Size and Scope of Human Capital Intensive Firms

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1 Introduction

This paper studies employee incentives to exert innovative effort, and the importance of encouraging teamwork to promote innovation in human capital intensive firms where firm value primarily depends on employee generated innovations. In today's knowledge-based economy, ownership of physical assets no longer represents a source of comparative advantage for firms since developments in financial markets and easier access to capital markets significantly increased firms' ability to invest in physical assets. Firms' value generating ability depends much more on the human capital they employ rather than on the physical capital they own, especially for entrepreneurial and innovative firms. Thus, recruiting, retaining and motivating employees becomes a critical requirement for value creation.

This paper studies the nature of employee incentives in human capital intensive firms as a function of firm size and scope. In addition, it shows the importance of promoting teamwork in promoting employee innovation effort and in increasing innovative output of the firm.

We consider a setting where a firm chooses first the number of employees to hire. We simplify the analysis by assuming that the firm can hire either one or two employees. The firm is human capital intensive in the sense that firm value depends on innovations generated by the employees of the firm. Each employee exerts unobservable effort which determines the probability that the employee obtains an innovation. We show that the size and the scope of the firm affect employee incentives ex-ante to exert effort as well as the firm's rent extraction ability at the ex-post wage negotiation stage.

When the firm hires two employees, the firm can choose to hire either substitute employees or complementary employees. This can be also interpreted as training employees in a way so that their contributions to firm value are either substitutes or complements. With two substitute employees, compared to having only one employee, the firm can extract higher rents from the employees as having two employees allows the firm to depress the hold-up power of each employee in the ex-post negotiations. Hence, hiring two employees is beneficial for the firm as it gives the firm a bargaining advantage. However, anticipating the bargaining advantage of the firm, the employees exert lower effort ex-ante. Hiring one employee eliminates the bargaining advantage of the firm but it leads to stronger effort incentives compared to the two-employee case. The firm can strike a better balance between its rent extraction ability and employee incentives by choosing to hire complementary rather than substitute employees. Hiring (two) complementary employees improves the firm's rent extraction ability relative to the case where the firm hires only one employee, but worsens it relative to the case where the firm hires two substitute employees. However, with complementary rather than substitute employees, expanding the firm size may have a less adverse impact on employee incentives. Complementary employees are more valuable together than alone. This implies that at the ex-post negotiations, it is more costly for the firm to fire one of the employees and keep only one of them. This cost reduces the bargaining advantage of the firm, increases employee rents and improves employee incentives compared to the case where employees are substitutes. Hence, hiring complementary employees is a way to mitigate the negative impact of firm size on employee incentives. However, hiring complementary employees has a cost as well. Complementarity implies that when one of the employees fails, the other employee's innovation is less valuable, affecting employee incentives and the firm's rents negatively. Under certain conditions, complementarity results in higher employee wages, stronger employee incentives and higher firm value.

Hiring complementary employees can also be interpreted as assigning employees to complementary rather than substitute tasks and promoting teamwork. It is common that firms, especially in human capital intensive industries where firm values depend to a great deal on employee motivation and incentives, encourage teamwork among their employees. Our paper derives the conditions under which teamwork formation can be an optimal strategy for a firm even though it commits the firm to pay higher rents to its employees. The firm can commit not to depress employee wages in the ex post negotiations by choosing to hire complementary employees or assign employees to complementary tasks.

We show that for high levels of human capital productivity, the firm hires only one employee not to dilute employee incentives. For highly productive employees, the cost of diluting effort incentives is particularly severe and the firm does not want to weaken employee incentives by expanding its size. At high levels of human capital productivity, the firm expands its size only if there is a sufficient degree of complementarity between the employees as complementarity helps restore the distortions in employee incentives. An implication of these results is that in human capital intensive industries the firm size will be small. Firm size will increase only if the firm can hire employees who will work together in teams, being responsible for different aspects of the same production task. At low levels of human capital productivity, the firm always chooses to hire two employees. The bargaining advantage of the firm from expanding the firm size dominates the negative impact of size on employee incentives since at low levels of productivity employee incentives are already weak. Whether the firm hires two complementary rather than two substitute employees depends on the level of complementarity (synergies) between the employees. The firm hires complementary employees if the level of complementarity is sufficiently high, and substitute employees otherwise.

