Incentives to help or sabotage among co-workers*

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Abstract

This paper studies compensation contracts and career concerns of co-workers when a worker’s individual production depends on her colleague’s effort and ability. We show that a manager who commits herself to a life-time salary path may induce a low risk-averse worker to help her colleague, while she may induce a high-risk averse worker even to sabotage. We argue that the manager may allow little sabotage in order to decrease the provided insurance and motivate the worker to focus on her own project and increase her own production. If commitment is not feasible and thus the contracts are renegotiated in each period, career concerns arise and a worker now has incentives to help or sabotage her colleague in her attempt to shape market assessments about her own ability. The manager will now use explicit contracts as a mean of diminishing the worker’s (implicit) incentives to sabotage. We show that career incentives to affect their colleagues’ production also arise for temporary workers who will be paired with another worker in the next period. This happens in this model because a worker can build up her own reputation by influencing her current colleagues’ production.

Keywords: career concerns, compensation contracts, sabotage incentives, relative performance

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1 Introduction

In recent years, the re-engineering of R&D process in large corporations has shifted the organization of work towards various forms of teamworking and colleague collaboration. The cross-functional and multi-disciplinary nature of research departments often entails that co-workers have different abilities that bring in the workplace. The degree to which each researcher contributes to a colleague’s project and the number of years each researcher stays in a firm also vary. The U.S. Bureau of Labor Statistics shows that for 2016, the median tenure of engineers was 5.5 years, and that of mathematical and computer scientists was 4.4 years. Innovative firms also differ in their employment policies: they sign either long-term or short-term contracts with their workers, although a worker’s research outcome also depends on the abilities of her colleagues with whom she interacts.\(^1\) This paper studies how compensation contracts are shaped by managerial commitment and career concerns when a worker’s individual performance is influenced by her colleagues’ effort and ability.\(^2\)

We employ Holmström’s (1982, 1999) career concerns framework where neither the workers nor the market know workers’ innate abilities. We show that the manager who fully commits to a lifetime income path may induce a low risk-averse worker to help her colleague, while she may motivate a high risk-averse worker even to sabotage. We argue that the manager may allow little sabotage in order to decrease the provided insurance and motivate the workers to focus on their own projects and increase their own outputs. If commitment is not feasible and short-term contracts are provided which are renegotiated in each period, we show that a worker now has incentives to sabotage her colleague because she wants to bias the learning process about her ability in her favor and built up her reputation. The manager now will use explicit compensation to decrease the worker’s eagerness to sabotage. When a worker’s ability affects her colleague’s performance, help or sabotage incentives arise even for temporary workers who will be paired with another worker in the next period. This happens in our model because a worker can manipulate market perceptions about her own ability also through her current colleagues’ production.

In research labs and modern corporations, the ability of a worker to be a good team player is considered as an asset, but under certain conditions, allowing for little sabotage may be optimal. One can consider a case in which two workers in the same department of a corporation are up to performance review and only one of them will be promoted in the current year. In this case, while one is presenting her ideas or the progress of her project in a meeting, the other worker has incentives

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\(^1\)Empirical literature provides evidence that knowledge is transmitted among colleagues and skills diversity affects labor supply and productivity (Lazear (1999)). The benefits of colleague interactions depend on whether the workers have distinct or identical knowledge and skills, indicating the degree of heterogeneity among the co-workers.

\(^2\)The use of career concerns as an incentive device in the intra-firm relationships which may substitute explicit incentives due to compensation contracts is first discussed by Fama (1980) and elaborated by Holmström (1982). Gibbons & Murphy (1992) consider linear contracts and formalize this argument.
to address challenging questions to the speaker, in order to make her look bad. We can also consider active sabotage as effort to hide or destroy some part of the other’s output. The benefit of setting a contractual parameter negative, which induces sabotage, is to decrease the variance of a worker’s wage, and thus decrease the insurance that needs to be provided. The worker who experiences sabotage will also be motivated to focus more and work harder on her own project. Thus, in our example, the worker will have incentives to get better prepared for her presentation in the meeting and increase her performance, despite her colleague’s efforts to sabotage her.

We consider a risk-neutral manager who appoints two risk-averse workers whose individual project outputs are observable and contractible, allowing the manager to treat workers separately through individual-based schemes (Itoh (1991), Itoh (1992), Auriol, Friebel & Pechlivanos (2002)). The incentive packages are derived in a linear principal-agent model (Holmström & Milgrom (1987), Gibbons & Murphy (1992)) and are based on explicit comparisons of co-workers’ outputs. A worker’s production function is linear in her "work" effort and her own innate ability, her colleague’s "help" effort and ability, and a transitory shock. Workers consider work and help provision as two separate tasks and their cost-of-effort functions are task-specific. Thus, a worker’s ability influences her colleague’s performance. Workers’ abilities and the shocks in production are independent and normally distributed. We also consider different degrees of incoming and outgoing skills benefit to and from a worker, which indicate how sensitive a worker’s output is to her colleague’s characteristics. The degrees of colleague interactions that measure the contribution of a worker’s help effort to another’s production can also be different. All these parameters are exogenous.

First, we assume that multiperiod contracts are feasible, implying that the manager can commit herself to a life-time income path before the realization of production. The optimal contractual parameter based on a worker’s own project output is always positive, indicating that a higher performance is rewarded with a higher payment. However, the sign of the optimal contractual parameter based on her colleague’s project output is not straightforward. We argue that the manager will induce low risk-averse workers to help each other, inducing cooperation between them, but this may not be the case for a highly risk-averse worker whose contribution in her colleague’s production is small. In our model, both performance measures are sensitive to both worker’ unknown abilities, increasing the variance of the rewards. Due to risk-sharing, the manager provides insurance that involves a

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3The existing literature uses such contracts when the market shocks that hit workers’ production are correlated. In our setting, market shocks are independent, however, as in Chalioti (2016), individual outputs are correlated due to colleague interactions. Relative performance evaluation schemes are the consequence of the efficient use of information conveyed by both performance measures about a worker’s effort and ability.

4Some principal-agent models allow both parties to hold some bargaining power (e.g., Pitchford (1998)) while other models assume that either party can make a ‘take-it-or-leave-it’ offer (e.g., Mookherjee & Ray (2002)).

5Because of task-specific cost functions, there are benefits of influencing a colleague’s project output. Such incentives will not arise with a total-effort-cost function as in Holmström & Milgrom (1991a), where there are negative externalities between the tasks: providing support crowds out effort allocated to a worker’s own task.
negative help effort, inducing sabotage. It aims to decrease the variance of a worker’s wage and thus the required insurance. Because of sabotage, both workers also have stronger incentives to focus on their own projects and improve their own production. Thus, the manager is benefited because the cost of exerting effort decreases while the total production increases. This is in sharp contrast to Auriol et al. (2002) who assume that a colleagues’ support depends only on her effort (not her ability). They argue that the manager, who provides long-term contracts, always induces the workers to help each other, regardless of their degree of tolerance against risk.

Second, we establish that under full commitment, while a manager can induce a worker to help her colleague when tenure is short, she may induce the same agent to sabotage if tenure is long. That is because the covariance of a worker’s wages that are provided in different periods depends on the variance of both workers’ abilities. As employment extends to many periods, the risk associated with both workers’ abilities increases and influences significantly the manager’s perception about workers’ effort levels. Thus, a manager who establishes help between the co-workers when employment is short, she may allow for sabotage as the duration of long-term contracts increases.

Third, assuming that commitment is not feasible, the manager offers short-term contracts that give rise to career concerns. She now renegotiates the contracts with the workers in each period. The market draws inferences about abilities via both workers’ past project outputs. By exerting effort, a worker can influence her own and her colleague’s performance measures in order to bias the learning process in her favor. A worker now wants to help or sabotage her colleague in her attempt to induce an upward revision of her own estimate of ability and thus increase her future remuneration. She wants to look as productive as possible in absolute and relative terms. The manager now uses explicit (short-term) contracts to weaken a worker’s reputational incentives to help or her desire to sabotage.

Different compensation contracts are offered to temporary workers who will stay in the firm but be paired with another worker in the next period or be hired by a different firm. They know that they are unable to capitalize any change in market beliefs about her current colleague’s ability. However, in our model, reputational incentives to help or sabotage also arise for a temporary worker because her own reputation depends on her current colleague’s output. In Auriol et al. (2002), any implicit incentives to influence a teammate’s production disappears in the case of temporary workers. Our analysis shows that if sabotage incentives arise between the co-workers, the manager would prefer to hire them on a permanent basis because sabotage between pairs who stay together is not as intense as for temporary workers. If the co-workers have incentives to help, the manager will prefer to reshuffle teams every period in order to undo the distortions that arise due to the uncertainty about a co-worker’s ability. We analyze the conditions under which incentives to help or sabotage arise, attempting to better understand team formation.

