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Repeated Interaction in Teams: Tenure and Performance

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Abstract. Many of the activities performed in firms are done by teams, where a common output is observed, but outsiders cannot observe the individual contributions of each team member. This leads to the possibility of some of the members of the team free-riding on the contributions of others. Repeated interactions of a team can then potentially lead to cooperation among the members of the team under the credible threat of returning to a free-riding equilibrium. However, repeated interaction under cooperation of a team may lead to decreasing overall output over time because the benefits of the team working together may exogenously decrease over time. This then leads to the optimal duration of a team being finite but stochastic, creating inefficiency, but being sufficiently long so that the elements of the team have an incentive to cooperate. This provides a theory of successive team formation and termination in a firm. The possibility for a too long duration for full team cooperation may then lead the firm to reduce the extent of team cooperation, to be able to reduce the expected duration of a team, and have fewer losses of the team lasting for too long.

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1. Introduction

Many of the productive activities performed in firms are done with teams of employees, because of the need for several types of expertise within the team, or because the activity to be performed actually needs or is better performed with a greater number of team members. Dumain (1994) estimated that around two-thirds of U.S. firms use work teams. AlliedSignal Aerospace claimed an 11% increase in revenue from a team-based approach in marketing.[1] Procter & Gamble treated teams as its trade secret (Manz and Sims 1993). Strategic consulting companies have their projects organized in teams. Firms worry about having effective marketing teams (Bacon 2016). Griffin and Hauser (1992) argue that in new product teams, performance is improved by better communication among marketing, engineering, and manufacturing.[2] Sarin and Mahajan (2001) compare the effect of process- and output-based rewards on the performance of product development teams.

One central issue in teamwork is that the firm may only be able to observe a common output of the team and cannot observe the individual contribution of each team member. This can then potentially lead to free-riding by some team members on the effort and work of others (Holmstrom 1982).

One way in which free-riding may not happen in a team is because of repeated interaction of the team members in the team, such that lack of cooperation by a team member could be punished with a free-riding

equilibrium. That is, the team members enter into a relational or implicit contract. (See, for example, MacLeod and Malcomson 1989, among several others; we further discuss this literature below.) This then can lead to mutual accountability and implicit trust among team members for greater team performance (Katzenbach and Smith 1993).

However, the productivity of a team under cooperation may decline at some point over time because the potential complementarities of the team members have been mostly exploited (see also Slotegraaf amd Atuahene-Gima 2011). Teams are formed to work on some projects, and at some point those projects on which the team is working are of decreasing productivity. This means that there is a trade-off on the lifetime of the team. If the team lasts for a long time, cooperation is easier to sustain, but the average productivity of the team during its lifetime decreases. There is then an optimal lifetime for a team so that cooperation within the team can be sustained.

In the same spirit, companies do job rotation of their employees because the advantages of being in the same job, working with the same team, diminish through time (Eriksson and Ortega 2006). This could be because when working in a team, an employee learns from the other team members and improves her or his human capital, but after learning what there is to learn from the other team members, the benefits of remaining in the team diminish. Alternatively, employees can be more motivated when rotating into new

teams (e.g., Cosgel and Miceli 1999), and this extra motivation wears out as the same team stays together. It could also be that the firm learns about the different employees abilities by having them in different teams over time, and what there is to learn is learned after some time (e.g., Ortega 2001). All of these effects indicate that the surplus of the team working together decreases over time. Instead of micromodeling these effects, we consider these effects here through a decreasing productivity over time of a new team that is formed.

There is also some evidence that job rotation increases with team-related activities, such as the practices of self-managed teams, and quality circles (Osterman 2000), which seems to indicate that the effect of decreasing productivity with a team working together is important in the real world. There is also some evidence that tenure in a company is negatively related to job rotation (Campion et al. 1994), which can be interpreted in the context of this paper as cooperation being more important for employees with longer tenure, possibly because they are in charge of decisions that have a greater impact on the organization.[3]

Another question that may arise is whether maximum cooperation among the team members is optimal for the firm. It turns out that it may be optimal for teams to have a shorter duration, which would lead to less than maximum cooperation among the team members. By having less than maximum cooperation, the team does not need to last as long, with a greater average performance during the periods when the team is working.

Note also that the lifetime of a team has to be stochastic for cooperation to be sustained; otherwise, by backward induction, the only possible equilibrium would be the free-riding equilibrium.

From a firm's perspective, we may think of a company composed of many employees that the firm organizes in teams for greater total output. The firm would then reorganize team membership once in a while to trade off sustainable cooperation with decreasing productivity of a team once formed.

The optimal incentive scheme set up by the firm affects the effort provided by the employees and the potential surplus for the firm. Greater incentives decrease the surplus by the firm, given a certain effort level, but generate greater joint surplus of employees and firm. The optimal incentives trade off these two effects, taking into account the potential cooperation between employees.

There has been substantial research on the incentives for teams where individual effort is not observable or verifiable. Holmstrom (1982) presents an incentive scheme in that context that can achieve first-best for the case where the total amount paid to the team members can be less than the total output produced by the team. The incentive scheme involves paying a bonus to the team members if the team output is greater than some threshold and zero otherwise. This incentive scheme continues to be effective under uncertainty if under very low or very large values of the output one can discern precisely whether the right effort was exerted (as in Mirrlees 1974). Here, we consider the case with uncertainty where the support of outputs is bounded and the same for all possible levels of effort exerted.

Using the repeated nature of the employment contract, several authors have noted that cooperation between an employer and an employee may be sustained through the credible threat of noncooperative behavior in future interactions—relational or implicit contracts. MacLeod and Malcomson (1989) present the case of symmetric information, and Levin (2003) analyzes the case of asymmetric information.[4] For the case of several employees, where (potentially noisy) signals of employees' effort levels are available for the employer—see, for example, Che and Yoo (2001), Levin (2002), and Rayo (2007). In relation to these papers, in this paper there is no individual output, and there is only a common team output that is observable. Effort levels may be observable by other team members but are not observable by the employer.[5]

Kvaløy and Olsen (2016) consider relational contracts in teams when only the aggregate output is observable and is composed of unobservable individual contributions. They find that the employer can use team size and team composition to improve incentives.[6] In relation to that paper, here I consider the case in which the expected productivity of a team for given effort levels decreases over time, and explore the effect of this on optimal duration of teams in a firm and on the effort levels that are implemented.

There is also some empirical work supporting the idea that work in teams may lead to more cooperation—for example, Knez and Simester (2001), Hamilton et al. (2003), and Boning et al. (2007). One argument that is presented is that better monitoring of teammates' efforts allows for more cooperation. Experimentally, similar results are obtained in, for example, Nalbantian and Schotter (1997).[7]

The remainder of the paper is organized as follows. The next section presents a two-person team model with declining productivity and repeated interaction, which illustrates the optimal duration of a team for full cooperation and the benefits of less-than-perfect cooperation. Section 3 considers a full firm model where a manager sets incentive schemes for the teams that are formed. Section 4 concludes.

2. Teams

Consider a firm with a large number of employees and where all of the productive activities have to be

done in teams of two. Let us further assume in this section that all of the output produced in a team is distributed equally among the team members in each period, and that the team output is deterministic given the effort levels chosen by the team members. In the next section, we consider the case in which the output is stochastic and where the firm manager decides how much to pay each team member depending on the output level.