An interesting application of our results is to the diversification literature in financial economics, which investigates the benefits and the costs of diversification. If we interpret the employees in our model as the divisions of a firm, our analysis establishes when the firm endogenously chooses to stay as a stand-alone focused firm and when it chooses to diversify. Moreover, we identify the conditions under which the firm diversifies into unrelated business areas (substitute employees) and when the firm follows a focused diversifying strategy by entering into related business areas (complementary employees). Our results have the testable empirical implication that for higher levels of human capital productivity firms will be more likely to be undiversified and focused. Such firms will diversify only if they can combine businesses with a sufficiently high degree of focus and complementarity (synergies).

Our work is related to Stole and Zwiebel (1996a, 1996b) showing that when labor contracts are nonbinding, and a given firm and its employees have the ability to enter into intrafirm wage negotiations at any time prior to production, the firm overemploys as overemployment enables the firm to minimize the hold-up power of each employee in the intrafirm wage negotiations. Expanding employment ex ante gives the firm a higher "rent extraction" ability at the ex-post wage negotiations. When firm value is affected by unobservable effort exerted by employees prior to wage bargaining, it is no longer clear that the firm will benefit from expanding its size. The firm size has a new effect in addition to the "rent extraction" effect, identified by Stole and Zwiebel. Hiring a large number of employees provides the firm with a higher rent extraction ability at the bargaining stage which affects employee incentives adversely, referred to as the "incentive effect". The higher rent extraction ability of the firm depresses employee rents, leading to lower effort incentives, and lower firm value, all else equal. Hence, the firm faces a trade-off in choosing its size. The number of employees the firm hires depends on the relative magnitudes of the incentive effect and the rent extraction effect. When the rent extraction effect dominates the incentive effect, firm size will be large. In the opposite case, when the incentive effect dominates the rent extraction effect, firm size will be small.

The paper is organized as follows. Section 2 presents the main model of the choice between hiring one or two employees and hiring substitute or complementary employees. Section 3 characterizes the optimal firm size and scope and presents the comparative static results of the model. Section 4 concludes. All the proofs are in the Appendix.

2 The Model

There are four dates - 0,1,2 and 3 - and two types of agents, a firm and employees. Employees are wealth constrained. All agents are risk-neutral and there is no discounting between periods.

At date $t = 0$, the firm hires either one, $\eta = 1$, or two, $\eta = 2$, (substitute or complementary) employees and each employee is assigned to a project.[1]

At date $t = 1$, each employee exerts a level of effort p, at a personal cost of $\frac{k}{2}p^2$ where $k > 1$, which determines the probability that the employee obtains an innovation at $t = 2$. The effort

[1] We make the assumption that the firm hires only one or two employees for analytical tractability and simplicity.

choice cannot be observed and thus it is not possible to write contingent contracts on it.

At date $t = 2$, everyone learns whether a given employee obtains an innovation (which is obtained with probability p). Each innovation will generate a payoff (to be specified later) at date $t = 3$, provided that the employee and the firm stay together for the implementation of the innovation until date $t = 3$. The firm enters into bilateral bargaining with each employee to determine the allocation of the payoff from implementing employee innovations.

At date $t = 3$, each innovation generates a payoff, which is distributed between the firm and the employee(s).

3 Firm hires one employee

This section analyzes the case where the firm hires only one employee at $t = 0$. The employee obtains an innovation with probability p at $t = 2$. [2] The innovation generates a surplus of x at $t = 3$, conditional on the employee and the firm staying together until $t = 3$. After observing whether the employee obtains an innovation, the firm and the employee enter into bilateral bargaining at $t = 2$. [3] Following Stole and Zwiebel (1996a), we assume that the employee is irreplaceable in the short run. Both the firm and the employee have zero outside options in the bilateral negotiations. This assumption is plausible considering that the employee exerts a firm-specific effort and generates a firm-specific innovation. It takes time for outside employees from the general labor pool to obtain the firm specific skills. Hence, the firm cannot immediately replace the original employee with a new employee from a replacement labor pool.[4] Similarly, the

[2] Innovation can be broadly interpreted as any idea, product or process which improves profitability if implemented by the firm.