This paper is tied to the literature on career concerns based on Holmström (1982a). In his
single-agent model, career concerns induce a worker who has bargaining power vis-à-vis the market to work harder in the current period in order to build up her reputation, seeking for higher future rewards. In a two-agent model, Meyer & Vickers (1997) show that a worker with no bargaining power wants to increase her reputational bonus but a ratchet effect arises. This happens because in her attempt to convince the market that she is of higher ability, the worker increases the expectations with respect to her production, allowing the manager to become more demanding. Thus, assuming that workers’ abilities are positively correlated, each worker free-rides on the effort of the other to enhance reputation. Auriol et al. (2002) use relative performance evaluations, and consider work and help as two separate tasks, while a worker’s output depends only on her own ability. The process of inference of each worker’s ability is independent. They examine ‘passive’ sabotage because agents become reluctant to help their colleagues. Lazear (1989) considers sabotage incentives in tournaments. In our setting, the workers’ innate characteristics are independent but they enter in both workers’ production functions. We show that incentives to help or sabotage arise through career concerns and explicit contracts to both long-term and temporary workers. Nevertheless, the channels through which explicit incentives are determined in these two contractual environments are different.\footnote{Bernhardt (1995) studies how the unobservability and composition of a worker’s skills affect wage and promotion paths. Bar-Isaac & Deb (2014) depart from the assumption of homogeneous ‘audiences’ who will assess agents’ abilities and examine career concerns when the audiences have diverse preferences. Ferrer (2010) studies the effects of lawyers’ career concerns on litigation when the outcome of a trial depends on the opposing lawyers’ effort and abilities. Cisternas (2017) considers that a worker’s skills follow a Gaussian process with an endogenous component reflecting human-capital accumulation and discusses the worker’s decisions to exert effort or invest in skill acquisition. Bilanakos (2013) argues that the provision of general training increases the worker’s bargaining power vis-à-vis the employer.}

We also contribute to the existing literature on moral hazard in teams.\footnote{This paper is related to the literature on team incentives that examines the degree of visibility of workers’ characteristics; i.e. Ortega (2003), Jeon (1996), Bar-Isaac (2007), Arya & Mittendorf (2011), Dewatripont, Jewitt & Tirole (1999), Dewatripont, Jewitt & Tirole (2000), Effinger & Polborn (2001), Milgrom & Oster (1987), Mukherjee (2008).} In a multi-agent environment where individual outputs are observable and correlated, a worker’s compensation contract is made contingent on her colleague’s production. Holmström (1982b) and Mookherjee (1984) show that relative performance evaluation (RPE) schemes can filter out the common shock from a worker’s reward, assuming that there are no technological interactions among workers. Since the workers are exposed to lower risk, the trade-off between insurance and incentives is shifted, facilitating stronger explicit incentive schemes. Itoh (1991, 1992) shows that a manager who uses RPE can install cooperation among workers only if the correlation between the workers’ performances is low. We assume that the abilities and production shocks are uncorrelated but individual productions depends on both workers’ innate abilities which are unknown as in Chalioti (2016). We investigate how effectively a manager can induce cooperation or competition between workers through RPE when principal’s commitment power changes.

This paper also complements the literature on the substitutive relationship between explicit and
implicit incentives based on Gibbons & Murphy (1992), due to the additive production technology. Dewatripont et al. (1999) show that explicit and implicit (reputation) incentives may become complements, assuming that ability and effort enter the production function in a multiplicative fashion. Meyer, Olsen & Torsvik (1996) state that the ratchet effect can be weakened by inducing teamwork. In our setting where RPE schemes are provided and a worker’s ability influences both workers’ performance measures, a worker’s implicit incentives to help or sabotage depend on both contractual parameters of her future explicit compensation.

The paper is organized as follows. Section 2 describes the model and discusses the production technologies. Section 3 analyzes the contracts when the manager can fully commit herself to a lifetime income path. It analyzes the optimal explicit incentives in a two-period and a multi-period setting. Section 4 studies short-term contracts when workers stay together as long as employment lasts. It discusses the process of inference of workers’ abilities and the trade-off between explicit and implicit incentives for these long-term workers. We also focus on the explicit and implicit motivation for temporary workers. Section 5 concludes.

2 The model

There are two risk averse workers, denoted by $i$ and $j$, where $i \neq j$. They live for two periods indexed by $t = \{1, 2\}$ and they do not discount the future. They are also appointed by a risk neutral and profit seeking manager who compensates them with explicit contracts. At each period $t$, each individual works to fulfill her own project, while interacting with her colleague. Both project outputs are observable and contractible, allowing the manager to deal with each worker separately as in Itoh (1991, 1992).

2.1 Production technology

In period $t$, each worker $i$ controls a stochastic production process in which her project output, $z^i_t$, is the sum of her own innate ability, $\theta^i$, her nonnegative work effort, $e^i_t$, her colleague’s support and a transitory shock, $\varepsilon^i_t$. Worker $j$’s support depends on her own ability, $\theta^j$, weighted by a parameter $h_j \in [0, 1]$, and her help effort, $a^j_t$, weighted by $k_j \in [0, 1]$. Thus, worker $i$’s production function is

$$z^i_t = \theta^i + e^i_t + \varepsilon^i_t + h_j \theta^j + k_j a^j_t. \quad (1)$$

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8We normalize the price of each worker’s output to one and in all periods, we assume that the scale of production remains the same.
Before production takes place, all parties have symmetric but imperfect information about workers’ abilities as in Holmström (1982). However, the workers and all prospective employers believe that \( \theta^i \) is drawn from a normal distribution with zero mean and variance \( \sigma_i^2 \), where \( \sigma_i^2 < \sigma_j^2 \). Thus, there is less uncertainty about worker \( i \)'s attribute. The abilities are also independent of each other and of the noise terms. Worker \( i \)'s attribute \( \theta^i \) can manifest the worker’s ability to successfully accomplish a project which is symmetrically unknown to all parties at each stage. The random terms \( \varepsilon_i^t, \varepsilon_i^j \) follow a normal distribution with zero mean and variance \( \varphi_i^2 \) and \( \varphi_j^2 \), respectively, where \( \varphi_i^2 < \varphi_j^2 \). They are also independently distributed across workers and periods.

In this model, a worker’s ability and "help" effort enter her colleague’s production process additively. Note that although a worker always exerts (positive) work effort to improve her own project outcome, her career concerns and the principal-agent problems may induce her, in equilibrium, either to help or even sabotage her colleague. Thus, workers’ help efforts \( a_i^t \) and \( a_j^t \) can be negative. The parameter \( h_j \) measures the degree of incoming skills benefit to worker \( i \) that is generated by working together with a worker of ability \( \theta^j \). It indicates how sensitive worker \( i \)'s output is to her colleague’s attribute. Similarly, \( h_i \) denotes the degree of outgoing skills benefit from worker \( i \) to worker \( j \). These parameters are exogenous and less than one, so are \( k_i \) and \( k_j \). The parameter \( k_j \) captures the degree of incoming colleague interactions which is the fraction of worker \( j \)'s help effort that increases worker \( i \)'s project output, while \( k_i \) represents the degree of outgoing colleague interactions. It shows the contribution of worker \( i \)'s help effort to worker \( j \)'s production. The nature of such interactions is imperfect, implying that putting effort into a worker’s own task is more productive than providing help to a fellow worker. The level of all these parameters affects each worker’s capacity to influence individual production as well as manipulate market perceptions about abilities.

### 2.2 Workers’ preferences and objectives

Worker \( i \) receives the reward \( w_i^t \) and has constant absolute risk-averse (CARA) preferences. She is endowed with the utility function

\[
U^i = -\exp \left( -r_i \sum_{t=1}^{2} \left[ w_i^t - g \left( e_i^t \right) - y \left( a_i^t \right) \right] \right),
\]

where \( r_i \) is the Arrow-Pratt measure of risk aversion, \( 0 < r_i < r_j \). Due to the additive separability of the utility function, workers do not consider income smoothing across periods. They make their decisions as if they enjoy access to perfect capital markets in each period.

The contracts depend linearly on both workers’ project outputs since the performance measures

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9Some papers study the optimal explicit incentives when the worker is better informed about her own characteristics than the market (Laffont & Tirole (1988)).
are correlated due to colleagues’ interactions. Holmström & Milgrom (1987) establish that in a model much like the single-period version of this model (but lacking the uncertainty about a worker’s ability), the optimal contract is linear.\textsuperscript{10} Gibbons & Murphy (1992), in a single-agent model, and Auriol et al. (2002), in their multi-agent framework, also consider contracts that are linear in outputs. At each period \( t \), the manager offers contracts of the form \( C_i^t \equiv (\omega_i^t, \beta_i^t, \gamma_i^t) \) and worker \( i \) receives

\[
w_i^t = \omega_i^t + \beta_i^t x_i^t + \gamma_i^t z_i^t, \tag{3}\]

where \( \omega_i^t \) denotes the fixed salary component and \( \beta_i^t, \gamma_i^t \) are the incentive parameters. Such incentive schemes introduce either cooperation or competition between the workers, depending on the sign of \( \gamma_i^t \).

Risk-aversion on the part of the workers is essential when explicit contracts are provided so that the incentive parameters are less than one. Otherwise, the optimal contract will impose substantial human capital risk on the workers. Gibbons & Murphy (1992) consider explicit payments and state that risk-aversion is necessary so that optimal contracts do not completely eliminate career concerns. In particular, a risk-averse worker wishes to be insured against low realizations of her project output and thus, weaker explicit incentives are provided. Given that explicit payments decrease, reputational incentives increase.

We assume that workers’ disutilities are task specific, as in the multi-agent models of Auriol et al. (2002), and Itoh (1992). The cost functions of work effort and help effort, \( g(e_i^t) \) and \( y(a_i^t) \) respectively, are twice continuously differentiable and convex, implying that there are diminishing returns to scale in the production process. However, it is more costly for a worker to exert effort to influence her colleague’s production rather than working to accomplish her own project; i.e.,

\[
g'(\{x\}) \leq y'(\{x\}) \quad \text{and} \quad g''(\{x\}) \leq y''(\{x\}) \quad \text{for any} \quad x \in \mathbb{R}. \]

We also assume that \( g'(0) = 0, y'(0) = 0, \lim_{e_i^t \to -\infty} g'(e_i^t) = \infty \) and \( \lim_{a_i^t \to +\infty} y'(a_i^t) = +\infty.\textsuperscript{11} \) The cross-partial of the cost function is also zero: the cost of exerting effort to perform a given task is independent of the cost of the other task. A worker can focus on eliciting effort to affect her colleague’s project output without having to consider simultaneously technologically founded externalities. Putting effort in a task does not require effort away from the other task. Multitasking in the absence of crowding out effects between the tasks keep worker highly motivated to elicit effort in environments where sabotage incentives may emerge. However, we assume that exerting work effort is less costly than exerting help effort, implying that

\textsuperscript{10}Holmström & Milgrom (1987) show that in a static version of their dynamic model, the optimal compensation scheme that is offered to a worker with CARA preferences is a linear function of the performance measures.

\textsuperscript{11}Other models of multitasking based on Holmström & Milgrom (1991b) assume total-effort-cost functions. The cross-partial derivatives with respect to two tasks are positive. As a worker increases the effort devoted to one task, the marginal cost of effort to the other task will also increase. Thus, exerting help effort would be costly to a worker and it crowds out effort directed to her own project, decreasing her own production. In equilibrium, each worker equates the marginal return to effort in both tasks.
the agent finds it relatively more productive to direct her effort to her own project.

