\Lambda\, b(\hat{R}, \hat{N}; \cdot) + 2\,(1-\Lambda)\,b(\hat{R}, \hat{R}; \cdot) - \lambda\,c, \qquad (56)\\ V_{00}^{TR} &= p\,\pi + 2\,b(\hat{R}, \hat{R}; \cdot). \qquad (57) \end{aligned}$$

$$\begin{aligned} V_{11}^{TR} - V_{10}^{TR} &= \Lambda\,\left[\Lambda\,(p_{NN} - p_N) + (1-\Lambda)\,(p_N - p)\right]\,\pi\\ &\quad + 2\Lambda\left[\Lambda\, b(\hat{N}, \hat{N}; \cdot) + (1 - 2\,\Lambda)\,b(\hat{R}, \hat{N}; \cdot) - (1-\Lambda)\,b(\hat{R}, \hat{R}; \cdot)\right] - \lambda\,c\\ &= \lambda\,\left(2\,c_+^{TR} - c\right), \qquad (58)\\ V_{11}^{TR} - V_{00}^{TR} &= \Lambda\,\left[\Lambda\,(p_{NN} - p_N) + (2-\Lambda)\,(p_N - p)\right]\,\pi\\ &\quad + 2\Lambda\left[\Lambda\, b(\hat{N}, \hat{N}; \cdot) + 2(1-\Lambda)\,b(\hat{R}, \hat{N}; \cdot) - (2-\Lambda)\,b(\hat{R}, \hat{R}; \cdot)\right] - 2\,\lambda\,c\\ &> 2\,\lambda\,\left(c_+^{TR} - c\right). \qquad (59) \end{aligned}$$

If $c \leq c_+^{TR}$ ex ante team utility is maximized with a contract that implements high effort.

E Proof of Lemma 7

For the case in which sabotage cannot be contractually excluded, we again need to verify that a contract inducing high effort with sabotage maximizes expected team utility at the contracting stage.

$$\begin{aligned}
V_{11}^{(IR,S)} &= \left[\Lambda^2 p_{NN} + (1-\Lambda^2)\, p\right] \pi + 2\,\Lambda^2\, b_i(\hat{N},\hat{N};\cdot) + (1-\Lambda^2)\, b_i(\hat{R},\hat{R};\cdot) - 2\,\lambda\, c, \\
V_{10}^{(IR,S)} &= V_{00}^{(IR,S)} - \lambda\, c, && (60)\\
V_{00}^{(IR,S)} &= p\,\pi + 2\, b_i(\hat{R},\hat{R};\cdot). && (61)
\end{aligned}$$

$$\begin{aligned}
V_{11}^{(IR,S)} - V_{10}^{(IR,S)} &> V_{11}^{(IR,S)} - V_{00}^{(IR,S)} \\
&= \Lambda^2 \left[(p_{NN} - p_N)\,\pi + 2\,\left(b_i(\hat{N},\hat{N};\cdot) - b_i(\hat{R},\hat{R};\cdot)\right)\right] - 2\,\lambda\, c \\
&= 2\,\lambda\,\left(c_{(+,S)}^{IR} - c\right). && (62)
\end{aligned}$$

F Proof of Lemma 8

Again we need to check that a contract inducing high effort with cooperation maximizes expected team utility at the contracting stage.

$$\begin{aligned}
V_{11}^{(IR,C)} &= \left[\Lambda^2 p_{NN} + 2\,\Lambda\,(1-\Lambda)\, p_N + (1-\Lambda)^2 p\right] \pi && (63)\\
&\quad +2\,\Lambda^2\, b_i(\hat{N},\cdot;\cdot) + 2\,\Lambda\,(1-\Lambda)\,\left[b_i(\hat{N},\cdot;\cdot) + b_i(\hat{R},\cdot;\cdot)\right] + 2\,(1-\Lambda)\, b_i(\hat{R},\cdot;\cdot) - 2\,\lambda\, c, \\
V_{10}^{(IR,C)} &= \left[\Lambda\, p_N + (1-\Lambda)\, p\right] \\
&\quad +\Lambda\,\left[b_i(\hat{N},\cdot;\cdot) + b_i(\hat{R},\cdot;\cdot)\right] + 2\,(1-\Lambda)\, b_i(\hat{R},\cdot;\cdot) - \lambda\, c, && (64)\\
V_{00}^{(IR,C)} &= p\,\pi + 2\, b_i(\hat{R},\hat{R};\cdot). && (65)
\end{aligned}$$