[3] As in Stole and Zwiebel (1996a), we treat labor contracts to be nonbinding. Contractual incompleteness arises from the ability of both the firm and the employee to withdraw their involvement from production after the employee obtains an innovation and before production takes place. After an employee generates an innovation, the innovation will generate a payoff only if both the firm and the employee stay together and participate in the implementation phase of the innovation.

[4] See Fontenay and Gans (200?) for discussion.

employee generates a firm specific innovation and develops a firm-specific human capital which is not transferable to other firms. Therefore, in bargaining, the outside options of the two parties upon failing to reach an agreement are given by zero. An even division of the surplus, assuming the firm and the employee have equal bargaining power, gives that $x - w = w$, or $w = \frac{x}{2}$ where w denotes the wage of the employee.[5]

The employee exerts effort, p, to maximize his expected profit, $\pi_E(1)$, given by :

$$\max_p \quad \pi_E(1) \equiv p\frac{x}{2} - \frac{k}{2}p^2.^6 \tag{1}$$

The first order condition with respect to p is

$$\frac{x}{2} - kp = 0. \tag{2}$$

Solving (2) for p gives

$$p^* = \frac{x}{2k}.^7 \tag{3}$$

The firm's expected profit from hiring one employee is given by

$$\pi_F^*(1) \equiv p^*\frac{x}{2} = \frac{x^2}{4k}. \tag{4}$$

Plugging p^* into (1) gives the employee's expected profit π_E^*:

$$\pi_E^*(1) \equiv \frac{x^2}{8k}. \tag{5}$$

4 The firm hires two employees

4.1 Employees are substitutes

The firm sets $\eta = 2$ and hires two employees at $t = 0$. The employees are substitutes in the sense that the firm assigns each employee to an independent project where the payoff from each

[5] It is straightforward to extend our results where the firm and the employee have different bargaining power.

[6] We use a linear production technology with convex effort costs for analytical tractability. It is well known that the curvature of the production function may affect the results. In our analysis, the specifics of the production technology will affect the strenght of the incentive effect and the rent extraction effects. However, the two effects of firm size will be present under any p

[7] We assume that $x < 2k$ so that we have an interior solution.

employee's project depends only on the effort exerted by the employee himself. There are no interdependence between the projects. [8] Each employee exerts unobservable effort p_i^S; $i = 1, 2$ at $t = 1$ which determines the probability that he generates an innovation. Whether the employees obtain an innovation or not is observed at $t = 2$. There can be 4 different states of the world at $t = 2$: In state SS both employees have an innovation, in state SF(FS) only employee 1(2) obtains an innovation, employee 2(1) does not, and in state FF both employees fail.

In state SS, both employees have an innovation and need to stay with the firm in order to implement their innovation. The firm enters into bilateral negotiations with each employee. The bilateral negotiations determine the allocation of the surplus from implementing the innovations. We model the multi-person bargaining between the firm and the two employees as in Stole and Zwiebel (1996b). In the SS state, if the firm retains both employees, the firm can implement each employee's innovation at a reduced scale and each innovation generates a surplus of $\frac{x}{2}$, resulting in a total surplus of x. This follows from the capacity and resource constraint of the firm.[9]

If the firm fires one of the employees and uses all its resources to implement only the other employee's innovation, then the innovation implemented generates a surplus of x. Following Stole and Zwiebel (1996a), assuming equal bargaining power for the firm and the employees, the firm and the employees bargain and determine employee wages denoted by w^S:

$$x - 2w^S - \frac{x}{2} = w^S. \tag{6}$$

When the firm implements the innovations of both employees, each employee's innovation generates $\frac{x}{2}$, resulting in a total surplus of x. The right hand side of (6) gives the difference between the firm's payoff from bargaining with two employees, that is, $(x - 2w^S)$ and payoff