A team interacts repeatedly over time, and at some stochastic time the team dissolves and its elements are paired up with other employees in the firm. We will consider the probability of a team being dissolved as a decision that a firm can make. When deciding on the effort level to exert at each moment in time, each employee considers the potential effect of that effort level on the expected future interactions within the team.[8]

Given a vector of effort levels by the team members, the performance of a team may evolve exogenously over time as the team interacts. For the same vector of effort levels, the performance could be increasing as the team learns to work together, or decreasing because of the decreased novelty of information exchanged within the team. If the performance is always increasing, then both for cooperation within the team and for performance, the organization would like the team to last forever, or as long as possible, unless better matches appear for the team members. Potentially more interestingly, and also likely, the productivity of a team may start decreasing at some point as the benefits of the team members working together exhaust over time. We could imagine that, in practice, the productivity of a team can first increase as the team is set up and the team members learn to work together, and then diminishes over time. Because the tension in the paper is going to be about the team lasting for too long, we focus on the case in which, given the effort levels, the productivity of the team is always decreasing over time (without having to add other forces into the model).

Suppose that an employee alone has zero productivity, and that a team with two or more members has the same productivity as a team of just two members. Suppose that the firm wants to maximize the sum of the productivity of all of the teams in the firm. Therefore, the firm will organize itself in teams of two members.

Let e_i be the effort level exerted by member i in a team, with $i = 1, 2$, and the cost of exerting effort e_i is $c(e_i) = \frac{1}{2}e_i^2$. The productivity of a team that has lasted for t periods would be $\phi(t)(e_1 + e_2)$ where we will use $\phi(t) = g^t$. We focus the analysis on the case in which $g \in (0, 1)$, but discuss when appropriate what happens if $g > 1$.[9]

Given the effort levels in the team, the payoff for a team member i in period t after the team started operating is

$$U_i(e_1, e_2, t) = \frac{1}{2}\phi(t)(e_1 + e_2) - c(e_i). \quad (1)$$

If a team member behaves noncooperatively, the team member maximizes $\max_{e_i} U_i(e_1, e_2, t)$, which yields that the equilibrium effort provided by each team member is $e_n(t) = \varphi(t)/2$. If both team members behave noncooperatively, the payoff for each team member is then $U_n(t) = \frac{3}{8}\phi(t)^2$.

If a team behaves cooperatively, the team member maximizes $\max_{e_i} U_1(e_1, e_2, t) + U_2(e_1, e_2, t)$, which yields that each team member would exert the effort $e_c(t) = \phi(t)$, and would get the payoff of $U_c(t) = \frac{1}{2}\phi(t)^2$. The difference between the cooperative effort and noncooperative effort is due to the well-known free-riding of team members on the efforts of other team members (Holmstrom 1982).

Although cooperation in a single period interaction may not be possible, repeated interaction in the team without knowing when the team is dissolved may allow for cooperation in the team, as an application of the folk theorem results. To investigate this possibility, let δ be the per-period discount factor of future payoffs, and consider the best one-period possible payoff that a team member could obtain if the other member of the team is exerting the cooperating effort level. That best possible deviating payoff would be obtained by $\max_{e_i} U_i(e_i, e_c(t), t)$, which yields an optimal deviating effort level $e_n(t)$, and would lead to a payoff of $U_d(t) = \frac{5}{8}\phi(t)^2$.

Suppose that the firm considers dissolving the team with some constant hazard rate during the existence of the team, such that the probability of the team continuing is $\alpha \in [0, 1]$. Then, the expected number of periods that a team lasts is $\frac{1}{1-\alpha}$. As noted above, the probability α is a decision that the firm potentially can make. We discuss at the end of this section the ability of the firm committing to this probability α.

Consider then a possible repeated game equilibrium in which a strategy for each team member is to cooperate as long as the other team member cooperates, and to go to the free-riding equilibrium for as long as the team lasts if the other team member ever ceases to cooperate. This threat of the free-riding equilibrium is credible: if one team member is exerting the noncooperative effort level whatever the other team member is doing, then both exerting the noncooperative effort level in every period is a subgame perfect equilibrium. The expected present value of payoffs going forward from the current team—that is, in tth period of existence—of exerting the cooperating effort level is then $\sum_{s=t}^{\infty}(\delta\alpha)^{s-t}\frac{1}{2}\phi(s)^2$. The payoff for a team member

to deviate would be $\frac{5}{8}\phi(t)^2 + \sum_{s=t+1}^{\infty}(\delta\alpha)^{s-t}\frac{3}{8}\phi(s)^2$. The condition that each team member wants to continue cooperating at any time t then reduces to

$$\frac{\phi(t)^2}{2}\frac{1}{1-\delta\alpha g^2} \geq \frac{5}{8}\phi(t)^2 + \delta\alpha g^2\frac{3}{8}\frac{\phi(t)^2}{1-\delta\alpha g^2}, \quad (2)$$

which yields

$$\alpha \geq \frac{1}{2\delta g^2}. \quad (3)$$

To see the impact of the probability of the team continuing to operate, α, on the expected payoff, denote V as the expected present value of payoffs for each employee when a new team is formed. Then, we have

$$V = \sum_{t=0}^{\infty}(\delta\alpha g^2)^t\frac{\phi(0)}{2} + (1-\alpha)\sum_{t=1}^{\infty}\delta^t\alpha^{t-1}V, \quad (4)$$

where we take into account the possibility of the team terminating in each period and a new team forming. From this, one can then obtain

$$V = \frac{\phi(0)}{2}\frac{1-\delta\alpha}{1-\delta\alpha g^2}\frac{1}{1-\delta}, \quad (5)$$

which is decreasing in α. Note that if $g > 1$, then V is increasing in α and the team is better off if the firm never terminates the team, $\alpha = 1$. Alternatively, one could introduce in the model the possibility of the availability of better matches outside of the team, even if the team is more productive over time, and then it could still be better for a firm to choose to disassemble teams in finite time.

Assuming that the productivity goes down over time for a given level of effort, the firm wants to set the probability of the team continuing at the lower bound of (3) given that it wants to implement the efficient amount of effort. The following proposition specifies the result.

Proposition 1. *Suppose that production is done in teams of two, and that the firm wants to implement the efficient amount of effort. Then, the probability of a team continuing together in each period is set at $\alpha = \frac{1}{2\delta g^2}$.*

From this, we can see that the expected tenure of a team becomes longer the more agents discount the future (lower δ) and the more the productivity of a team given effort declines over time. When agents discount the future more, the firm has to keep teams together for longer, for the team members to have enough incentives to cooperate. Interestingly, when the productivity of a team given effort declines more over time, the firm has also to increase the duration with which a team stays together if the firm wants to implement the efficient effort level. Again, given that the productivity falls over time, the firm has to

compensate with a longer duration of the team to provide incentives for cooperation.

It is interesting to briefly discuss the ability of the firm to commit to a duration of a team. In the real world, this represents the idea that teams are formed to last for some time, to potentially induce cooperation among team members, but that the exact date when the team is disassembled is not determined in advance. Note that this uncertainty about the team duration also helps in the cooperation among team members. Of course, if teams are not working well, the firm may have a temptation to come in and break up the team, which could potentially give another incentive for team cooperation. However, the firm may have limited information about how well the team is working together (for factors outside the model), and therefore, this temptation to intervene may be reduced. In any case, the organization of the work within the firm (projects done by different teams, and their uncertain duration) may allow the firm to commit not to dissolve a team for some time.[10] The company also creating a reputation of being truthful about the average duration of a team may also be another form of commitment to the duration of teams.

2.1. Adjusting the Effort Level

The analysis above assumes that the firm wants to implement the efficient effort levels in the team. This may require the tenure of the team to be too long and result in having the team work together when the productivity is already too low. The firm may then want to investigate whether to implement lower effort levels, which may allow teams to not last as long.