Under full information, the manager observes the workers’ effort levels and thus can make contract offers that achieve specific effort assignments. In particular, worker $i$’s payment is fixed and equal to the sum of the cost of both efforts, $g(e_i^t) + y(a_i^t)$. The workers receive the same contract in each period which is the repetition of the optimal contract in a one-shot game. The first best contracts provide perfect insurance to the workers against low realizations of production. The first-best levels of work and help efforts, $e_i^{t,FB}$ and $a_i^{t,FB}$, satisfy the conditions $g'(e_i^{t,FB}) = 1$ and $y'(a_i^{t,FB}) = k_i$, respectively.

3 Long-term contracts

We assume that long-term contracts are feasible. In a two-period model, the manager can commit herself to a second-period salary before the observation of the first-period outputs. Thus, the manager succeeds in insulating a worker’s expected life-time compensation from the risk associated to true abilities - actual $\theta^i$ and $\theta^j$. This risk significantly affects each period’s explicit incentives when short term contracts are provided and career concerns arise. However, in the case where the manager commits herself to a life-time salary path, a worker’s problem is identical in each period. Note that a long-term contract is not identical with two one-period contracts.

3.1 Two-period model

The manager’s net profit equals the sum of the project outputs net of workers’ compensations. In a two-period model, the manager’s problem is

$$
\max_{c_i^t,s_i^t,a_i^t} E\{U^P\} = E \left\{ \sum_{t=1}^{2} \sum_{i=1}^{2} (z_i^t - w_i^t) \right\}
$$

subject to $CE^i \equiv \sum_{t=1}^{2} \left[ E\{w_i^t\} - g(e_i^t) - y(a_i^t) - \frac{1}{2} Var\{w_i^1 + w_i^2\} \right] \geq 0, \; \forall i \quad (IR^i)$

$$
e_i^{i*} = \arg \max_{e_i^t} CE^i, \; \forall i,t \quad (IC_{e,i}^i)
$$

$$
a_i^{i*} = \arg \max_{a_i^t} CE^i, \; \forall i,t \quad (IC_{a,i}^i)
$$

where $Var\{w_i^1 + w_i^2\} = \left[ \sum_{t=1}^{2} (\beta_i^t + h_i \gamma_i^t) \right]^2 \sigma_i^2 + \left[ \sum_{t=1}^{2} (h_j \beta_i^t + \gamma_i^t) \right]^2 \sigma_j^2 + \sum_{t=1}^{2} \left[ (\beta_i^t)^2 \varphi_i^2 + (\gamma_i^t)^2 \varphi_j^2 \right]$.

The individual rationality $(IR^i)$ constraint shows that the worker will participate in the production process only if the certainty equivalence of her utility, $CE^i$, exceeds her outside option.$^{12}$ Since the

$^{12}$In this multi-agent framework, the monotone likelihood ratio property (MLRP) and the convexity of the distribution function condition (CDFC) are not sufficient for the first-order approach to be valid as in a single-agent
manager specifies the long-term incentive schemes before the realization of the first period outputs, the outside option is equal to her expected innate ability, which is normalized to zero.\textsuperscript{13}

In this framework where workers’ utility is additively separable across time, and current production is independent of the workers’ past outcomes, the manager cannot exploit any gains from intertemporal risk sharing. Instead, the certainty equivalence specifies compensation contracts that are contingent only on the contemporaneous outcomes: the second-period rewards depend only on the second-period outcomes, ignoring the first-period production. Thus, the same payment schemes are provided in both periods, implying that the workers’ problem is identical across time. The \((IR^i)\) constraint is binding at the optimum. Notice that only the sum of the base payments in both periods, \(\omega_{1,f} + \omega_{2,f}\), is determined by the optimal contract; the subscript \(f\) denotes the equilibrium values in the full commitment case. Because of this feature, the manager can guarantee that her workers will not exercise their right to quit before the end of this relationship. By setting a very low first-period base payment and a very large second-period base payment, the manager can costlessly make unprofitable the option of quitting for both workers.

The incentive compatibility constraints, \((IC^i_e,t)\) and \((IC^i_a,t)\), guarantee that a worker chooses the (expected) utility maximizing efforts. The optimal work and help efforts satisfy, respectively,

\[
\beta^i_t = g' (e^i_t) \quad \text{and} \quad \gamma^i_t = y' (a^i_t), \quad \forall i.
\]

The long-term explicit incentives are\textsuperscript{14}

\[
\beta^i_f = \frac{1}{1 + r_i \left( \Sigma^i_f + \Phi_f^i \Sigma^{ij}_f \right) g^u_f} \quad \text{and} \quad \gamma^i_f = \Phi_f^i \beta^i_f,
\]

where \(\Phi_f^i \equiv k_f^2 \left( 1 - r_i \Sigma^{ij}_f y^u_f \right) - 2 r_i \Sigma^{ij}_f y^u_f\), \(\Sigma^{ii}_f \equiv \phi_i^2 + 2 \left( \sigma_i^2 + h_i^2 \sigma_j^2 \right)\) and \(\Sigma^{ij}_f \equiv h_i \sigma_i^2 + h_j \sigma_j^2\). The second derivatives \(g^u_f\) and \(y^u_f\) are always positive because of the convexity of the cost-of-effort functions. Proposition 1 establishes that the manager who provides long-term contracts may find it optimal to induce a worker to sabotage her colleague. This is in sharp contrast to Auriol et al. (2002) where the long-term explicit incentives based on both workers’ performance measures are always positive, inducing a worker always to help her colleague.

\textsuperscript{13}If a worker does not enter the labor marker or her alternative is to work in an informal sector in the absence of moral hazard, her payoff equals her expected ability. The manager’s problem is solved in appendix (A.1).

\textsuperscript{14}In case of perfect colleague interactions and identical skills benefit, \(h_i = h_j = k_i = k_j = 1\), where there are no frictions in interacting with a coworker, both incentive parameters in (5) are identical. Wages are contingent on the total output and only the observation of the aggregate measure \(z^i_t + z^j_t\) is needed.

setting. Itoh (1991) argues that, in a model with cross-agent interactions, a generalized CDFC for the joint probability distribution of the outputs is needed and the wage schemes must be nondecreasing. The coefficient of absolute risk aversion must also not decline too fast. Our model with workers’ CARA preferences, linear contracts and production technologies satisfies all these assumptions and thus the first-order approach applies.
Proposition 1 (Long-term explicit incentives) Given that the manager fully commits to a worker’s life-time income path, the equilibrium pay-for-own-performance parameter is always positive, $\beta_i^j > 0$, while the pay-for-other-performance parameter is negative, $\gamma_i^j < 0$, inducing a high-risk averse worker to sabotage, if and only if
\[
\frac{k_i^j(1+\sum g''_j)}{2\sigma_i^j} - h_j \sigma_i^j < h_i.
\]

Proof. In Appendix (A.1). ■

The positive sign of $\beta_i^j$ indicates that a worker’s higher own project output is compensated with a higher wage. In particular, under moral hazard, workers seek insurance against the risk they face. Due to risk-sharing, the manager provides insurance that involves underprovision of effort in respect to the accomplishment of both tasks. The more risk averse the workers are, the lower powered is the incentive scheme. Indeed, both $\beta_i^j$ and $\gamma_i^j$ fall short from their efficient levels. However, the sign of $\gamma_i^j$ is less straightforward.

The degree of colleague interactions and the contribution of workers’ abilities in performance measures play a key role in specifying the optimal long term explicit incentives. The manager sets $\gamma_i^j$ positive if the outgoing colleague interactions are large (high $k_i$), implying that the provided help effort will significantly increase the co-worker’s output. The manager anticipates the support a worker provides to her colleague and rewards her when her colleague does better. The "compensation ratio" $\left| \frac{\gamma_i^j}{\beta_i^j} \right|$ is also larger in compensation packages that are rewritten to accommodate an increasing $k_i$. The higher $k_i$ is, the more sensitive is worker $j$’s project output to worker $i$’s help effort. Relative performance evaluation schemes can effectively be used as means of internalizing the positive effects of providing support. The optimal $\gamma_i^j$, when positive, increases with the uncertainty about worker $i$’s ability and the variance of worker $i$’s transitory shock, $\sigma_i^2$ and $\varphi_i^2$, while decreases with $\sigma_j^2$ and $\varphi_j^2$.

A positive $\gamma_i^j$ also requires the outgoing skills benefit, captured by $h_i$, to be small enough. A risk-averse worker will require additional insurance because of both workers’ (unknown) abilities which affect both performance measures, and indeed, a positive $\gamma_i^j$ increases the variance of worker $i$’s wage. However, it also increases the performance of her co-worker. If $z_i^j$ is more sensitive to worker $i$’s help effort rather than on her ability ($h_i$ lower than $k_i$), implying that the increase in the cost of exerting help effort is smaller than the increase in a colleague’s production, the manager motives a worker to help.

As the degree of outgoing colleague interactions increases (higher $k_i$), implying that worker $i$’s help effort weights more in her colleague’s project output, the manager sets a lower $\beta_i^j$ and a higher $\gamma_i^j$. Worker $i$’s support to her colleague becomes increasingly more important and the manager is benefited by shifting worker $i$’s focus on improving her colleague’s production. Any change in $k_j$ leaves worker $i$’s incentives unaffected since the channel through which her efforts influence the total production and the risk to which she is exposed only depend on $h_i$, $h_j$ and $k_i$. Besides, as the
degree of the incoming skills benefit from worker $j$ to worker $i$, measured by $h_{ij}$, increases, $\beta_{ij}$ will decrease. Worker $i$’s output as a performance measure becomes noisier, implying that it conveys less information about worker $i$’s work effort. In turn, the manager relies less on $z_i^t$ to anticipate $e_i^t$. Given also that the variance of her compensation increases due to higher risk which is introduced by a factor incorporated in $z_i^t$, a lower $\beta_{ij}$ will mitigate this effect. Thus, the manager considers to balance between the optimal incentives and the focus of the agent.

Given also that the variance of her compensation increases due to higher risk which is introduced by a factor incorporated in $z_i^t$, a lower $\beta_{ij}$ will mitigate this effect. Thus, the manager considers to balance between the optimal incentives and the focus of the agent.