[8] Note that the projects undertaken by the employees can be interpreted as divisions of the firm and the employees can be interpreted as the divisional managers. A firm with substitute divisions will refer to a diversified multi-division firm. A firm with complementary divisions will refer to a focused multi-division firm. A firm with a single employee will refer to a stand-alone firm. Hence, this way, our paper is related to the diversification literature in financial economics.

[9] See Rotemberg and Saloner (1994) for a similar assumption.

from bargaining with only one employee, that is, $(x - w = \frac{x}{2})$. Note that if the bargain with, say, employee 1 breaks down, the firm has employee 2 to bargain with and obtains a payoff of $\frac{x}{2}$. This payoff represents the firm's outside option when bargaining with employee 1, and allows the firm to extract more surplus from employee 1, compared to the case where the firm has only one employee to bargain with. Hence, when bargaining with two employees, the firm has the outside option in the sense that if bargaining with one of the employees fails, the firm has the other employee to bargain with.

Solving (6) for w^S gives that $w^S = \frac{x}{6}$. Hence the firm's rent in the SS state is $x - \frac{2x}{6} = \frac{2x}{3}$. Note that the firm extracts a higher rent when it has two employees than when it has only one; that is, $\frac{2x}{3} > \frac{x}{2}$. Hence, having two employees to bargain with, rather than one, increases the firm's rent (from $\frac{x}{2}$ to $\frac{2x}{3}$) and reduces each employee's rent (from $\frac{x}{2}$ to $\frac{x}{6}$).

In state SF and state FS, the firm has only one employee with an innovation. Hence, the firm and the successful employee bargain and share the total surplus equally. In state FF, both employees fail and the projects are terminated.

Employee i, anticipating the outcome of the bargaining in each state, exerts effort p_i^S ; $i = 1, 2$ to maximize his expected profit, given by $\pi_{Ei}^S(2)$:

$$\max_{p_i} \quad \pi_{Ei}^S(2) \equiv p_i^S p_j^S \frac{x}{6} + p_i^S(1 - p_j^S)\frac{x}{2} - \frac{k}{2}(p_i^S)^2; \; i, j = 1, 2; i \neq j. \tag{7}$$

Taking the first order condition of (7) with respect to p_i^S gives

$$p_i^S(p_j^S) = \frac{(4 - 3p_j^S)x}{8k}; \; i, j = 1, 2; i \neq j. \tag{8}$$

Note from (8) that p_i^S decreases in p_j^S. This is the incentive effect of overemployment (hiring two employees as opposed to one). Each employee, anticipating the bargaining advantage of the firm and that the total resources of the firm will be split between the two innovations in the SS state, exerts a lower level of effort compared to the case where he is the only employee hired by the firm. Hence, with substitute employees, the effort levels p_i^S and p_j^S are strategic substitutes.

Setting $p_j^S = p_i^S$ and solving (8) for p_i^S gives that

$$p_1^{S*} = p_2^{S*} = \frac{4x}{3x + 8k}. \tag{9}$$

Proposition 1 *The optimal level of employee effort, $p_1^{S*}(= p_2^{S*})$, when the firm has two employees is lower than the optimal level of effort when the firm has only one employee, p^*.*

Note that there are two different reasons why employee effort is lower when the firm hires two employees than only one. The first reason is the production technology employed, which is linear in effort with convex effort costs. Ignoring the firm's higher rent extraction ability with two employees, that is, assuming the firm can extract the same level of rents independent of the number of employees it employs, the linear production function with convex effort costs favors a small firm size since employee effort is higher with one employee than two employees, and the first best outcome is to hire only one employee.[10] The second reason for why employee effort is lower with two employees is that, in the SS state, the firm extracts higher surplus from each employee in the ex-post negotiations as it has the outside option of firing one of the employees and implementing only the other employee's innovation. As a result, a given employee exerts lower effort when there is another employee competing with him and allowing the firm to extract greater rents than when he is the only employee of the firm.