Consider that in each period the firm tries to implement an effort level that is a constant fraction γ of the efficient effort level, $e_c(t) = \gamma\phi(t)$, where we expect that γ will be in $[\frac{1}{2}, 1]$, with effort in between the noncooperative effort level and the full-cooperative effort level.[11]

With this effort level, the payoff for an agent t periods after the formation of the team would be $U_c(t) = \gamma(1-\gamma/2)\phi(t)^2$. The optimal deviation for a team member if the other team member exerts effort $\gamma\phi(t)$ is to exert effort $\frac{1}{2}\phi(t)$ and get a payoff of $U_d(t) = \frac{1+4\gamma}{8}\phi(t)^2$. The condition of no deviation at any period t since the formation of the team reduces to

$$\gamma(1-\frac{\gamma}{2})\frac{1}{1-\delta\alpha g^2} \geq \frac{1+4\gamma}{8} + \delta\alpha g^2\frac{3}{8}\frac{1}{1-\delta\alpha g^2}, \quad (6)$$

which yields a condition of the probability of the team's tenure continuing as

$$\alpha \geq \frac{2\gamma-1}{2\delta g^2} \quad (7)$$

under the assumption that $\gamma \in [1/2, 1]$.

In a similar fashion, we can get the expected payoff of an employee when starting with a new team as

$$V = \phi(0)^2 \gamma \left(1 - \frac{\gamma}{2}\right) \frac{1 - \delta\gamma}{1 - \delta\alpha g^2} \frac{1}{1 - \delta}. \quad (8)$$

In this case, we can also see that V is decreasing in α, so that the optimal probability of the tenure of the team continuing on in each period is given by the lower bound of (7). Substituting for this in (8), and differentiating with respect to γ and making it equal to zero, we can obtain the optimal adjustment to the effort level to be given by

$$\frac{4\gamma^3 - 14\gamma^2 + 15\gamma - 3}{2(\gamma^2 - 3\gamma + 3)} = g^2. \quad (9)$$

From this, we can check that $\gamma > 1/2$ if $g^2 > 3/7$ and, in this case, see the effect of the rate of decline in team productivity, $1 - g$, on optimal effort to implement. The following proposition states the result.

Proposition 2. *Suppose that production is done in teams of two. Then, if $g^2 \geq 3/7$ the ratio of the optimal effort to implement to the fully cooperative effort, γ, is given by (9). If $g^2 < 3/7$, then the optimal effort to implement is the non-cooperative effort level, $\gamma = 1/2$. For $g^2 > 3/7$, the optimal γ is increasing in g and independent of the discount factor δ. The average optimal tenure of a team is decreasing in the discount factor δ and in the decline rate of team productivity $1 - g$.*

If the productivity of teams, given effort levels, declines too fast (low g), then the firm finds it best not to implement any effort level above the non-cooperative effort, and to just switch up teams every period. When the decline of the productivity of teams is not too severe ($g > 3/7$), the firm chooses to implement an effort level above the noncooperative effort. Note that as long as there is a decline in team productivity over time, the optimal effort level to implement is less than the fully cooperative effort, with $\gamma \to 1$ when $g \to 1$.

Note also that when there is a greater decline of team productivity over time (lower g), the firm will adjust by reducing both the expected duration of the team and the effort level that is implemented. By reducing the expected duration of the team, the firm is able to avoid the deteriorated performance of the team and reconstitute teams for greater performance. The duration of the team can be further reduced if the firm is willing to implement a lower effort level, which can be more beneficial when the team productivity declines more over time.

Note also that the expected duration of the team declines when the team productivity falls more over time in this case, while the reverse occurred above when the firm always wanted to implement the fully cooperative effort level. In that case, the fact that the team's productivity falls more over time forced the firm to increase the expected duration of the team to be able to implement the fully cooperative effort.

The firm has to worry about two possible inefficiencies: the possibility of the team members not being able to fully cooperate, and the possibility of the team being less productive the longer it lasts. The firm has to find the best trade-off of these two inefficiencies, by having the team not last too long and the team duration giving incentives for the team members to better cooperate. If the team duration is too short, the firm reduces the inefficiency of the declining team productivity, but it has a large inefficiency on the lack of cooperation among team members. If the team duration is too long, the firm can reduce the inefficiency on the cooperation between team members but has a large inefficiency of the declining team productivity. The optimum involves having a little inefficiency of each type.

Figure 1 presents the optimal solution to this trade-off as the point of tangency of the constraint on the effort level being implemented, $\alpha = \frac{2\gamma - 1}{2\delta g^2}$, and the expected discounted payoff curve, V. A greater expected payoff is obtained when a greater effort is implemented (greater γ) and when teams turnover faster (lower α), but the team has to last for some time to implement a certain level of effort.

2.2. Exogenous Team Termination

Let us now briefly discuss what happens if team members can potentially leave the team. If team members can leave the team, or the organization, with some exogenous probability that is fixed through

Figure 1. (Color online) Optimal Team Tenure (α) and Effort (γ) in Space (α, γ)
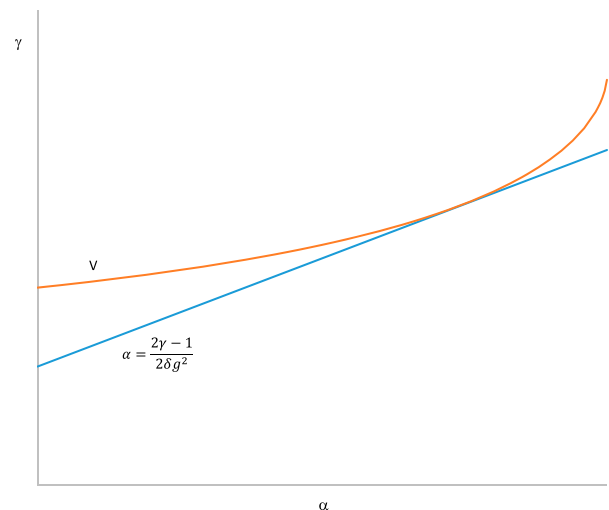
Note. Optimum is at the tangency of effort implementation constraint, $\alpha = \frac{2\gamma-1}{2\delta g^2}$, and expected discounted payoff curve, V.

time, then the analysis above continues to hold except that now the discount factor δ used above (not the control of the firm), is equal to the product of the true discount factor (denote this by $\widetilde{\delta}$) and the probability of the team continuing to operate if only the exogenous factors were present (e.g., some team member leaving exogenously; denote this probability by β). That is, $\delta = \widetilde{\delta}\beta$. The interpretation of α would then just be the probability of the firm terminating the team if no team member had left the team exogenously. For a given discount factor $\widetilde{\delta}$, if there is a greater likelihood of team members leaving exogenously, then the firm chooses a lower probability of dissolving the team.

Alternatively, one could also think of the possibility of team member choosing to leave the organization, if the teammate does not behave cooperatively.[12] In that case, the results here would carry through if there is some cost incurred by an agent when leaving the organization. This cost could be some length of time to find employment in another firm, or lower wages in the new firm, at least for some period.

2.3. Human Capital Improvement in Teams
As discussed above, one possible factor for decreasing benefits of membership in a team is that by being in a team an employee has human capital gains from interacting with the other team members, but those benefits decrease over time. In terms of the model considered here, the benefit for a team member i of belonging to a team would be composed of a private benefit, say $\phi(t)e_i$ plus a share of the total team productivity, which would be a function of the efforts of the team members that is stable through time, for example, $e_1 + e_2$. As the benefits of human capital for the team members decrease over time, $\phi(t)$ is assumed to decrease over time. The private benefit for a team member, $\phi(t)e_i$, would be decreasing over time for a certain effort level.[13] Instead of (1), given the efforts levels in the team, the payoff for a team member i in period t after the team started operating is now

$$U_i(e_1, e_2, t) = \phi(t)e_i + \frac{1}{2}(e_1 + e_2) - c(e_i). \qquad (10)$$

Note that in this formulation the benefits of a greater human capital are completely internalized in the current period. Alternatively, this could be micro-modeled with future employee productivity.