For a high risk averse worker $i$ whose help effort weights less than her ability in her colleague’s performance (high $h_i$ and low $k_i$), the manager sets $\gamma_f^i$ negative. Under full commitment to a life-time salary path, negative explicit incentives are in contrast to the existing literature on motivation in teams as in Auriol et al. (2002). In their model, the pay-for-other-performance parameter is lower than the optimal pay-for-own-performance parameter, but always positive. In our framework, such incentives can be reversed. This happens because the sensitivity of both performance measures on both colleagues’ abilities, which are unknown, increases the variance of the rewards, and by setting $\gamma_f^i$ negative, the manager aims exactly in decreasing the variance of worker $i$’s wage. Notice that because of a negative $\gamma_f^i$, worker $i$ is induced to sabotage, while she is rewarded for the effort she put in sabotaging her colleague; i.e., worker $i$’s wage depends on $k_i\gamma_f^ia_i^t$ which is positive.

Given that the manager’s benefit equals the sum of both projects’ outputs, $z_i^t + z_j^t$ at each period $t$, one could consider that the manager would prefer to shut down any incentives of worker $i$ to affect her colleague’s output by setting $\gamma_f^i$ zero. In this case, $\beta_f^i$ is smaller, so is the total production $z_i^t + z_j^t$. It is optimal for a profit-seeking manager to set a negative $\gamma_f^i$ and increase $\beta_f^i$ so as to motivate worker $i$ to focus on her own project. Because $k_i$ is small, the effect of sabotage will also be small. Thus, we argue that the manager may allow for little sabotage in order to decrease the provided insurance and encourage a worker to focus on her own projects, increasing her own outputs. Even if the degree of cross-agent interactions are equal, the intensity of optimal incentives and thus workers’ focus of
attention will depend on the amount of noise about each worker's abilities which is reflected by the variance of $\theta$s.

**Proposition 2 (Precision about abilities & optimal incentives)** Suppose $k_i = k_j = h_i = h_j$, $r_i = r_j$, and that the manager has a better precision about worker $i$'s ability, $\sigma^2_i < \sigma^2_j$. Then, the manager will offer an incentive scheme to worker $i$ which is more individually oriented than the one given to worker $j$: $\beta^i_f > \beta^j_f$ and $|\gamma^i_f| < |\gamma^j_f|$.

Proposition 2 highlights that the manager will exert a higher work effort and a lower help effort by the worker with the lower variance of her ability. Since the manager has more information about $\theta^i$, worker $i$ is induced to focus more on the own project than influencing her colleague's production.

### 3.2 Multiperiod model

We now examine the effects of fully committing to a life-time salary path when employment extends to many periods. Suppose that the workers are appointed for $\tau$ periods, where $\tau > 2$. In this framework, the variance of the life-time payments is

$$\text{Var} \left( \sum_{t=1}^{\tau} w^i_t \right) = \left[ \sum_{t=1}^{\tau} (\beta^i_t + h_i \gamma^i_t) \right]^2 \sigma^2_i + \left[ \sum_{t=1}^{\tau} (h_j \beta^i_t + \gamma^i_t) \right]^2 \sigma^2_j + \sum_{t=1}^{\tau} \left[ (\beta^i_t)^2 \varphi^2_i + (\gamma^i_t)^2 \varphi^2_j \right].$$

In equilibrium, the contractual parameters become

$$\beta^i_{r,f} = \frac{1}{1 + r_i (\Sigma_{r,f} + \Phi^i_{r,f} \Sigma^{ii}) g^m}$$
and
$$\gamma^i_{r,f} = \Phi^i_{r,f} \beta^i_{r,f},$$

where
$$\Phi^i_{r,f} \equiv \frac{k^2_i (1 + r_i \Sigma^{ii}_{r,f} g^m - \tau r_i \Sigma^{ii} y^m_{r,f})}{k^2_i (1 - r_i \Sigma^{ii} g^m) + r_i \Sigma^{ii} y^m_{r,f}},$$
and
$$\Sigma^{ii}_{r,f} \equiv \varphi^2_i + \tau (\sigma^2_i + h^2_j \sigma^2_j).$$

Proposition 3 highlights that for a short employment period, an agent can be induced to help her colleague, while for a long employment period, such incentives can be negative. Thus, sabotage incentives are more likely to prevail for highly risk-averse agents whose tenure is long.

**Proposition 3 (Incentives & multiperiod employment)** Given that the manager fully commits to a life-time income path, equilibrium pay-for-other-performance parameter is negative, $\gamma^i_{r,f} < 0$, if and only if worker $i$'s work employment period is long enough,

$$\frac{k^2_i (1 + r_i \varphi^2_i y^m_{r,f})}{r_i \Sigma^{ii} y^m_{r,f} - k^2_i (\sigma^2_i + h^2_j \sigma^2_j) g^m} < \tau.$$

Note that under the assumption of independently distributed random terms, the covariance of wages offered in different periods depends solely on $\sigma^2_i$ and $\sigma^2_j$ (not $\varphi^2_i$ and $\varphi^2_j$), since we have
E. Chalioti: Incentives to help or sabotage among co-workers.

\[ \text{cov} \left( w_i^t, w_{i+1}^t \right) = 2 \left[ \left( \beta^i_t + h_i \gamma^i_t \right) \left( \beta^i_{t+1} + h_i \gamma^i_{t+1} \right) \sigma^2_i + \left( h_j \beta^i_t + \gamma^i_t \right) \left( h_j \beta^i_{t+1} + \gamma^i_{t+1} \right) \sigma^2_j \right], \text{for any} \ t. \]

Thus, for a longer employment period, the noise in the production processes introduced by a colleague’s ability matters more in shaping workers’ contracts. As employment extends to many period, a colleague’s unknown ability affects a worker’s production in many periods, increasing the risk to which the worker is exposed. Higher risk in longer-term contracts is compensated with weaker pay-for-own-performance incentives; i.e., \( \frac{\partial \beta^i_{t+1}}{\partial \theta^i_t} < 0 \) for all \( \tau \). Besides, although for a short employment period, the manager would incentivize a worker to help her colleague (positive \( \gamma^i_{t+1} \)), for a longer employment period, the manager will induce the same worker to sabotage (negative \( \gamma^i_{t+1} \)), seeking to decrease the variance of her wage. Under full commitment, contracts with different duration can provide opposing incentives to the same worker on how to influence a colleague’s production because of principal’s attempts to decrease the insurance she needs to provide.

This analysis indicates that the manager would prefer to hire low-risk averse workers with work experience suitable to both projects, so that their efforts have a significant impact in both project outputs (high \( k_s \)). The variance of their \( \theta_s \) should also be small enough. Having formed a pair whose members have incentives to help each other, the manager will prefer to sign long-term contracts with them for many years of employment - i.e., manager’s net payoffs increase with \( \tau \).

4 Short-term contracts

We now examine the explicit incentives in a 2-period setting where the manager cannot commit herself to a life-time compensation scheme. Instead, she renegotiates a contract offer in each period. Career concerns arise and substitute explicit motivation.

4.1 Timing of the game and reputational bonus

The timing of the game has as follows. In the beginning of period 1, the manager simultaneously makes a contract offer to each worker. If a worker accepts the offer, she makes the effort choices. Events beyond the workers’ control occur, both project outputs are realized and the contracts are executed. In period 2, all parties observe the realization of \( z^i_1 \) and \( z^j_1 \), and update their assessments about abilities. Thus, past production affects future remuneration and incentives. A new contract offer is made to each worker and if she stays in the firm, she chooses the new effort levels. After the observation of the current production, the rewards are paid.

If a worker rejects the contract offer, she receives her outside option that equals her reputational bonus

\[ \Theta^i_t \equiv (1 + h_i) E \left\{ \theta^i_t \mid z^i_{t-1}, z^j_{t-1} \right\} + c^i_t + k_i \tilde{a}^i_t. \]
That is a fixed payment equals the total rents each worker can claim for her contribution to both workers’ project outputs. Given the available information, her payment increases with an upward revision of the market’s estimate of her own ability.

4.2 Learning process and career concerns

All parties observe past production in order to infer the level of workers’ abilities. When output shocks are uncorrelated and a worker’s ability does not affect her colleague’s performance as in Auriol et al. (2002), the process of inference of each worker’s ability is independent. However, in this model where worker i’s ability enters worker j’s production function, \( z_j^1 \) also conveys information about \( \theta_i \). As in Chalioti (2016), both performance measures can be used in the updating process about \( \theta_i \).

We compute the conditional distribution of \( \theta_i \) in period 2, which is normal with mean and variance, respectively,

\[
E\{\theta_i | z_i^1, z_j^1\} = \rho_{i1} \left( z_i^1 - \tilde{c}_i^1 - k_j \tilde{a}_i^1 \right) + \rho_{ij} \left( z_j^1 - \tilde{c}_j^1 - k_i \tilde{a}_j^1 \right),
\]

\[
\sigma_{i2}^2 = \sigma_i^2 \left( 1 - \rho_{i1} - h_i \rho_{ij} \right),
\]

where \( \tilde{c}_i^1 \) and \( \tilde{a}_i^1 \) are the conjectures of worker i’s current efforts. In comparison to the full commitment case, the variance of each worker’s second-period production is smaller because all parties observe past performance and thus have more precise predictions about workers’ abilities. The conditional correlation coefficients are, respectively,

\[
\rho_{i1}^i \equiv \text{corr} \{\theta_i, z_i^1 | z_j^1\} = \frac{\sigma_{i2}^2}{\lambda_1} \left[ \varphi_i^2 + (1 - h_i h_j) \sigma_j^2 \right],
\]

\[
\rho_{ij}^i \equiv \text{corr} \{\theta_i, z_j^1 | z_i^1\} = \frac{\sigma_{i2}^2}{\lambda_1} \left[ h_i \varphi_j^2 - (1 - h_i h_j) h_j \sigma_j^2 \right],
\]

where \( \lambda_1 = \varphi_i^2 \varphi_j^2 + (1 - h_i h_j)^2 \sigma_i^2 \sigma_j^2 + \varphi_i^2 \left( \sigma_i^2 + h_i^2 \sigma_i^2 \right) + \varphi_j^2 \left( \sigma_j^2 + h_j^2 \sigma_j^2 \right). \)

The signal \( \rho_{i1}^i \) is always positive, \( \rho_{i1}^i > 0 \), implying that given the realization of a colleague’s production, a worker’s high own performance signals high own ability and vice versa. However, the sign of \( \rho_{ij}^i \) is less straightforward. It is positive as long as the outgoing skills benefit to worker j is substantial (high \( h_i \)), while the incoming skills benefit is small enough (low \( h_j \)) so that worker i’s performance is not very sensitive to her colleague’s ability \( \theta_j \). Given \( z_i^1 \), a higher colleague’s output \( z_j^1 \) is a good signal for worker i since it is attributed to her own ability, resulting in an upward revision of the market estimate of \( \theta_i \). Effort is a substitute for ability, implying that a worker can manipulate market perceptions about her ability by distorting effort levels. Thus, in the absence of explicit motivation where a worker’s reward exactly equals her reputational bonus, worker
i would have incentives to help her colleague in order to build up her reputation. Worker i’s help will increase $z^j_1$, inducing the market to update its assessments about $\theta^j$ upwards, increasing worker’s future remuneration.