An alternative interpretation of this result is that having two employees rather than one induces competition between the employees for the firm's limited resources. In the SS state where both employees are successful, the employees share the firm's limited resources and each innovation generates only $\frac{x}{2}$, rather than x. Moreover the firm extracts higher surplus from each employee in the ex-post negotiations, diluting effort incentives even further.

This result is consistent with the empirical finding of Schoar (2002) which documents that when firms diversify, the productivity of the existing divisions deteriorates. Our result can be

[10] This can be seen as follows. Suppose that the firm can extract half of the surplus both with one employee and two employees. If it hires only one employee, optimal employee effort level will be $\frac{x}{2k}$, and expected firm profit will be $\frac{x^2}{4k}$. If the firm hires two employees, each employee's effort level will be $\frac{x}{4k}$, and expected firm profits will be $\frac{x^2}{8k}$.

interpreted as when the firm has two divisions (employees) as opposed to one, the total resources are spread over the two divisions and the firm has a stronger negotiating position, affecting incentives (productivity) of each division adversely, compared to the case where the firm devotes and commits all its resources to only one division and limits the strength of its bargaining position. An interesting question is why firms diversify at the expense of worsening the incentives of their existing divisions. We will prove below that under certain conditions the firm will find it optimal to have two employees (divisions) as opposed to one since the bargaining benefit of having two employees dominates the negative incentive effect of expanding the firm size.

Plugging p_1^{S*} and p_2^{S*} into (7) gives the expected profit of each employee:

$$\pi_{E1}^{S*}(2) = \pi_{E2}^{S*}(2) = \frac{9x^2k}{8\left(x+3k\right)^2}. \tag{10}$$

Comparing (5) and (10) reveals that employee profits are lower when the firm hires two employees than when the firm hires only one employee. This result is not surprising given that expanding the firm size has a negative impact on effort incentives, induces competition for the limited amount of resources and reduces the employees' rent extraction ability at the ex-post negotiations.

The expected profit of the firm is given by

$$\pi_F^{S*}(2) = p_1^{S*}p_2^{S*}\frac{2x}{3} + p_1^{S*}(1-p_2^{S*})\frac{x}{2} + p_2^{S*}(1-p_1^{S*})\frac{x}{2} = \frac{3x^2(x+6k)}{4\left(x+3k\right)^2}. \tag{11}$$

The firm compares its expected profit from hiring two substitute employees, $\pi_F^{S*}(2)$, to its expected profit from hiring only one employee, $\pi_F^*(1)$ given in (4), in choosing the number of employees to hire.[11]

Proposition 2 *The firm hires two employees for* $x < \bar{x} \equiv 3\left(\frac{1}{2}\sqrt{5} - \frac{1}{2}\right)k$ *and one employee for* $x \geq \bar{x}$.

[11] Note that in the first best complete contract benchmark in the absence of moral hazard, the firm always hires two employees because of the linear production technology with convex effort cost that we employ in the analysis.

The firm faces a trade-off between having strong employee incentives and a lower rent extraction ability (paying higher wages) versus having weaker employee incentives and a higher rent extraction ability (paying lower wages). The firm chooses the optimal size by comparing the rent extraction effect of size with the incentive effect of size. When the value of x is low, that is, when $x < 3\left(\frac{1}{2}\sqrt{5} - \frac{1}{2}\right)k$, the positive rent extraction effect dominates the negative incentive effect, and the firm chooses to hire two employees. When $x \geq 3\left(\frac{1}{2}\sqrt{5} - \frac{1}{2}\right)k$, the firm forgoes the bargaining advantage of a large size for the incentive advantage of a small size and hires only one employee.