$$\begin{aligned}
V_{11}^{(IR,C)} - V_{00}^{(IR,C)} &= \lambda\,\left(2\, c_{(+,C)}^{IR} - c\right), && (66)\\
V_{11}^{(IR,C)} - V_{00}^{(IR,C)} &< V_{11}^{(IR,S)} - V_{00}^{(IR,S)}, && (67)
\end{aligned}$$

since $V_{11}^{(IR,C)} > V_{11}^{(IR,S)}$ and $V_{00}^{(IR,C)} < V_{00}^{(IR,S)}$.

G Proof of Lemma 9

From an ex ante perspective, both workers exerting effort if talented is better than no effort provision if and only if

$$\begin{aligned}
&\left[\Lambda^2 p_{NN} + 2\,\Lambda\,(1-\Lambda)\, p_N + (1-\Lambda)^2 p\right] \pi - 2\,\lambda\, c \geq p\,\pi \\
\Leftrightarrow \quad & c \leq c_{00}^{11} \equiv \eta\,\left[\,\Lambda\,(p_{NN} - p_N) + (2-\Lambda)(p_N - p)\right] \pi/2. && (68)
\end{aligned}$$

Both workers exerting effort if talented is better than only worker i exerting effort if talented and the other worker j never exerting effort if and only if

$$\left[\Lambda^2 p_{NN} + 2\,\Lambda\,(1-\Lambda)\,p_N + (1-\Lambda)^2\,p\right]\,\pi - 2\,\lambda\,c \geq \left[\Lambda\,p_N + (1-\Lambda)\,p\right]\,\pi - \lambda\,c$$
$$\Leftrightarrow \qquad c \leq c_{10}^{11} \equiv \eta\,\left[\,\Lambda\,(p_{NN}-p_N) + (1-\Lambda)(p_N - p)\right]\,\pi. \tag{69}$$

Only worker i exerting effort if talented and the other worker j never exerting effort is better than no effort provision if and only if

$$\left[\Lambda\,p_N + (1-\Lambda)\,p\right]\,\pi - \lambda\,c \geq p\,\pi \quad \Leftrightarrow \quad c \leq c_{00}^{10} \equiv \eta\,(p_N - p)\,\pi. \tag{70}$$

H Thresholds $\mathbf{c_{sym}^{PR}}$, $\mathbf{c_{sym}^{TR}}$, and $\mathbf{c_{sym}^{IR}}$

The expressions for NUM and $Pr(1)$ are given in Section 3.1.

$$\begin{aligned}
c_{sym}^{PR} &\equiv \Lambda\left[\Lambda(p_{NN}-p_N) + (1-\Lambda)(p_N-p)\right] \qquad (71)\\
&\times \left[\underline{q}_2 + \frac{NUM}{Pr(1)}\,\Delta q_2 - \left(\underline{q}_1 + \frac{\lambda - NUM}{1-Pr(1)}\,\Delta q_1\right)\right],\\
c_{sym}^{TR} &\equiv \Lambda^2\left[\bar{q}_3 - \left(\underline{q}_2 + \left(1+\frac{\lambda-\Lambda}{1-\Lambda}\right)\frac{\Delta q_2}{2}\right)\right] \qquad (72)\\
&+ \Lambda(1-\Lambda)\left[\underline{q}_2 + \left(1+\frac{\lambda-\Lambda}{1-\Lambda}\right)\frac{\Delta q_2}{2} - \left(\underline{q}_1 + \frac{\lambda-\Lambda}{1-\Lambda}\Delta q_1\right)\right],\\
c_{sym}^{IR} &\equiv \Lambda^2\left[\bar{q}_3 - \left(\underline{q}_1 + \frac{\lambda-\Lambda^2}{1-\Lambda^2}\Delta q_1\right)\right]. \qquad (73)
\end{aligned}$$