The opposite occurs in a setting with a small outgoing skills benefit, $h_i$, but high $h_j$. Now, both signals are sensitive to $\theta^j$, while the impact of worker i’s ability, $\theta^i$, on worker j’s production is insignificant. In this case, it is more likely that both performance measures reflect the level of a colleague’s ability $\theta^j$. If both workers perform well, the market attributes these outcomes to high $\theta^j$, causing the estimate of $\theta^j$ to be revised downwards. A higher output from worker j is now a bad signal of worker i’s ability. By helping a colleague to further increase her project output, worker i will induce market inferences to be revised against her. Instead, bad performance by her colleague will be a good signal of her own ability. A decrease in $z^j_1$ will increase worker i’s reputation so that even when explicit contracts are not provided, she will now have incentives to sabotage her colleague because of career concerns. She want to sabotage in her attempts to bias the learning process in her favor.

Assuming also that all parties have rational expectations, we have $\hat{c}^i_1 = c^i_1$ and $\hat{a}^i_1 = a^i_1$. The equilibrium conjectures must be correct. The presence of noise insures that there are no off-equilibrium realizations of observables, and in equilibrium, each agent is restricted to exert the levels of effort that are expected of her. Under provision of effort will influence the updating process against her.

### 4.3 Permanent workers

The manager’s problem is the same as in the full commitment case, but with a different individual rationality ($IR^2_i$) constraint in each period $t$,

$$CE^i_t \equiv \sum_{t=1}^{2} \left[ E \{ w^i_t \mid z^i_{t-1}, z^j_{t-1} \} - g(c^i_t) - y(a^i_t) - \frac{r^i_t}{2} \text{Var} \left\{ \sum_{t=1}^{2} w^i_t \mid z^i_{t-1}, z^j_{t-1} \right\} \right] \geq \Theta^i_t.$$ 

In period 2, each worker i can now take a report of both her own and her colleague’s first-period outputs to her manager and other prospective employers in order to let them compare the performances. Given both reports, the manager offers to each worker i her reputational bonus $\Theta^i_2 = (1 + h_i) E \{ \theta^i \mid z^j_1, z^j_1 \}$. The $IR^2_i$ constraint is binding at the optimum, implying that the manager is equally well-off by hiring either a high reputation worker at a high wage or a low reputation worker at a low wage. Each worker knows that competing employers cannot make a better offer than $\Theta^i_2$.\(^{15}\)

\(^{15}\)Gibbons & Murphy (1992), Holmström (1999), among others, assume that the workers have all the bargaining power, and thus the manager maximizes subject to a zero-profit condition. In a multi-agent setting, this assumption would be problematic. Following Auriol et al. (2002), we consider a bargaining process that effectively makes each worker the residual claimant only to her reputational bonus. Though, the qualitative results would be the same in both bargaining environments.
This bargaining outcome can arise as the equilibrium of an extensive-form game. In this game, a worker is randomly assigned to a prospective employer and queues with the other job applicants. The employer makes a contract offer to the first worker in line. If the worker accepts the offer, she works for this employer. Otherwise, the worker queues for another job and the employer makes an offer to the next worker in line. Therefore, each worker receives only her own reputational bonus. The manager signs the most appealing contracts.

The second period in the short-term contracting framework is isomorphic to the incentives raised in the first period in the full-commitment case, analyzed in Section 3. In particular, the optimal work and help efforts, $e_i^*$ and $a_i^*$, satisfy equations (4). We also compute the base payment by solving the $IR_i^2$ constraint when binding:

$$\omega_i^2 = \Theta_i^2 - E\{\beta_i^2 z_i^2 + \gamma_i z_i^2 \mid z_i, z_1\} + g(e_i^*) + y(a_i^*) + \frac{r_i}{2} Var\{w_i^2 \mid z_i, z_1\}.$$ 

The optimal contractual parameters $\beta_i^*$ and $\gamma_i^*$ can be obtained by (5) replacing $\Sigma_i^i$ with $\Sigma_i^2 \equiv \varphi_i^2 + h_i^2 \sigma_i^2 + \sigma_{j_2}^2$ and $\Sigma_i^j$ with $\Sigma_j^i \equiv h_i^2 \sigma_{i_2}^2 + h_j^2 \sigma_{j_2}^2$. We also have $\Phi_i^2 \equiv \frac{k_i^2(1-r_i\Sigma_i^2 y_i''')-r_i\Sigma_i^j y_i'''}{k_i^2(1-r_i\Sigma_j^2 y_i''') + r_i\Sigma_i^j y_i'''}$.

In period 1, workers have explicit incentives from the compensation contracts and implicit incentives from career concerns. There is an implicit dependence of the future wage on the current project outputs. Current efforts affect the intercept of future wage, $\omega_i^2$, but not the incentive parameters $\beta_i^*$ and $\gamma_i^*$ because there are no wealth effects in worker utility and the production functions are additive. Both workers have the same marginal product of effort regardless of their true ability. The optimal explicit incentives depend on the variance of outputs but not on their mean. As a result, worker $i$ chooses the effort levels that satisfy the conditions

$$\beta_i^* + M_p^i = g'(e_i^*) \quad \text{and} \quad k_i (\gamma_i^* + M_p^i) = y'(a_i^*),$$

where $\frac{\partial \omega_i^*}{\partial e_i} \equiv M_p^i$ and $\frac{\partial \omega_i^*}{\partial a_i} \equiv k_i M_p^i$. A permanent worker $i$'s implicit incentives that arise through work and help efforts are, respectively,

$$M_p^i \equiv (1 + h_i - \beta_i^* - h_i \gamma_i^*) \rho_{1i}^i - (h_j \beta_j^* + \gamma_j^*) \rho_{1j}^i,$$ (6)

$$M_p^j \equiv (1 + h_i - \beta_j^* - h_i \gamma_j^*) \rho_{1j}^j - (h_j \beta_j^* + \gamma_j^*) \rho_{1j}^j.$$ (7)

Notice that the terms $(\beta_i^* + h_i \gamma_i^*) \rho_{1i}^i$ and $(h_j \beta_j^* + \gamma_j^*) \rho_{1i}^i$ in equation (6) arise due to the effect of $e_i^*$ on $E\{\theta_i^2 \mid z_i, z_1\}$ and $E\{\theta_i^2 \mid z_i, z_i^2\}$ through $z_i$. Similarly, the terms $(\beta_i^* + h_i \gamma_i^*) \rho_{1j}^j$ and $(h_j \beta_j^* + \gamma_j^*) \rho_{1j}^j$ in equation (7) arise due to the effect of $a_i^*$ on the conditional expectations of $\theta_i^j$ and $\theta_i^j$ through $z_i$. 
The implicit incentives captured by $M_{ij}^{ii}$ indicate that by exerting more work effort in the first period, a worker aims to increase her reputation, and thus gain by the subsequent increase in her reputational bonus by $(1 + h_i) \rho_{ij}^{ii}$. However, this bonus is diminished by $(\beta_2^{i*} + h_i \gamma_2^{i*}) \rho_{ij}^{ii} + (h_j \beta_2^{j*} + \gamma_2^{j*}) \rho_{ji}^{ij}$. Suppose that a worker is low risk averse, requiring small insurance, and the outgoing colleague interactions are large (high $k_i$) so that $\gamma_2^{ij} > 0$. If $\rho_{ij}^{ij} \equiv \text{corr} \{\theta_j, z_1^j | z_1^i\}$ is positive, the manager anticipates that worker $j$ has reputational incentives to help her co-worker $i$ and increase her project output. Thus, because worker $i$ is going to be assessed as being of higher ability and the explicit incentive component of her future remuneration is going to be large, the manager offers a contract whose base payment increases by less than the increase in the worker’s reputational bonus. Notice though that if $\rho_{ij}^{ii}$ is negative, worker $j$ has reputational incentives to sabotage. The manager now anticipates such incentives and adjusts the base payment upwards by $(h_j \beta_2^{j*} + \gamma_2^{j*}) \rho_{ji}^{ij}$. Sabotage by a colleague makes it harder for a worker to perform well and enjoy a high output. The manager takes it into account. For a high risk averse worker who receives a contract with $\gamma_2^{ij} < 0$ in order to be insured against risk, the base payment is also adjusted. Because of the effort-insurance trade-off, the explicit component of the second-period contract is going to be smaller, resulting in a higher base payment.

Worker $i$’s reputational incentives to influence her colleague’s output are captured by $M_{ij}^{ij}$. The most interesting cases are when $\rho_{ij}^{ij} < 0$. If a worker helps her colleague, the latter’s output will increase, benefiting her colleague, but making herself worse off. The manager will perceive that the worker is paired with a high productivity colleague. It is in worker $i$’s interest to convince the manager the opposite, sabotaging her colleague because of her career concerns. A negative $\gamma_2^{ij}$ is going to make worker $i$ less eager to sabotage. The manager can now use a negative $\gamma_2^{ij}$ as a tool to decrease the risk to which the worker is exposed as well as reduce her appetite to sabotage because of her career concerns.