Note that for large values of x and small values of k, the firm prefers to provide its employees with high powered incentives by limiting its bargaining advantage and hiring only one employee. If we interpret a high value of x and a low value of k as a measure of employee talent or human capital productivity, the firm is better off hiring only one employee for high levels of human capital productivity not to dilute employee incentives. Note that employee effort, thus the probability of obtaining an innovation, is lower for lower values of x and higher values of k. If we interpret these parameters as proxies for technological uncertainty (lower x, higher k, higher technological uncertainty) an implication of this result is that firm size will be larger in industries in which technological uncertainty is high. In such industries increasing the number of employees working for an innovation increases the profits of the firm. Baldwin and Clark (1994) notes that in the computers industry in which technological uncertainty is high, firms increase the number of employees and projects simultaneously working for innovation to maximize the rate of innovation and output.

In the context of diversification literature, Proposition 2 reveals that the firm optimally chooses to diversify when the human capital productivity is low (low x) or technological uncertainty is high (high k), and chooses to remain small and focused when the productivity is higher (high x) or technological uncertainty is low (low k).

Note that Rotemberg and Saloner (1994) considers a similar problem to ours where a firm optimally commits to pursue a narrow business strategy not to dilute employee innovation incentives. Keeping the firm size small by hiring only one employee in our model can be interpreted as following a narrow business strategy. However, in our analysis, pursuing a narrow business strategy is costly since it limits the firm's rent extraction ability. The optimal firm size in our model (equivalently pursuing a narrow or broad business strategy) obtains as a balance of the rent extraction and the incentive effects of firm size.

4.2 Complementary employees

The previous section established the trade-off between the benefits and the costs of expanding the firm size with substitute employees. This section shows that the firm can mitigate the negative incentive effect of firm size by hiring complementary employees.[12]

The firm sets $\eta = 2$ and hires two employees and assigns each employee to a project. The employees exert effort as before, and if successful, generate an innovation. The payoffs from innovations are such that in the SS state where both employees succeed in generating an innovation, the total payoff from implementing both employee innovations, is sx, where $s \geq 1$, and the payoff from implementing only one of the employee innovations is lx where $l \leq 1$.[13] Compared to the case where the employees are substitutes, complementarity between the employees increases the surplus from employee innovations to sx from x, provided that both employee innovations are implemented. If only one of the employees is successful in generating an innovation (SF state or FS state), the payoff from the successful employee's innovation drops to lx. Hence, complementarity increases the value of employee innovations when both employees obtain an innovation and the firm implements both innovations. The cost of hiring complementary employees relative to substitute employees is that the stand-alone value of each employee's innovation is lower if the other employee fails in generating an innovation and if the firm implements only one of the innovations in the SS state. Moreover, complementarity reduces the bargaining advantage of the

[12] Hiring complementary employees can be interpreted as the firm assigning the employees to complementary tasks or training the employees in a way that their contributions to firm value are complementary to each other.

[13] Note that we maintain the resource constraint of the firm. The reason why employee innovations generate a payoff of sx rather than x is because under complementarity employee innovations are more valuable together than alone. Thus, each employee innovation generates $\frac{sx}{2}$, provided that both employee innovations are implemented.

firm in the SS state by making it more costly to fire one of the employees and to implement only the other employee's innovation.

In terms of the production technology, the advantage of hiring complementary employees over substitute employees is $sx - x$, and the disadvantage is $x - lx$. In the following analysis we will assume that $sx-x < x-lx$, that is, $s+l < 2$. This assumption makes sure that if the firm chooses complementary employees over substitute employees, this choice is not due to the technological superiority of the production technology under complementarity.

Formally, in the SS state, assuming equal bargaining power for the firm and the employees, the firm and the employees negotiate employee wages, denoted by w^C which satisfies

$$sx - 2w^C - \frac{lx}{2} = w^C. \tag{12}$$

Similar to the bargaining setting with substitute employees, the firm bargains with each employee bilaterally in a multi-person bargaining game. (12) gives the difference in the firm's payoff from bargaining with two employees and bargaining with only one employee. If the firm and, say, employee 1 fail to reach an agreement, the firm has the option to bargain with employee 2 and obtains a payoff of $\frac{lx}{2}$. Hence, the firm has an outside option of $\frac{lx}{2}$ in the bilateral bargaining with each employee.[14] Note that the firm's outside option is now lower compared to the case where the employees are substitutes, that is, $\frac{lx}{2} < \frac{x}{2}$. Hence, the firm's rent extraction ability measured by the firm's outside option is lower with complementary employees than with substitute employees.