I Proof of Proposition 5

Given market beliefs that both workers exert effort and that sabotage occurs unless both workers innovate, we have

$$b_i(\hat{R}_i, \hat{R}_j; \cdot) \;=\; \underline{k} + \frac{\lambda - (1-x)\,\Lambda^2}{1-(1-x)\,\Lambda^2}\,\Delta\,k. \tag{74}$$

As in Section 4 one needs to check that contracts cannot induce a profitable deviation to cooperation. Following the same steps as there, we find the sufficient condition

$$\breve{\alpha}_S \;\equiv\; \frac{\Lambda\,(1-\lambda)\,[1-(1-x)\,\Lambda]}{(1-\Lambda)\,\left[1-(1-x)\,\Lambda^2\right]}\,\frac{\Delta\,k}{p_N\pi} \geq 1. \tag{75}$$

This is implied by $\breve{\alpha}_C \geq 1$ since

$$\breve{\alpha}_S - \breve{\alpha}_C = \frac{(1-x)\,\Lambda\,(1-\lambda)\,\left[1-\Lambda\,(2-(1-x)\,\Lambda)\right]}{(1-\Lambda)\,\left[1-(1-x)\,\Lambda^2\right]\,\left[x+(1-x)\,(1-\Lambda)^2\right]}\,\frac{\Delta\,k}{p_N\pi} > 0. \tag{76}$$

Again, maximum incentives can be guaranteed with an equal split of profits on the equilibrium path. The incentive constraint for a talented worker i becomes

$$(1-x)\,\Lambda\,\eta\,\left[\bar{k}+\tfrac{p_{NN}}{2}\,\pi\right]+(1-(1-x)\,\Lambda\,\eta)\,\left[b_i(\hat{R}_i,\hat{R}_j;\cdot)+\tfrac{p}{2}\,\pi\right]-c\geq b_i(\hat{R}_i,\hat{R}_j;\cdot)+\tfrac{p}{2}\,\pi$$

$$\Leftrightarrow\quad (1-x)\,\Lambda\,\eta\,\left[(p_{NN}-p)\,\tfrac{\pi}{2}+\tfrac{1-\lambda}{1-(1-x)\,\Lambda^2}\,\Delta\,k\right]\geq c. \tag{77}$$

J Thresholds $\mathbf{c^{PR}_{i,A}}$, $\mathbf{c^{TR}_{i,A}}$, and $\mathbf{c^{IR}_{i,A}}$ for i=1,2

$$c^{PR}_{i,A} \equiv \frac{\Lambda_j\,(p_{NN}-p_N)+(1-\Lambda_j)\,(p_N-p)}{2\,Pr_A(1)\,[1-Pr_A(1)]}\times\Big\{\Lambda_1\,\Lambda_2\,\eta\,(2-\lambda_1-\lambda_2)(p_{NN}-p)$$
$$+\;[\Lambda_1\,\eta\,(1-\lambda_1)(1-\Lambda_2)+\Lambda_2\,\eta\,(1-\lambda_2)(1-\Lambda_1)]\;(p_N-p)\Big\}\,\Delta\,k, \tag{78}$$

$$Pr_A(1) = \Lambda_1\,\Lambda_2\,p_{NN}+[\Lambda_1\,(1-\Lambda_2)+(1-\Lambda_1)\,\Lambda_2]\,p_N+(1-\Lambda_1)(1-\Lambda_2)\,p, \tag{79}$$

$$c^{TR}_{i,A} \equiv \frac{\Lambda_j\,(1-\eta)\,(\lambda_1-\lambda_2)^2+\lambda_1\,(1-\lambda_1)(1-\Lambda_2)^2+(1-\Lambda_1)^2\,\lambda_2\,(1-\lambda_2)}{2\,(1-\Lambda_1)(1-\Lambda_2)\,[\lambda_1\,(1-\Lambda_2)+(1-\Lambda_1)\,\lambda_2]}\,\eta\,\Delta\,k, \tag{80}$$

$$c^{IR}_{i,A} \equiv \frac{\Lambda_j\,\eta\,(1-\lambda_i)}{1-\Lambda_1\,\Lambda_2}\,\Delta\,k. \tag{81}$$

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