To derive the first period explicit incentives, we denote $B_{ij}^i \equiv \beta_1^i + M_{ij}^{ii}$ and $\Gamma_1^i \equiv \gamma_1^i + M_{ij}^{ij}$. The equilibrium incentive parameters in the first period are

$$
\beta_1^{i*} = \frac{1}{\Omega_1^i} - M_{ij}^{ij} - r_i g_{1i}^{in} \left( k_i^2 + r_i \varphi_2^{ij} g_{1i}^{in} \right) \left[ (\sigma_i^2 + h_j^2 \sigma_j^2) \beta_2^{ij*} + \Sigma_{ij}^{ij} \gamma_2^{ij*} \right] + r_i (1 - h_i h_j) \sigma_i^2 \sigma_j^2 g_{1i}^{in} \beta_2^{ij*},
$$

(8)

$$
\gamma_1^{i*} = \frac{\Phi_1^i}{\Omega_1^i} - M_{ij}^{ij} - r_i g_{1i}^{in} \left( 1 + r_i \varphi_2^{ij} g_{1i}^{in} \right) \left[ \Sigma_{ij}^{ij} \beta_2^{ij*} + (\sigma_j^2 + h_i^2 \sigma_i^2) \gamma_2^{ij*} \right] + r_i (1 - h_i h_j) \sigma_i^2 \sigma_j^2 g_{1i}^{in} \gamma_2^{ij*},
$$

(9)

where $\Omega_1^i \equiv 1 + r_i \left( \Sigma_{ij}^{ij} + \Phi_1^i \Sigma_{ij}^{ij} \right) g_{1i}^{in}$ and $\zeta_1^i \equiv k_i^2 \left( 1 - r_i \Sigma_{ij}^{ij} g_{1i}^{in} \right) + r_i \Sigma_{ij}^{ij} g_{1i}^{in}$ (see appendix (A.2)).

To better understand these results, we decompose the optimal explicit incentives and examine the underlying effects. The first term in (8) reflects a *noise reduction effect* that arises due to changes in the ‘amount’ of available information about ability. In the next period, as the market learns
more about abilities and their conditional variances decrease, we have $\Omega_1^i > \Omega_2^i$. Therefore, learning reduces risk over time and stronger explicit incentives to work can be provided, $\beta_2^{is} > \frac{1}{\Omega_1^i}$. Higher $k_i$ shifts the incentive-insurance trade-off towards the former even more.

The last terms in both equations (8) and (9) capture human capital insurance effects: risk-aversion and uncertainty about abilities induce each worker to require insurance against low realizations of both $\theta^i$ and $\bar{\theta}^i$. The manager offers contracts that insure the workers against the intertemporal risk they face. When both $\beta_2^{is}$ and $\gamma_2^{is}$ are positive and large, a worker $i$ incurs higher risk in the second period. Thus, the manager reduces the first-period incentives $\beta_1^{is}$ and $\gamma_1^{is}$ in order to share the intertemporal risk. If the manager uses a negative $\gamma_2^{is}$ as a tool to decrease the risk a worker $i$ faces in the second-period, the decrease in $\beta_1^{is}$ and $\gamma_1^{is}$ that is caused by the human capital insurance effects is smaller.

The manager also adjusts the optimal explicit incentives to account for workers’ career concerns. Equation (8) shows that the manager imposes a lower pay-for-own performance relation when the optimal reputational incentives to work are stronger. Similarly, equation (9) shows that when $M_{ij}^j > 0$, $\gamma_1^{is}$ is adjusted downwards. However, if a worker $i$ has reputational incentives to sabotage her colleague, the optimal $\gamma_1^{is}$ increases. Such incentives need to be undone by a higher $\gamma_1^{is}$. The first term in equation (9) captures the compensation ratio effect which shows how effective relative performance evaluation schemes are in inducing help or sabotage between the co-workers from the beginning of their employment.\textsuperscript{16}

The workers’ optimal incentives are differ from those in Lazear (1989) where sabotage incentives arise in tournaments because a worker’s compensation is conditioned negatively to her colleagues’ performances. Using such schemes, workers may desire to destroy other workers’ output rather than to work harder on their own project. In our model, even if workers have incentives to sabotage because of career concerns, a negative $\gamma_2^{is}$ is used to decrease the risk to which a worker $i$ is exposed and also to weaken worker’s eagerness to sabotage. A negative $\gamma_2^{is}$ is also associated with a higher $\beta_2^{is}$, motivating the worker to focus more on her own project. This result is also different from Meyer & Vickers (1997) where the workers’ abilities are correlated and reputational incentives are weakened due to the ratchet effect. In Auriol et al. (2002), reputational incentives to sabotage arise only when explicit contracts are provided, because workers become reluctant to help their colleagues. There is an implicit ratchet effect. In turn, the manager offers more collectively oriented incentives contracts.\textsuperscript{17}

\textsuperscript{16}If we analyze a one-period model, we have $\gamma_1^{is} = \frac{\epsilon_2^i}{\Omega_1^i} = \Phi_{ij} \beta_1^{is}$.

\textsuperscript{17}Fama (1980)’s conclusion that explicit contracts are unnecessary to solve the principal-agent conflicts, since the market induces the "right" effort levels, also holds in our model. As in Holmström (1999), we assume that $T \rightarrow \infty$ and workers discount the future with some factor $\delta \in [0, 1]$. Abilities fluctuate over time and remain unknown to the parties: $\theta_{i+1}^j = \theta_i^j + \eta_i^j$, where $\eta_i^j \sim N(0, \sigma_i^j)$ is independently distributed. In the supplementary material, we show that if there is no discounting, $\delta = 1$, and $r_i > 0$, the stationary explicit incentives are zero and efforts are efficient for any $h_i, h_j, k_i$ and $k_j$. Bar-Isaac & Hörner (2014) and Bonatti & Hörner (2017) discuss the relationship between
4.4 Temporary workers

We have assumed so far that workers differ with respect to their innate abilities and they are assigned to work together as long as employment lasts. Tenure is long and a worker \( i \) sees her employment in a firm with a specific co-worker \( j \) as a life-time career. Instead, we can assume that in the end of each period, either a worker enters the external labor market seeking for a new employer since her tenure in a specific firm is short, or a worker stays in the firm but is paired to work with a different worker of different ability. We want to examine how reputational incentives and explicit contracting are shaped when employment or partnerships are temporary. Workers do not intent to manipulate the market’s assessments about her current colleague’s ability since there are no benefits of convincing the market that she is paired with a low productivity worker. Market perceptions about \( \theta^j \) play no role in worker \( i \)’s future remuneration. However, in our setting, reputational incentives to help or sabotage still arise because the current colleague’s output is used in the updating process about a worker’s own ability.

Each worker knows that in each period, she will be paired with another worker or work for another firm. In Auriol et al. (2002), any reputational incentives to influence the current colleague’s output disappear. Each worker knows that she is unable to capitalize any change in market beliefs about her current colleague’s ability while she has to bear the cost of exerting effort to bias these beliefs. The learning process about her own ability is also independent from her current colleague’s output. However, in our model, this is not the case.

Reputational incentives to work and help or sabotage still arise when the duration of pairing is short:

\[
M_{ii}^T = (1 + h_i - \beta_2^{i*} - h_i \gamma_2^{i*}) p_{1i}^i, \tag{10}
\]

\[
M_{ij}^T = (1 + h_i - \beta_2^{i*} - h_i \gamma_2^{i*}) p_{1j}^{ij}. \tag{11}
\]

The comparison of equations (6) and (10) reveals that a temporary worker does not bother to influence the expected ability of her current colleague, since she will not be paired with her in the following period. Thus, the last term in (6) which reflects the incentives of a long-term worker \( i \) to manipulate market perceptions about \( \theta^i \) disappears. In our model, a worker who is appointed in a temporary basis still intends to exert \( \alpha^i_1 \) in order to affect her current colleague’s output because she will induce an upward revision of the market estimate of her own ability \( \theta^i \). By influencing \( z_1^i \), worker \( i \) can bias the learning process in her own favor, regardless the fact that indirectly the estimate of \( \theta^i \) is also affected. Lemma 1 will help us compare the reputational incentives to work and help of permanent and temporary workers.

career concerns and market structure in different settings.
Lemma 1 If 
\[ \frac{(1+h_{ij})k_i^2}{(\Sigma_j^i - h_{ij}\Sigma_j^i)y_{ji}^i + (h_{ij}\Sigma_j^i - \Sigma_i^i)g_{ji}^i} > r_i, \] then \( h_{ij}\beta_{2i}^* + \gamma_{2i}^* > 0. \)

Proposition 4 compares the intensity of reputational incentives of a worker \( i \) when she is paired with her colleague at a temporary or permanent basis. What plays a key role is whether her colleague has reputational incentives to help (when \( \rho_{ji}^i > 0 \)), or sabotage her (when \( \rho_{ji}^i < 0 \)).

**Proposition 4 (Career concerns of temporary workers)** Suppose that worker \( i \) is low risk-averse so that \( h_{ij}\beta_{2i}^* + \gamma_{2i}^* > 0 \) holds from Lemma 1.

(i) A temporary worker \( i \) has stronger reputational incentives to work than a permanent worker \( i \), \( M_{ij}^T - M_{ij}^P > 0 \), if and only if \( \rho_{ji}^i > 0 \).

(ii) Reputational incentives to help or sabotage arise for a temporary worker \( i \) and are always stronger than for a permanent worker \( i \), \( |M_{ij}^T| - |M_{ij}^P| > 0 \).

A permanent low-risk averse worker, so that \( h_{ij}\beta_{2i}^* + \gamma_{2i}^* > 0 \), who receives help from her colleague has weaker career concerns compared to a temporary worker. She needs to exert lower effort in order to build up her reputation. However, when a higher work effort, \( e_1^i \), induces a downward revision of the estimate of \( \theta_j \), worker \( j \) will have reputational incentives to sabotage, making harder for worker \( i \) to perform well in her own project. Thus, to secure a higher reputation bonus, a long-term worker \( i \) who receives sabotage and is also going to be paired with the same worker \( i \) in the next period, she has to focus and work more on her own project compared to what a temporary worker does. The opposite results hold for a high risk-averse worker. For instance, when this worker receives help from her long-term colleague, she now has weaker reputational incentives. Exerting work effort to influence the learning process in her favor becomes more costly for her.