Solving (12) for w^C gives that

$$w^C = \frac{sx}{3} - \frac{lx}{6}. \tag{13}$$

Comparing w^C to w^S reveals that $w_1^C \geq w_1^S$ for $s \geq \frac{l+1}{2}$. A high level of s and a low level of l increases the rent extracted by the employees at the bargaining stage. Comparing the firm's

[14] In the bargaining with employee 2, both the firm and employee 2 have zero outside options, given that the bargaining with firm and employee 1 broke down, and thus, each party obtains half of the total surplus of lx,.

rent in the SS state with complementary employees, that is, $\frac{sx}{2} + \frac{sx}{2} - 2w^C = \frac{sx+lx}{3}$ to that with substitute employees, $\frac{2x}{3}$, gives that the firm extracts lower rents under complementarity as $\frac{sx+lx}{3} < \frac{2x}{3}$ always holds when $s + l < 2$. This result has been established by Stole and Zwiebel (1996, page 214) which discusses the impact of complementarity (and scope) on the intrafirm bargaining and shows that complementarity allows the employees to extract higher surplus from the firm. An interesting question we analyze here is how the complementarity between the employees impacts employee incentives and whether the firm will be better off with complementary employees rather than with substitute employees.

In the SF (FS) state employee 1 (2) succeeds, and employee 2 (1) fails in generating an innovation and employee 1's innovation has a lower payoff, only lx rather than x, resulting in a payoff of $\frac{lx}{2}$ for both employee 1 (2) and the firm.

The first effect of complementarity on incentives is positive. The employees, compared to the case with substitute employees, anticipating that in the SS state the firm will extract lower rents in the bargaining and their innovation will generate a payoff of sx rather than x, will have stronger incentives to exert effort ex-ante. The second effect is negative as in the SF (FS) state, the payoff from employee 1 (2)'s innovation goes down to lx.

The overall level of incentives under complementarity will depend on the relative magnitude of the positive effect and the negative effect. In the following analysis, we will characterize explicitly when the incentives will be stronger with complementary employees than with substitute employees and the firm will be better off under complementarity in spite of paying higher wages.

Employee i, $i = 1, 2$, anticipating the outcome of the bargaining process, will determine his level of effort p_i^C by maximizing his expected profit given by $\pi_{Ei}^C(2)$:

$$\max_{p_i^C} \pi_{Ei}^C(2) \equiv p_i^C p_j^C \left(\frac{sx}{3} - \frac{lx}{6}\right) + p_i^C(1 - p_j^C)\frac{lx}{2} - \frac{k}{2}(p_i^C)^2; i, j = 1, 2; i \neq j. \tag{14}$$

Taking the first order condition of (14) with respect to p_i^C gives

$$p_i^C(p_j^C) = \frac{(3l + (2s - 4l)p_j^C)x}{6k}. \tag{15}$$

From (15), it can be seen that if $(2s - 4l) > 0$, p_i^C is an increasing function of p_j^C, and the effort levels are strategic complements. Recall from the previous section, in the absence of complementarity, that p_1^S is always a decreasing function of p_2^S.

Setting $p_j^C = p_i^C$ and solving (15) for p_i^C gives that

$$p_1^{C*} = p_2^{C*} = \frac{(3lx)}{2(3k - sx + 2lx)}[15]. \tag{16}$$

The optimal effort level with complementary employees is an increasing function of x, s and a decreasing function of k. It is an increasing function of l for $s \leq 3\frac{k}{x}$ and decreasing function of l for $s > 3\frac{k}{x}$. The intuition for non-monotonicity of effort in l is that at high levels of s, employee incentives are strong, and the probability of being in the state SS is relatively higher than the probability of being in the SF state. Each employee's payoff is decreasing in l in the SS state and increasing in l in the SF state. Hence, at high levels of s, the employees get hurt from an increase in the level of l and reduce the effort they exert. Similarly, at lower levels of s employee incentives are weaker and the probability of being in the SF state is relatively higher than probability of ending up in the SS state. Thus, the employees benefit from an increase in the level of l and exert more effort.