If the team members behave noncooperatively, the equilibrium effort level exerted is $e_n(t) = \frac{1}{2} + \phi(t)$, with a payoff for each team member $U_n(t) = \frac{1}{2}(1 + \phi(t))^2 - \frac{1}{8}$. If the team members behave cooperatively, the effort level exerted is $e_c(t) = 1 + \phi(t)$, with a payoff for each team member $U_c(t) = \frac{1}{2}(1 + \phi(t))^2$.

To understand the possible incentives for cooperation, we also need to understand the potential payoff from a team member deviating from the cooperative effort level. The best possible deviating effort level turns out to be $e_n(t)$, which would lead to a payoff of $U_d(t) = \frac{1}{8} + \frac{1}{2}(1 + \phi(t))^2$.

With a probability $\alpha < 1$ of the firm continuing, a cooperation equilibrium is possible at some time τ if

$$\sum_{t=\tau}^{\infty}(\delta\alpha)^{t-\tau}\frac{1}{2}(1 + \phi(t))^2 \geq \frac{1}{2}(1 + \phi(t))^2 + \frac{1}{8}$$

$$+ \sum_{t=\tau+1}^{\infty}(\delta\alpha)^{t-\tau}\left[\frac{1}{2}(1 + \phi(t))^2 - \frac{1}{8}\right], \qquad (11)$$

which reduces to

$$\alpha \geq \frac{1}{2\delta}. \qquad (12)$$

As above, if the team probability of continuing is sufficiently high, then team cooperation is possible, although now this condition is independent on how the benefits of working in the team fall over time. As the benefits of working in the team fall over time, we can obtain as above that the optimum will be at the lowest possible value of α, which is $\alpha = \frac{1}{2\delta}$.

3. Overall Firm Perspective
In the previous section, we considered the problem of cooperation in a team, where the payoff per team member was the team's output divided by the number of team members. As the team members are employees of the firm, the payoff for each employee may be a function of the team's output, such that the firm gets the most profit, and the firm optimizes on this incentive scheme.

To set this up in the simplest way possible, consider that the output for a team after t periods together is either $\phi(t)$ or zero, with the probability of being $\phi(t)$ equal to the sum of the efforts in that period of the team members, $p = e_1 + e_2$. The cost of effort for team member i is assumed to be $c(e_i) = \frac{k}{2}e_i^2$ where k is assumed sufficiently large, such that at the realized efforts we always have $p < 1$. Suppose also that the team members have limited liability in each period, such that the amount that they receive in each period cannot be less than zero. Denote as w the payment to be made in period t to a team member if the team's output is $\phi(t)$.[14] To illustrate the forces at work, we first consider the case in which the productivity of the team does not change over time, $\phi(t) = \overline{\phi}$ for all t, which is the case considered in the literature mentioned above on implicit contracts. We then investigate what happens when the productivity of teams falls down over time and the firm implements the efficient team effort levels. Finally, next we consider the question of the optimal effort levels to implement.[15]

3.1. Constant Productivity over Time

Consider the case in which the productivity of a team is constant over time, and the team goes on forever.

Then, if a team is behaving noncooperatively, the effort level exerted by each team member would be given by $w = c'(e_i)$, which yields $e_n = \frac{w}{k}$. The expected payoff for each team member in that situation would be $U_n = (\frac{w}{k} + \frac{w}{k}) - \frac{k}{2}(\frac{w}{k})^2 = \frac{3}{2}\frac{w^2}{k}$.

If a team is behaving cooperatively, each member maximizes $2w(e_1 + e_2) - c(e_i)$, which leads to $e_c = \frac{2w}{k}$, and yields an expected payoff $U_c = 2\frac{w^2}{k}$.

If one team member is cooperating, the best that the other team member can do to deviate in a particular period is to exert an effort of $\frac{w}{k}$ and get an expected payoff of $U_d = \frac{5}{2}\frac{w^2}{k}$.

Putting these possible payoffs together, to check the possibility of cooperation in the team under the threat of behaving noncooperatively forever, yields that the team is able to sustain cooperation as long as $\delta > \frac{1}{2}$.

Finally, to see the optimal incentive scheme for the firm to offer, note that the expected profit for the firm per period is $(e_1 + e_2)(\overline{\phi} - 2w) = \frac{4w}{k}(\overline{\phi} - 2w)$ under cooperation. Maximizing this expected profit, one obtains $w = \frac{\overline{\phi}}{4}$ and the equilibrium effort level exerted by each team member under cooperation $(\delta > \frac{1}{2})$ as $e_c = \frac{\overline{\phi}}{2k}$. Note that this is lower than the effort that generates greater overall surplus, which is $\frac{\overline{\phi}}{k}$.

Note also that in this case, under cooperation $(\delta > 1/2)$, the optimal incentive scheme and effort exerted is independent of the discount factor δ.

3.2. Decreasing Team Productivity over Time

Now consider that the productivity of the team goes down over time, with $\phi(t) = \overline{\phi}g^t$, with $g \in (0, 1)$. Given that the incentive scheme is constant over time, the effort levels that are exerted under cooperation continue to be $e_c = \frac{2w}{k}$.

Suppose also that now the firm dissolves the team with probability α in each period. Then, for cooperation to occur at the highest level, we need $\alpha \geq \frac{1}{2\delta}$.

Denoting the expected present value of the firm's profits when a team is first assembled as V, we can obtain

$$V = (e_c + e_c)\left(\frac{\overline{\phi}}{1 - g\delta\alpha} - \frac{2w}{1 - \delta\alpha}\right) + \frac{\delta(1 - \alpha)V}{1 - \delta\alpha},$$

which yields

$$V = \frac{4w}{k}\left(\frac{\overline{\phi}}{1 - g\delta\alpha} - \frac{2w}{1 - \delta\alpha}\right)\frac{1 - \delta\alpha}{1 - \delta}. \tag{13}$$

Maximizing V with respect to α, under the constraint of full team cooperation being implemented, yields $\alpha = \frac{1}{2\delta}$. That is, if agents are more patient the firm can reduce the tenure of the team.

Maximizing V with respect to the incentive scheme w, one obtains

$$w = \frac{\overline{\phi}}{4}\frac{1 - \delta\alpha}{1 - g\delta\alpha}. \tag{14}$$

One can then obtain that, for a given α that sustains team cooperation, the more the team productivity decreases over time (lower g), the lower is the incentive scheme offered, which means that the lower is the effort level that is implemented.

Substituting for $\alpha = \frac{1}{2\delta}$ one obtains $w = \frac{\overline{\phi}}{4(2-g)}$, which shows that at the optimal α, we also have that the more that the team productivity decreases over time, the lower is the incentive scheme offered and the effort level that is implemented.

3.3. Less than Full Team Cooperation

Consider now that the firm may have the possibility of implementing less than full cooperation in the team given the existing incentive scheme. This can be obtained by reducing the expected tenure time of the teams—that is, by reducing α.

Let e^* be the effort that is implemented given w, where $e^* \in [\frac{w}{k}, \frac{2w}{k}]$. Then, the present value of profit generated by the the two elements in the team from the period in which the team is assembled is

$$V = 2e^*\left(\frac{\overline{\phi}}{1 - g\delta\alpha} - \frac{2w}{1 - \delta\alpha}\right)\frac{1 - \delta\alpha}{1 - \delta}. \tag{15}$$

To check the condition for the implementability of e^*, note that we have that the expected payoff for a team member under the possible team cooperation is $U^* = 2e^*w - \frac{k}{2}e^{*2}$, and the expected payoff of a deviating team member is $U_d = e^*w + \frac{w^2}{2k}$. The condition for implementation of e^* is $\delta\alpha = \frac{U_d - U^*}{U_d - U_n}$, which yields

$$\delta\alpha = \frac{ke^* - w}{2w}, \tag{16}$$

as the present value of profits is decreasing in α for a given e^* and w. Maximizing (15) with respect to e^* and w subject to (16) and $e^* \in [\frac{w}{k}, \frac{2w}{k}]$, one obtains the following proposition.