A permanent low-risk averse worker, so that \( h_{ij}\beta_{2i}^* + \gamma_{2i}^* > 0 \), also has weaker reputational incentives to help and stronger incentives to sabotage her colleague compared to a temporary worker. Influencing market’s perceptions about a colleague’s reputation is important for a long-term worker. In that sense, a long-term worker seems to be less ‘altruistic’, although she will be paired with her co-worker as long as employment lasts. However, a high risk-averse worker seems to be more altruistic when she tries to build up her reputation, with stronger incentives to help and weaker incentives to sabotage compared to temporary workers. The contractual incentives will also be different. When pairing is short, a temporary worker does not bear any intertemporal risk associated with her current colleague’s human capital. The equilibrium incentive parameters in the first period are

\[
\beta_{1T}^i = \frac{1}{\Omega_{1T}^i} - \frac{r_i\sigma_i^2y_{iT}^i}{\zeta_{1T}^i\Omega_{1T}^i} \left[ k_i^2 + r_i(\varphi_j^2 + (1-h_{ij})\sigma_j^2) \right] \left( \beta_{2i}^* + h_i\gamma_{2i}^* \right), \tag{12}
\]

\[
\gamma_{1T}^i = \frac{\Phi_{1T}^i}{\Omega_{1T}^i} - \frac{r_i\sigma_i^2y_{iT}^i}{\zeta_{1T}^i\Omega_{1T}^i} \left[ h_i + r_i(h_i\varphi_i^2 - h_j(1-h_{ij})\sigma_j^2) \right] \left( \beta_{2i}^* + h_i\gamma_{2i}^* \right), \tag{13}
\]
The terms $\Phi_{i1T}$, $\Omega_{i1T}$ and $\zeta_{i1T}$ are the same to those for the permanent workers replacing $y_i''$ with $y_i''$, and $g_i''$ with $g_i''$.

This analysis suggests that if low-risk averse workers are hired whose help efforts have a significant impact in both project outputs (high $k$s) and the variance of their abilities is small so that they have incentives to help each other, the manager will prefer to reshuffle teams after one period. She can undo the distortions due to the unknown abilities of the co-workers by forming the ‘teams’ at a temporary basis. However, if the workers are high risk-averse and there is high uncertainty about their abilities - for example, they can be junior workers hired at the entry level - so that they have incentives to sabotage, the manager will prefer to sign two-year contracts with them. The manager aims to use explicit contracts as a tool to weaken workers’ incentives to sabotage in their attempt to build up their reputation. Sabotage between pairs who stay together is not as intense as for temporary workers, given also that the manager is equally happy by hiring a high reputation worker at a high wage or a low reputation worker at a low wage.

5 Conclusion

This paper analyzes compensation contracts and reputational incentives of co-workers when a worker’s individual performance depends on the quality of her colleague. We assume that the support a worker receives depends on both her colleague’s effort and innate ability, as it is likely to happen in corporations with several work groups. We show that due to the incentives-insurance trade-off, the manager who fully commits to a life-time income path may provide long-term contracts that induce a high risk-averse agent even to sabotage her colleague. Under full commitment, career concerns do not arise since long-term contracts are offered and signed at the beginning of workers’ employment. Thus, sabotage is induced solely by the explicit contracts. We also argue that the duration of employment is a key determinant of workers’ contracts, in contrast to Auriol et al. (2002). While for a short-term employment, the principal can motivate an agent to help her colleague, as employment is extended to many periods, the same worker may be induced to sabotage.

This paper also examines short-term contracts which are renegotiated in each period. Career concerns now arise and shape explicit contracts. A worker now has reputational incentives to sabotage her colleague because she wants to manipulate market assessments about her own ability. The manager now can set a negative explicit incentive in her attempt to decrease a worker’s desire to sabotage. We show that reputational incentives also arise for temporary workers who will be paired with another worker in the next period. This happens because a worker can shape market assessment about her own ability by influencing her current colleague’s production.

The present model can be used as a reference point for future works and extensions. One can
consider production functions in which a worker’s help effort is multiplied with her colleague’s ability. The substitutive relationship between implicit and explicit incentives formulated by Gibbons & Murphy (1992) may be challenged. Dewatripont et al. (1999) examine this relationship in a single-agent model in which a worker’s effort is multiplied with her own ability. This paper can also be used as a reference point to develop a model in which a worker contributes to multiple projects and her commitment to be involved in each project varies. Given that she is paired with workers of different abilities in each project, one can examine if she has incentives to work in projects where her colleagues are of higher or lower productivity, or in projects of longer duration. The size of the work group and the degree of heterogeneity between the colleagues’ skills are other key determinants of compensation contracts in the presence of career concerns. For instance, in software and microelectronics-based industry, the research groups are small and the duration of a research project is short, while in pharmaceutical and biotechnology, the research groups are large, lacking the ability to break them up into small independent modules. The duration of a research project is also long, since it involves experimentation. One can also enrich this framework by considering different allocations of the bargaining power or allowing for side payments between the workers. Other forms of reputation structures, such as mimicking irrational types (Faingold & Sannikov (2011)), and signaling (Mailath & Samuelson (2001)) which rely on asymmetric information and require the workers to signal their type as a team player, will provide interesting insights in team formation.

References


A. APPENDIX

A.1 Long-term explicit incentives

In the beginning of period 1, given (4), the manager maximizes

$$L = \sum_{t=1}^{2} \sum_{i=1}^{2} E\left\{z_i - \omega_i - \beta_i z_i - \gamma_i z_i^\prime\right\} + \sum_{i=1}^{2} \lambda_i \left[\beta_i - g'\left(e_i\right)\right] + \sum_{i=1}^{2} \mu_i \left[k_i \gamma_i - y'\left(a_i\right)\right]$$

$$+ \sum_{t=1}^{2} \sum_{i=1}^{2} \eta_i \left[E\left\{\omega_i + \beta_i z_i + \gamma_i z_i^\prime\right\} - g\left(e_i\right) - y\left(a_i\right)\right] - \frac{r_i}{2} Var\left(w_i + w_i^\prime\right) - \Theta_1.$$

Omitting details, the Kuhn-Tucker condition with respect to $\omega_i$ gives $-1 + \xi_i = 0 \iff \xi_i = 1$, implying that the $IR^i$ constraint binds at the optimum. Then, the Kuhn-Tucker conditions become

$$\frac{\partial L}{\partial \lambda_i} = \beta_i - g'\left(e_i\right) \geq 0 \text{ or } \lambda_i \geq 0, \lambda_i^\prime \left[\beta_i - g'\left(e_i\right)\right] = 0, \forall i, t$$

$$\frac{\partial L}{\partial \mu_i} = k_i \gamma_i - y'\left(a_i\right) \geq 0 \text{ or } \mu_i \geq 0, \mu_i^\prime \left[k_i \gamma_i - y'\left(a_i\right)\right] = 0, \forall i, t$$

$$\frac{\partial L}{\partial \beta_i} = -r_i \left[\left(\beta_1 + \beta_2\right) \left(\sigma_1^2 + h_2 \sigma_2^2\right) + \left(\gamma_1 + \gamma_2\right) \Sigma^{ij} + \beta_i \psi_i^2\right] + \lambda_i \leq 0 \text{ or } \beta_i \geq 0, \frac{\partial L}{\partial \beta_i} \beta_i = 0, \forall i, t$$

$$\frac{\partial L}{\partial \gamma_i} = -r_i \left[\left(\beta_1 + \beta_2\right) \Sigma^{ij} + \left(\gamma_1 + \gamma_2\right) \left(\sigma_1^2 + h_2 \sigma_2^2\right) + \gamma_i \psi_i^2\right] + k_i \mu_i \leq 0 \text{ or } \gamma_i \geq 0, \frac{\partial L}{\partial \gamma_i} \gamma_i = 0, \forall i, t$$

$$\frac{\partial L}{\partial g_i} = 1 - \lambda_i g_i^\prime - g'\left(e_i\right) \leq 0 \text{ or } e_i \geq 0, \frac{\partial L}{\partial g_i} e_i = 0, \forall i, t$$

$$\frac{\partial L}{\partial a_i} = k_i - \mu_i g_i^\prime - y'\left(a_i\right) \leq 0 \text{ or } a_i \geq 0, \frac{\partial L}{\partial a_i} a_i = 0, \forall i, t$$

We have $\lambda_i = \frac{1 - g'\left(e_i\right)}{g_i}$ and $\mu_i = \frac{k_i - y'\left(a_i\right)}{y_i^\prime}$. Given that $\lambda_i > 0$ and $\mu_i > 0$, equations (4) hold. Thus, we solve the conditions with respect to $\beta_i$ and $\gamma_i$, and obtain equations (5). Note that substituting $\gamma_i = \Phi^i f \beta^i_f$ into the condition with respect to $\beta_i$ gives $\lambda_i = r_i \left(\Sigma^{ij} + \Omega^i_j \Sigma^{ij}_f\right) \beta_i^j > 0$. A long-term contract provides the same explicit incentives $\beta_i^j$ and $\gamma_i^j$ in each period. A positive $\gamma_i^j$ requires a positive $\Phi^i_f$, whose denominator (see equation (5)) is positive for all $h_i$, $h_j$, $k_i$ and $k_j$. Thus, its sign depends on the sign of the numerator. It is positive when the condition in Proposition 1 holds.
A.2 Short-term explicit incentives

To find the optimal incentives in period 1, we first need to derive the form of

\[
\text{Var} \{ \hat{w}^i_1 + w^i_2 \} = \text{Var} \{ \hat{w}^i_1 \} + \text{Var} \{ w^i_2 \} + 2 \text{Cov} \{ \hat{w}^i_1, w^i_2 \}, \tag{14}
\]

where

\[
\text{Var} \{ \hat{w}^i_1 \} = \text{Var} \{ w^i_1 \} + \text{Var} \{ \omega^{i*}_2 \} + 2 \text{Cov} \{ w^i_1, \omega^{i*}_2 \}. \tag{15}
\]

The variance of the first-period wage is given by

\[
\text{Var} \{ w^i_1 \} = (\beta^i_1 + h_i \gamma^i_1)^2 \sigma_i^2 + (h_j \beta^i_1 + \gamma^i_1)^2 \sigma_j^2 + (\beta^i_1)^2 \varphi_i^2 + (\gamma^i_1)^2 \varphi_j^2. \tag{16}
\]