Proposition 3. *Suppose that production is done in teams of two, and that the firm gets the surplus of production minus what it pays the team members. Then, if $g \geq 6/7$, the firm implements the most cooperative effort for the team, $e^* = 2w/k$, the incentive has $w = \frac{\overline{\phi}}{4(2-g)}$, and $\alpha = \frac{1}{2\delta}$. If $g < 6/7$, we have $e^* = \frac{3 - \sqrt{9 - 3g(2+g)}}{g}\frac{w}{k}$, increasing in g,*

$$w = \frac{\overline{\phi}}{2g}\frac{3 - \sqrt{9 - 3g(2 + g)}}{5 + g - \sqrt{9 - 3g(2 + g)}}, \tag{17}$$

and $\alpha = \frac{1}{2\delta}\frac{3 - g - \sqrt{9 - 3g(2+g)}}{g}$.

In this case, when the productivity of teams does not decline too quickly, $g > 6/7$, the firm decides to implement the effort level that is the most cooperative one for the team given the incentive scheme, which is the outcome of the previous subsection. Note that this is different from the case of Section 2, as here the firm gets the surplus net of payments to the team members, which leads to a lower effort level. This means that when g is relatively high, the firm prefers to keep the effort level at the highest possible level for cooperation in the team given the incentive scheme. For $g < 6/7$, the team productivity declines sufficiently over time, and the firm decides to implement lower effort levels, disassemble teams at a faster rate, and ultimately offer less steep incentive schemes. Figure 2 presents the evolution of the implement effort level e^*, the optimal incentive scheme w, the optimal team tenure α, and optimal expected payoff V, as a function of g.

It is interesting to note that, for $g < 6/7$, as g increases, the firm adjusts by having teams last longer (greater α), which allows the firm to implement greater effort levels (greater e^*). With the benefit of greater effort levels being possible because of the longer duration of teams, the firm can then reduce the power of the incentives w, as cooperation (and effort) is incentivized through the longer team duration. In this region, we can then have a negative correlation between the implemented effort e^* and the power of the incentives w, when g changes.

3.4. Declining Incentive Scheme over Time

In the subsections above, we considered that the incentive scheme remained constant over time, as that is typically seen in the real world in the situations where the model may apply. However, given that the stakes decline over time (declining team productivity over time), it could be better for the team to have an incentive scheme that declines in power over time. In the real world, this could be seen as greater support to teams closer to the time when they are assembled.

As a variation of the model above, consider that the payment to a team member when the team has a positive output, w, falls over time at a constant rate such that $w_{t+1} = w_t \gamma$, where $\gamma \in [0, 1]$.[16] We also assume that the effort being implemented also falls over time at the same rate. This restricted setup allows us to gain some insight about what happens when we allow the power of the incentive scheme to be declining over time. Let $\overline{w}$ be the w that is paid in the first period when the team is assembled, and $\overline{e^*}$ the effort that is implemented in that first period.

Then, the present value of profits from the team members starting at the time when the team is assembled is

$$V = \frac{2\overline{e^*}\overline{\phi}}{1 - \delta\alpha g\gamma} - \frac{4\overline{e^*}\overline{w}}{1 - \delta\alpha\gamma^2} + \frac{\delta(1 - \alpha)V}{1 - \delta\alpha}, \quad (18)$$

from which we can obtain

$$V = \frac{2\overline{e^*}\overline{\phi}}{1 - \delta\alpha g\gamma}\frac{1 - \delta\alpha}{1 - \delta} - \frac{4\overline{e^*}\overline{w}}{1 - \delta\alpha\gamma^2}\frac{1 - \delta\alpha}{1 - \delta}. \quad (19)$$

To obtain the optimal incentive scheme and effort level to be implemented over time, we can maximize (19) with respect to $\overline{w}$, $\overline{e^*}$, and γ subject to the effort level be among those that the team may wish to

Figure 2. (Color online) Optimal Incentive Scheme (w), Effort (e^*), Team Tenure (α), Average Firm Payoff ($(1 - \delta)V$), and Ratio $\frac{ke^*}{w}$ as a Function of g, for $\delta = .9, k = 1$, and $\overline{\phi} = 1$
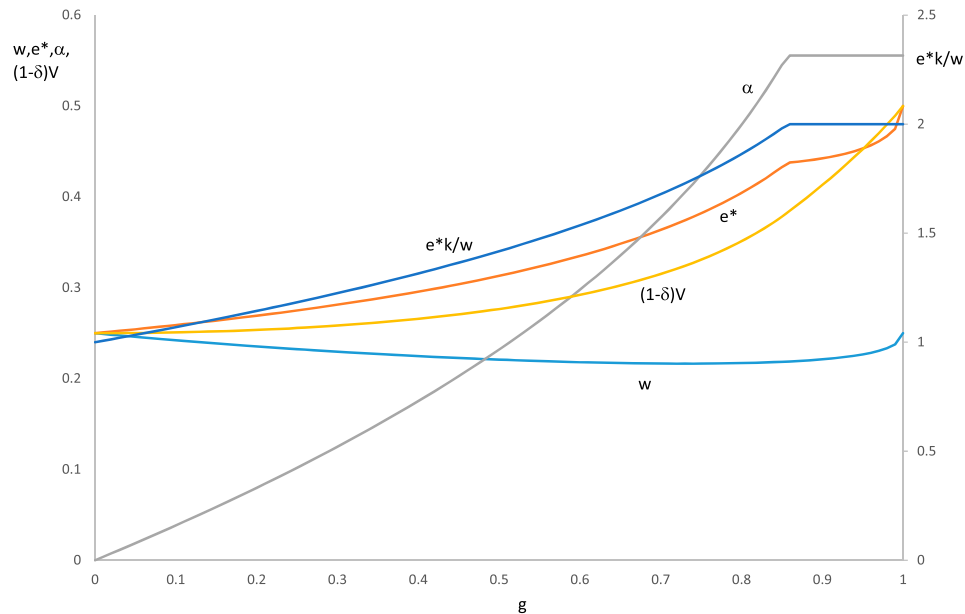
cooperate on given the incentive scheme, $\overline{e^*} \in [\frac{\overline{w}}{k}, \frac{2\overline{w}}{k}]$, and that the tenure of the team permits cooperation at that effort level,

$$\delta\alpha = \frac{k\overline{e^*} - \overline{w}}{2\overline{w}}. \tag{20}$$

Solving this problem yields the following solution.

Proposition 4. *Suppose that production is done in teams of two, that the firm gets the surplus of production minus what it pays the team members, and that the payment to team members and effort level decrease at the same constant rate. Then, the optimal rate of declining of the payment to team members and of effort level is the same as the rate of declining of team productivity, $\gamma = g$ and $\overline{w} = \overline{\phi}/4$. If $g \geq \sqrt{2/3}$, then $\overline{e^*} = \overline{w}/k$. If $g < \sqrt{2/3}$, then $\overline{e^*} = \frac{2+g^2-\sqrt{4-2g^2-2g^4}}{g^2}\frac{\overline{w}}{k}$.*

Interestingly, in this case when the incentive scheme and effort level is allowed to decline over time, we find that the declining rate of the incentive scheme and effort level is the same as the declining rate of the team productivity. This then leads the payment to each team member in case of success to be the same as a proportion of the high outcome, as in the case of no declining team productivity.

Note also that, as in the previous subsection, if team productivity does not decline too much (g high), the firm implements the effort level that generates full cooperation in the team given the incentive scheme. In this region of the parameter space, the optimal expected tenure of each team depends only on the discount factor δ. When the rate by which the team productivity declines is greater ($g < \sqrt{2/3}$), then the effort that is implemented and the optimal expected tenure of a team is decreasing in the rate of decline of team productivity.

The expected payoff for the firm in this case is greater than in the previous subsection, as the case of $\gamma = 1$ is the same as in the previous subsection, and we find that the optimal γ is different from 1.