Note that

\[
\Theta^i_2 - E \{ \beta^i_2 z^i_2 + \gamma^i_2 z^i_1 \mid z^i_1, z^i_2 \} =
\]

\[
= E \{ (1 + h_i - \beta^i_2 - h_i \gamma^i_2) \theta^i - (h_j \beta^i_2 + \gamma^i_2) \theta^j - \beta^i_2 e^i - k_i \gamma^i_2 a^i - k_j \beta^i_2 a^j - \gamma^i_2 e^j \mid z^i_1, z^i_2 \} =
\]

\[
M^i_P (z^i_1 - \tilde{c}^i_1 - k_i \tilde{a}^i_1) + M^j_P (z^i_1 - \tilde{c}^i_1 - k_i \tilde{a}^i_1) - \beta^i_2 \tilde{c}^i_2 - k_i \gamma^i_2 \tilde{a}^i_2 - k_j \beta^i_2 \tilde{a}^j_2 - \gamma^i_2 \tilde{c}^j_2,
\]

where \(M^i_P\) and \(M^j_P\) are given by (6) and (7). Thus, the variance of \(\omega^{i*}_2 (\beta^i_2, \gamma^i_2)\) is

\[
\text{Var} \{ \omega^{i*}_2 \} = (M^i_P + h_i M^j_P)^2 \sigma_i^2 + (h_j M^i_P + M^j_P)^2 \sigma_j^2 + (M^i_P)^2 \varphi_i^2 + (M^j_P)^2 \varphi_j^2. \tag{17}
\]

By (16) and (17), we also have

\[
\text{Cov} \{ w^i_1, \omega^{i*}_2 \} = (\beta^i_1 + h_i \gamma^i_1) (M^i_P + h_i M^j_P) \sigma_i^2 + (h_j \beta^i_1 + \gamma^i_1) (h_j M^i_P + M^j_P) \sigma_j^2 \tag{18}
\]

\[
+ \beta^i_1 M^i_P \varphi_i^2 + \gamma^i_1 M^j_P \varphi_j^2
\]

To obtain the variance of \(\hat{w}^i_1\), let \(B^i_1 \equiv \beta^i_1 + M^i_P\) and \(\Gamma^i_1 \equiv \gamma^i_1 + M^j_P\). Then, by (16), (17) and (18), the variance in (15) becomes

\[
\text{Var} \{ \hat{w}^i_1 \} = (B^i_1 + h_i \Gamma^i_1)^2 \sigma_i^2 + (h_j B^i_1 + \Gamma^i_1)^2 \sigma_j^2 + (B^i_1)^2 \varphi_i^2 + (\Gamma^i_1)^2 \varphi_j^2,
\]

and the covariance of \(\hat{w}^i_1\) and \(w^i_2\) can be written as

\[
\text{Cov} \{ \hat{w}^i_1, w^i_2 \} = (\beta^i_2 + h_i \gamma^i_2) (B^i_1 + h_i \Gamma^i_1) \sigma_i^2 + (h_j \beta^i_2 + \gamma^i_2) (h_j B^i_1 + \Gamma^i_1) \sigma_j^2.
\]

Therefore, equation (14) takes the form

\[
\text{Var} \{ \hat{w}^i_1 + w^i_2 \} = \left[ B^i_1 + \beta^j_2 + h_i (\tau^i_1 + \gamma^i_2) \right]^2 \sigma_i^2 + \left[ h_j (B^i_1 + \beta^i_2) + \Gamma^i_1 + \gamma^i_2 \right]^2 \sigma_j^2 \tag{19}
\]

\[
+ (B^i_1)^2 \varphi_i^2 + (\Gamma^i_1)^2 \varphi_j^2 + (\beta^i_2)^2 \varphi_i^2 + (\gamma^i_2)^2 \varphi_j^2.
\]
Provided that the $IR_i^1$ constraint binds and $\Theta^i_1$ is zero, the first-period base payment is

$$\omega^i_1 = -E \{ \beta^i_1 z^i_1 + \gamma^i_1 z^i_2 \} + g(e^i_1) + y(a^i_1) - E \{ w^i_2 \} + g(e^i_2) + y(a^i_2) + \frac{r_i}{2} \text{Var} \{ \hat{w}^i_1 + w^i_2 \}. \quad (19)$$

We take the Kuhn-Tucker conditions as in appendix (A.1) and solve the equations:

$$[B^i_1 + \beta^i_2 + h_i (\Gamma^i_1 + \gamma^i_2)] \sigma^2_i + [h_j (B^i_1 + \beta^i_2) + \Gamma^i_1 + \gamma^i_2] h_j \sigma^2_j + B^i_1 \varphi^i_j = \frac{\lambda_i}{r_i}$$

$$[B^i_1 + \beta^i_2 + h_i (\Gamma^i_1 + \gamma^i_2)] h_i \sigma^2_i + [(h_j (B^i_1 + \beta^i_2) + \Gamma^i_1 + \gamma^i_2)] \sigma^2_j + \Gamma^i_1 \varphi^i_j = \frac{k_i \mu_i}{r_i}$$

$$1 - B^i_1 - \lambda_i g^i_1 = 0$$

$$k_i (1 - \Gamma^i_1) - \mu_i g^i_1 = 0$$

We derive the optimal $\beta^i_1$ and $\gamma^i_1$, given by the equations (8) and (9).

### A.3 Temporary workers

To derive the optimal incentives of temporary workers in period 1, we first need to derive the variance $\text{Var} \{ \hat{w}^i_1 + w^i_2 \}$ given by (14), while (15) and (16) holds. Suppose that worker $i$ will be paired with worker $l$ in period 2, whose ability $\theta^l$ is normally distributed with zero mean and variance $\sigma^2_l$. Note that

$$\Theta^i_1 - E \{ \beta^i_2 z^i_2 + \gamma^i_2 z^i_2 \mid z^i_1, z^i_2 \} =$$

$$= E \{ (1 + h_i - \beta^i_2 - h_i \gamma^i_2) \theta^l - (h_i \beta^i_2 + \gamma^i_2) \theta^l - \beta^i_2 e^i_2 - k_i \gamma^i_2 a^i_2 - k_i \beta^i_2 a^i_2 - \gamma^i_2 e^i_2 \mid z^i_1, z^i_2 \}$$

$$= M^i_T (z^i_1 - \bar{c}^i_1 - k_j \bar{a}^i_1) + M^i_T (z^i_1 - \bar{c}^i_1 - k_j \bar{a}^i_1) - \beta^i_2 \bar{e}^i_2 - k_i \gamma^i_2 \bar{a}^i_2 - k_i \beta^i_2 \bar{a}^i_2 - \gamma^i_2 \bar{e}^i_2,$$

where $M^i_T$ and $M^i_T$ are given by equations (10) and (11). Thus, the variance of $\omega^i_2 (\beta^i_2, \gamma^i_2)$ is

$$\text{Var} \{ \omega^i_2 \} = (M^i_T + h_i M^i_T)^2 \sigma^2_i + (h_j M^i_T + M^i_T)^2 \sigma^2_j + (M^i_T)^2 \varphi^2_i + (M^i_T)^2 \varphi^2_j. \quad (20)$$

By (16) and (20), we also have

$$\text{Cov} \{ w^i_1, \omega^i_2 \} = \left( \beta^i_1 + h_i \gamma^i_1 \right) \left( M^i_T + h_i M^i_T \right) \sigma^2_i + \left( h_j \beta^i_1 + \gamma^i_1 \right) \left( h_j M^i_T + M^i_T \right) \sigma^2_j +$$

$$+ \beta^i_1 M^i_T \varphi^2_i + \gamma^i_1 M^i_T \varphi^2_j. \quad (21)$$

Let $b^i_1 \equiv \beta^i_1 + M^i_T$ and $g^i_1 \equiv \gamma^i_1 + M^i_T$. Then, by (16), (20) and (21), the variance in (15) becomes

$$\text{Var} \{ \hat{w}^i_1 \} = (b^i_1 + h_i g^i_1)^2 \sigma^2_i + (h_j b^i_1 + g^i_1)^2 \sigma^2_j + (b^i_1)^2 \varphi^2_i + (g^i_1)^2 \varphi^2_j,$$

and the covariance of $\hat{w}^i_1$ and $w^i_2$ is

$$\text{Cov} \{ \hat{w}^i_1, w^i_2 \} = (b^i_2 + h_i \gamma^i_2) (b^i_1 + h_i g^i_1) \sigma^2_i.$$
Thus, equation (14) takes the form

\[
\text{Var}\{\tilde{w}_1^i + w_2^i\} = \left[ b_1^i + \beta_2^i + h_i (g_1^i + \gamma_2^i) \right]^2 \sigma_i^2 + (h_i \beta_2^i + \gamma_2^i)^2 \sigma_j^2 + (h_j \beta_1^i + \gamma_1^i)^2 \sigma_l^2 + \left( b_i^j \right)^2 \varphi_i^2 + \left( g_i^j \right)^2 \varphi_j^2 + \left( \beta_2^i \right)^2 \varphi_i^2 + \left( \gamma_2^i \right)^2 \varphi_j^2. \tag{22}
\]

Given also that the first-period base payment is as in equation (19) and the IR_

we take the Kuhn-Tucker conditions as in appendix (A.2) and solve the equations:

\[
\begin{align*}
\left[ b_1^i + \beta_2^i + h_i (g_1^i + \gamma_2^i) \right] \sigma_i^2 + (h_j \beta_1^i + \gamma_1^i) h_j \sigma_j^2 + b_i^j \varphi_i^2 &= \frac{\lambda_i}{r_i} \\
\left[ b_1^i + \beta_2^i + h_i (g_1^i + \gamma_2^i) \right] h_i \sigma_i^2 + (h_j \beta_1^i + \gamma_1^i) \sigma_j^2 + g_i^j \varphi_j^2 &= \frac{k_i \mu_i}{r_i}
\end{align*}
\]

\[
1 - b_1^i - \lambda_i g_1^i = 0 \\
k_i (1 - g_1^i) - \mu_i y_1^i = 0
\]

We derive the optimal $\beta_1^i$ and $\gamma_1^i$, given by the equations (12) and (13).