3.5. Team Behavior to Hurt Firm

Another possibility of decreasing productivity of the team working together is that over time, the members of a team learn to capture some of the firm's resources for their own private benefit, hurting the firm. This capture of the firm's resources is done in a way that is not contractible, such that it cannot be part of the incentive scheme. For example, the equipment of the company could be deteriorating faster than it should because of less careful use by the team members, but the extent of deterioration of the firm's equipment is not contractible. As time passes, this capture increases, and at some point it is better for the firm to assign the employees to a new team.

A simple way to model this effect, starting from the model of Section 3.1, is to suppose that the payoff for

the firm at time t after the start of operation of the team is $(e_1 + e_2)(\overline{\phi} - 2w) - h(t)$, where $h(t)$ is the loss for the firm of the capture by the team members, with $h(0) = 0$ and $h'(t) > 0$.[17] The payoff for a team member i at time t would be $(e_1 + e_2)w + \beta h(t) - \frac{k}{2}e_i^2$, where $\beta \in (0, 1/2]$, which allows for the possibility that the benefit to the team member is lower than the extent to which the firm is hurt. Make also $h(t) = 1 - g^t$ with $g \in (0, 1)$.

Suppose that the firm dissolves the firm with probability α in each period. As the effort exerted under cooperation is $e_c = \frac{2w}{k}$, we can obtain as above that cooperation is possible as long as $\alpha \geq \frac{1}{2\delta}$.

Denoting the expected present value of the firm's profits when a team is first assmbled as V, we can obtain

$$V = (e_c + e_c)\frac{\overline{\phi} - 2w}{1 - \delta\alpha} - \frac{1}{1 - \delta\alpha} + \frac{1}{1 - g\delta\alpha} + \frac{\delta(1 - \alpha)V}{1 - \delta\alpha}, \tag{21}$$

which yields

$$V = \frac{4w}{k}\frac{\overline{\phi} - 2w}{1 - \delta} - \frac{1}{1 - \delta} + \frac{1 - \delta\alpha}{(1 - \delta)(1 - g\delta\alpha)}. \tag{22}$$

Maximizing V with respect to α under the constraint of full team cooperation yields $\alpha = \frac{1}{2\delta}$ and $w = \frac{\overline{\phi}}{4}$, which then gives $e_c = \frac{\overline{\phi}}{2k}$, the same as in Section 3.1.

We then obtain that when team members can learn to hurt the firm through time, the firm optimally rotates teams in finite time to trade off team cooperation against the team members learning to capture firm resources.

4. Concluding Remarks

We have found that forming teams that cooperate in a firm requires thinking about the tenure of the teams. With declining productivity over time in a team, a firm may want to extend the tenure of the team, so that credible punishments are possible to sustain cooperation in the team. The adjustment may also mean implementing less than full cooperation.

Overall, this can be seen as providing some factors in team formation because of the team's repeated interaction. It would also be interesting to investigate what happens when the incentive scheme can change over time, or when the team members play asymmetric roles in the team, which is not explored here. Furthermore, it would be interesting to investigate the effect of team size and how the benefit of cooperation may yield for firms to have smaller teams than optimal.

Appendix

Proof of Proposition 2. The result that the optimal γ is obtained from (9) for $g^2 > 3/7$ is obtained from the text, and by evaluating (9) at $\gamma = 1/2$. To check the second-order condition, note that the first-order condition is

$$\frac{dV}{d\gamma} = \frac{2\phi(0)}{g^2(1-\delta)} \frac{(2g^2 - 2\gamma + 1)(\gamma^2 - 3\gamma + 3) - \gamma(2-\gamma)(3-2\gamma)}{(3-2\gamma)^2}$$
$$= 0.$$

Then, we can obtain that the second-order condition reduces to

$$-(3-2\gamma)\big[2(\gamma^2 - 3\gamma + 3) + (3-2\gamma)(2g^2 - 2\gamma + 1)$$
$$+ (2-2\gamma)(3-2\gamma) + 2\gamma(2-\gamma) + 4\frac{dV}{d\gamma}\frac{g^2(1-\delta)(3-2\gamma)^2}{2\phi(0)}\big] < 0.$$

Given the first order condition, this second-order condition holds if $(3-2\gamma)^2 > 2(\gamma^2 - 3\gamma + 3)$, which holds for $\gamma \in [1/2, 1]$.

Let us now then consider the comparative statics on γ and α for $g^2 > 3/7$. From (9) it is immediate that the optimal γ is independent of δ. To consider the effect of g on γ, define $f(\gamma)$ as the right-hand side of (9). Then, note that $h(\gamma) = 4\gamma^4 - 24\gamma^3 + 63\gamma^2 - 78\gamma + 36$ has the same sign as $f'(\gamma)$. As $h''(\gamma) > 0$, $h(1) > 0, h(1/2) > 0, h'(1) < 0$, and $h'(1/2) < 0$, we have that $h(\gamma) > 0$ for all $\gamma \in [1/2, 1]$. Then, we have $\frac{d\gamma}{dg} > 0$.

Finally, to check the effect of g on $\alpha = \frac{2\gamma - 1}{2\delta g^2}$, note that the sign of $\frac{\partial \alpha}{\partial \gamma}$ is the same as the sign of $2g^2 - \frac{dg^2}{d\gamma}(2\gamma - 1)$, which can be shown to be positive for all $\gamma \in [1/2, 1]$.

Proof of Proposition 3. Differentiating (15) with respect to w under the constraint (16), and making it equal to zero, one obtains

$$\overline{\phi}ke^*(1-g) - [(2+g)w - gke^*] = 0. \tag{A.1}$$

Defining $n \equiv \frac{ke^*}{w}$, we can obtain from (A.1) that

$$w = \frac{\overline{\phi}n(1-g)}{(2 + g - ng)^2}. \tag{A.2}$$

Differentiating (15) with respect to e^* under the constraint (16), making it equal to zero, and using (A.1), one obtains

$$3(2+g)w - 6wke^* + gk^2e^{*2} = 0, \tag{A.3}$$

which yields

$$n = \frac{3 - \sqrt{9 - 3g(2+g)}}{g}. \tag{A.4}$$

The constraint $e^* \in [\frac{w}{k}, \frac{2w}{k}]$ is equivalent to $n \in [1, 2]$. We can then see that if $g > 6/7$, (iv) yields a $n > 2$, and in that case the optimal effort to implement has $e^* = \frac{2w}{k}$, and the optimal incentive scheme is $w = \frac{\overline{\phi}}{4(2-g)}$ as in the previous subsection. For $g \in [0, 6/7]$, (iv) yields $n \in [1, 2]$ and we can then obtain w from (A.1), $e^* = \frac{nw}{k}$, and $\alpha = \frac{ke^* - w}{2\delta w}$ as stated in the proposition.

Proof of Proposition 4. Differentiating (19) with respect to w given the constraint (20), and making it equal to zero, one obtains

$$\overline{\phi}k\overline{e^*}(1-g\gamma)[(2+\gamma^2)\overline{w} - \gamma^2 k\overline{e^*}]^2 - [3(2+\gamma^2)\overline{w}^2 + \gamma^2 k^2\overline{e^*}^2$$
$$- 6\gamma^2 k\overline{e^*}\overline{w}][(2+g\gamma)\overline{w} - g\gamma k\overline{e^*}]^2 = 0.$$
$$\tag{A.5}$$

Differentiating (19) with respect to γ given the constraint (20), and making it equal to zero, one obtains

$$4\overline{w}\gamma[(2+g\gamma)\overline{w} - g\gamma k\overline{e^*}]^2 - \overline{\phi}g[(2+\gamma^2)\overline{w} - \gamma^2 k\overline{e^*}]^2 = 0. \tag{A.6}$$

Differentiating (19) with respect to $\overline{e^*}$ given the constraint (20), making it equal to zero, and using (A.5), one obtains

$$[3(2+\gamma^2)\overline{w}^2 + \gamma^2 k^2\overline{e^*}^2 - 6\gamma^2 k\overline{e^*}\overline{w}][3(2+g\gamma)\overline{w}^2 + g\gamma k^2\overline{e^*}^2$$
$$- 2(2+g\gamma)k\overline{e^*}\overline{w}] - 2k\overline{e^*}\overline{w}(1-g\gamma)[3(2+\gamma^2)\overline{w}^2 + \gamma^2 k^2\overline{e^*}^2$$
$$- 2(2+\gamma^2)k\overline{e^*}\overline{w}] = 0.$$
$$\tag{A.7}$$

Solving for (A.5)–(A.7) together allows us to get $\overline{w}, \overline{e^*}$, and γ, as long as $\overline{e^*} \in [\overline{w}/k, 2\overline{w}/k]$. This yields $\gamma = g$ and $w = \overline{\phi}/4$. Furthermore, if $g < \sqrt{2/3}$, we get $\overline{e^*} = \frac{2 + g^2 - \sqrt{4 - 2g^2 - 2g^4}}{g^2}\frac{\overline{w}}{k}$, which is greater than $\overline{w}/k$ and smaller than $2\overline{w}/k$. If $g \geq \sqrt{2/3}$, then condition (A.6) does not hold and instead we have $\overline{e^*} = 2\overline{w}/k$, and we still have $\gamma = g$ and $\overline{w} = \overline{\phi}/4$.

Case with Multiplicative Effort Levels
Consider the model of the main text with the following variations: The productivity of a team is $\phi(t)e_1 e_2$, with $\phi(t) = k + (2-k)g^t$ with $k \in (1, 2), g \in (0, 1)$, and $e_i \in [0, \overline{e}]$. Under this case, the noncooperative effort equilibrium is $e_1 = e_2 = 0$, with the noncooperative equilibrium payoff $U_n(t) = 0$. The cooperative effort would be $e_1 = e_2 = \overline{e}$, and the cooperative effort payoff is $U_c(t) = \frac{1}{2}[\phi(t) - 1]\overline{e}^2$. The optimal deviating effort is $e_i = \frac{1}{2}\phi(t)\overline{e}$, which would lead to a payoff of $U_d(t) = \frac{1}{8}\phi(t)^2\overline{e}^2$.

The condition that each team member wants to continue cooperating at any time t can then be written as

$$\sum_{s=t}^{\infty}(\delta\alpha)^{s-t}\frac{1}{2}[k - 1 + (2-k)g^t] \geq \frac{1}{8}[k + (2-k)g^t]^2, \tag{A.8}$$

which reduces to

$$\frac{k-1}{1-\delta\alpha} + \frac{\phi(t) - k}{1 - \delta\alpha g} \geq \frac{1}{4}\phi(t)^2. \tag{A.9}$$

The left-hand side of (A.9) is increasing in α and δ, (A.9) holds strictly if $\delta, \alpha \to 1$, and (A.9) does not hold if $\delta = \alpha = 0$. Then, if δ is sufficiently high, there is a $\widehat{\alpha}$ such that (A.9) holds with equality, and, therefore, it holds for $\alpha \geq \widehat{\alpha}$. Similarly to the case in the main text, we can obtain that the expected present value of payoffs for each employee when starting in a new team is decreasing in α, and, therefore, the optimum is going to have $\alpha = \widehat{\alpha}$. The other results also follow in the same way.

Formulation of General Case of Declining Incentive Scheme over Time

This section presents the formulation of the problem for the firm if it wants to have a general declining incentive scheme, and implement a a time-varying cooperative effort level. Let e_t^* and w_t be the implemented effort level in period t and the payment in case of success in period t, respectively, where t is the number of periods since the team was assembled. The expected payoff in period t for each team member is $U^*(t) = 2e_t^* w_t - \frac{k}{2} e_t^{*2}$. If a team member deviates in period t, the best that that team member can obtain is $U_d(t) = e_t^* w_t + \frac{w_t^2}{2k}$. If both team members behave noncooperatively in period t, the expected payoff for each team member is $U_n(t) = \frac{3}{2k} w_t^2$.

Then, in period τ, for the team to want to cooperate at effort level e_τ^* it must be that

$$\sum_{t=\tau}^{\infty} (\delta\alpha)^{t-\tau} \left(2e_t^* w_t - \frac{k}{2} e_t^{*2} \right) \geq e_\tau^* w_\tau + \frac{w_\tau^2}{2k} + \sum_{t=\tau+1}^{\infty} (\delta\alpha)^{t-\tau} \frac{3}{2k} w_t^2. \tag{A.10}$$

As the firm is better off with greater effort, these inequalities will be satisfied with equality. Subtracting (A.10), evaluated at $\tau + 1$ and multiplied by $\delta\alpha$, from (A.10) evaluated at τ, one obtains,

$$e_\tau^* w_\tau - \frac{k}{2} e_t^{*2} + \delta\alpha e_{\tau+1}^* w_{\tau+1} = \frac{w_\tau^2}{2k} + (3 - \delta\alpha) \frac{w_{\tau+1}^2}{2k}, \tag{A.11}$$

which has to hold for all $\tau > 0$.

Consider then payoff for the firm. Setting V as the present value of profits when the team is assembled, we have

$$V = \sum_{t=0}^{\infty} \delta^t \left[2e_t^* \alpha^t (g^t \overline{\phi} - 2w_t) + \delta\alpha^t (1 - \alpha) V \right], \tag{A.12}$$

which reduces to

$$V = \frac{1 - \delta\alpha}{1 - \delta} \sum_{t=0}^{\infty} (\delta\alpha)^t \left[2e_t^* (g^t \overline{\phi} - 2w_t) \right]. \tag{A.13}$$

The optimum for the firm would then be to maximize (A.13) with respect to α, $\{e_t^*$, for $t \geq 0\}$, $\{w_t$, for $t \geq 0\}$ subject to the constraints (A.11) for all $\tau \geq 0$. It would be interesting to derive a further characterization of the solution to this problem in future research.

Endnotes

[1] See "How we brought teamwork to marketing" (*The Wall Street Journal*, August 26, 1996).

[2] See also Sethi and Nicholson (2001) and Sethi et al. (2001) for factors that may affect the performance of product development teams.

[3] An alternative explanation is that employees with a longer tenure in an organization have less to learn, or that the organization knows more about them, and therefore, the benefits of being in a team decrease less over time.

[4] See also Baker et al. (1994), Bernheim and Whinston (1998), and Fuchs (2007), among others.

[5] With teams, see also the work of Georgiadis (2014), who considers the dynamic problem of a team working toward completing a project, and has results on the optimal size of the team; and the work of Barron and Powell (2016), who consider the effects of firm policies on the possible relational contracts. Bonatti and Hörner (2011)

investigate the effect of procrastination as a form of free-riding in teams. Dogan and Yildirim (2017) considers the possibility of automation taking away the interaction among employees, and reducing the employees' peer monitoring capacity.

[6] Rajan and Reichelstein (2006) shows that correlation between performance measures by team members can benefit the firm.

[7] See the section on team organization in Lazear and Oyer (2012) for a survey on cooperation in teams, and Camerer and Weber (2012) for further discussion on the experimental evidence of organization incentives.

[8] We consider that the total number of employees is large enough such that the effect of future interactions with team members after the team is dissolved has minimal effect and is ignored. However, note that "contagious" punishments as in Ellison (1994) could be potentially possible and be an additional force toward cooperation in a team. This effect is not considered in this paper and would also be reduced with employee turnover. Another issue not considered here that would be interesting to investigate in future research is that employees may have input in team formation, for greater team productivity (like in matching settings; e.g., Kuksov 2007).

[9] The productivity of the team is formulated with additive efforts, but a case with multiplicative efforts is considered in the appendix, with the same general results.

[10] For example, in product development, a firm may give sufficient time for the team to have a chance to be successful, but at some point the team may be broken up (see Zhang 2016 for the importance of having deadlines in product development projects).

[11] One option not explored here is that, given that the productivity of the team is evolving over time for given effort levels, it may be that the firm can do better by implementing different effort levels over time, and adjusting over time the probability of the team being dissolved in a given period. Fully solving this problem is not possible given the infinite dimension of the effort levels to implement over time, and of the probability of dissolving the team at each instance.

[12] Note that leaving the team, and staying in the organization, is not possible as the teams are set up by the organization.

[13] We consider the private benefit of team membership to interact with the effort level, such that the team member is less motivated to exert effort over time and the equilibrium effort level falls over time. Alternatively, we could have the private benefit be independent of the effort level, and then the equilibrium effort level would not fall over time.

[14] We consider first the case in which the payment to the employee if there is a successful output is constant over time—constant incentive scheme—as this seems to represent what happens in the real world. Then, we also consider the case in which the incentive scheme can change over time.

[15] Not considered here, one could also potentially think of the full cooperation between all team members and the firm. The possibility of cooperation with the firm/manager may be less likely because the firm cannot see the efforts of the team members, while it is assumed here that the team members can observe the efforts of one another, which may be seen as a good approximation in several settings. The contracts considered here also do not allow for possible messages of the team members to the firm about the behavior of the other team members (such as "recommendation letters"), which may be an interesting possibility to explore in future research. In this regard, the possibility of cheap talk communication (e.g., Gardete 2013 and Gardete and Bart 2018) from the team members could also be interesting to investigate.

[16] The appendix shows the formulation of the problem for a general declining incentive scheme.

[17] This effect can potentially be micromodeled in more interesting ways. The current formulation just highlights the general effect.

References

Bacon J (2016) How to build good marketing teams. *Marketing Week* (June 22), https://www.marketingweek.com/2016/06/22/how-to-build-good-marketing-teams.

Baker G, Gibbons R, Murphy K (1994) Subjective performance measures in optimal incentive contracts. *Quart. J. Econom.* 109(4): 1125–1156.

Barron D, Powell M (2016) Policies in relational contracts. Working paper, Northwestern University, Evanston, IL.

Bernheim BD, Whinston MD (1998) Incomplete contracts and strategic ambiguity. *Amer. Econom. Rev.* 88(4):902–932.

Bonatti A, Hörner J (2011) Collaborating. *Amer. Econom. Rev.* 101(2): 632–663.

Boning B, Ichniowski C, Shaw K (2007) Opportunity counts: Teams and the effectiveness of production incentives. *J. Labor Econom.* 25(4):613–650.

Camerer, CF, Weber RA (2012) Experimental and organizational economics. Gibbons, Roberts J, eds. *Handbook of Organizational Economics* (Princeton University Press, Princeton, NJ), 213–262.

Campion M, Cheraskin L, Stevens M (1994) Career-related antecedents and outcomes of job rotation. *Acad. Management J.* 37(6): 1518–1542.

Che Y-K, Yoo S-W (2001) Optimal incentives for teams. *Amer. Econom. Rev.* 91(3):525–541.

Cosgel M, Miceli T (1999) Job rotation: Costs, benefits, and stylized facts. *J. Inst. Theoret. Econom.* 155(2):301–320.

Dogan M, Yildirim P (2017) Men vs. machine: When should firms adopt automation? Working paper, Carnegie Mellon University, Pittsburgh/University of Pennsylvania, Philadelphia.

Dumain B (1994) The trouble with teams. *Fortune* 130(5):86–92.

Ellison G (1994) Cooperation in the prisoner's dilemma with anonymous random matching. *Rev. Econom. Stud.* 61(3):567–588.

Eriksson T, Ortega J (2006) The adoption of job rotation: Testing the theories. *Indust. Labor Relations Rev.* 59(4):653–666.

Fuchs W (2007) Contracting with repeated moral hazard and private evaluations. *Amer. Econom. Rev.* 97(4):1432–1448.

Gardete P (2013) Cheap-talk advertising and misrepresentation in vertically differentiated markets. *Marketing Sci.* 32(4):609–621.

Gardete P, Bart Y (2018) Tailored cheap talk: The effects of privacy policy on ad content and market outcomes. *Marketing Sci.* 37(5):733–752.

Georgiadis G (2014) Projects and team dynamics. *Rev. Econom. Stud.* 82(1):187–218.

Griffin A, Hauser JR (1992) Patterns of communication among marketing, engineering and manufacturing—A comparison between two new product teams. *Management Sci.* 38(3):360–373.

Hamilton BH, Nickerson JA, Owan H (2003) Team incentives and worker heterogeneity: An empirical analysis of the impact of teams on productivity and participation. *J. Political Econom.* 111(3):465–497.

Holmstrom B (1982) Moral hazard in teams. *Bell J. Econom.* 13(2): 324–340.

Katzenbach JR, Smith DK (1993) The discipline of teams. *Harvard Bus. Rev.* 71(2):111–120.

Knez M, Simester D (2001) Firm-wide incentives and mutual monitoring at continental airlines. *J. Labor Econom.* 19(4):743–772.

Kuksov D (2007) Brand value in social interaction. *Management Sci.* 53(10):1634–1644.

Kvaløy O, Olsen TE (2016) Relational contracts for teams. Working paper, University of Stavanger, Stavanger, Norway/Norwegian School of Economics, Bergen, Norway.

Lazear EP, Oyer P (2012) Personnel economics. Gibbons R, Roberts J, eds. *The Handbook of Organizational Economics* (Princeton University Press, Princeton, NJ).

Levin J (2002) Multilateral contraction and the employment relationship. *Quart. J. Econom.* 117(3):1075–1103.

Levin J (2003) Relational incentive contracts. *Amer. Econom. Rev.* 93(3): 835–857.

MacLeod WB, Malcomson JM (1989) Implicit contracts, incentive compatibility, and involuntary unemployment. *Econometrica* 57(2):447–480.

Manz CC, Sims HP (1993) *Business Without Bosses* (Wiley, New York).

Mirrlees J (1974) Notes on welfare economics, information and uncertainty. Balch M, McFadden D, Wu S, eds. *Essays on Economic Behavior under Uncertainty* (North-Holland, Amsterdam), 243–258.

Nalbantian HR, Schotter A (1997) Productivity under group incentives: An experimental study. *Amer. Econom. Rev.* 87(3):314–341.

Ortega J (2001) Job rotation as a learning mechanism. *Management Sci.* 47(10):1361–1370.

Osterman P (2000) Work reorganization in an era of restructuring: Trends in diffusion and effects on employee welfare. *Indust. Labor Relations Rev.* 3(2):179–196.

Rajan M, Reichelstein S (2006) Subjective performance indicators and discretionary bonus pools. *J. Accounting Res.* 44(3):585–618.

Rayo L (2007) Relational incentives and moral hazard in teams. *Rev. Econom. Stud.* 74(3):937–963.

Sarin S, Mahajan V (2001) The effect of reward structures on the performance of cross-functional product development teams. *J. Marketing* 65(2):35–53.

Sethi R, Nicholson CY (2001) Structural and contextual correlates of charged behavior in product development teams. *J. Product Innovation Management* 18(3):154–168.

Sethi R, Smith DC, Park CW (2001) Cross-functional product development teams, creativity, and the innovativeness of new consumer products. *J. Marketing Res.* 38(1):73–85.

Slotegraaf RJ, Atuahene-Gima K (2011) Product development team stability and new product advantage: The role of decision-making processes. *J. Marketing* 75(1):96–108.

Zhang J (2016) Deadlines in product development. *Management Sci.* 62(11):3310–3326.