Proposition 3 *Comparing p_1^{C*} to p_1^{S*} reveals that $p_1^{C*} > p_1^{S*}$ if and only if $s > \frac{1}{8}\frac{7lx - 24lk + 24k}{x}$. Similarly, comparing p_1^{C*} to p^* gives that $p_1^{C*} > p^*$if and only if $s > \frac{-3lk + 3k + 2lx}{x}$.*

Note that with substitute employees expanding the firm size always has an adverse impact on incentives. However, for sufficiently high values of complementarity or synergies between the employee innovations (high s), effort incentives will be stronger with complementary employees than with substitute employees or with only one employee. It is interesting to note that effort level

[15] We assume that $s < \frac{1}{2}\frac{lx+6k}{x}$ to make sure that we obtain an interior solution where the probability of success is lower than 1. Combining $s < \frac{1}{2}\frac{lx+6k}{x}$ with $s < 2 - l$ implies that $s < \min\{\frac{1}{2}\frac{lx+6k}{x}, 2 - l\}$.

with complementary employees will be higher than that with substitute employees even for some values of s and l where $s < 1$. Formally, if $1 > l \geq \frac{24k-8x}{24k-7x}$, then $p_1^{C*} > p_1^{S*}$ for $\frac{1}{8}\frac{7lx-24lk+24k}{x} < s < 1$. This means that even the productivity of the employees with complementary tasks is lower than that with substitute tasks, it will be optimal for the firm to hire complementary employees. The reduction in the rent extraction ability of the firm will improve employee incentives sufficiently that the firm will be better off with complementary employees than substitute employees even when $s < 1$.

Plugging (16) into (14) gives the employees' expected profits under complementarity denoted by π_{E1}^{C*}

$$\pi_{E1}^{C*}(2) = \pi_{E2}^{C*}(2) = \frac{9}{8}\frac{kl^2x^2}{(3k - sx + 2lx)^2}. \tag{17}$$

Lemma 1 *Employee profits under complementarity are increasing in x, s and decreasing in k, and increasing in l if and only if $s < 3\frac{k}{x}$.*

Similar to optimal effort level under complementarity, employee profits are also a non-monotonic function of l. At high levels of s, that is, $s > 3\frac{k}{x}$, the employees benefit from a reduction in l as this implies that the firm can extract lower rents from the employees as l goes down. Note that this effect exists only in the SS state where both employees are successful. A high level of s, keeping everything else constant, implies a high success probability and a high probability for state SS. The opposite reasoning explains why employee profit is an increasing function of l at low levels of s, that is, $s \leq 3\frac{k}{x}$.

The firm's expected profit under complementarity, denoted by π_F^{C*}, is given by

$$\pi_F^{C*}(2) \equiv \frac{3}{4}\frac{l^2x^2(-sx + 2lx + 6k)}{(3k - sx + 2lx)^2}. \tag{18}$$

Lemma 2 *Firm profit under complementarity, π_F^{C*}, is increasing in x, s and decreasing in k, and increasing in l if and only if $s < \frac{3lx+9k-\sqrt{l^2x^2+18lxk+9k^2}}{2x}$.*

Parameter l impacts firm profit in two different ways. The first is that the rent extracted by the firm in all three states is an increasing function of l, as seen in the three terms in (18). The second way is that l also impacts employee effort, which is the second determinant of firm profits. The expected profit of the firm is an increasing function of l at low levels of s since employee effort is increasing in l. For higher levels of s, employee effort is decreasing in l, and the impact of l on employee effort dominates the impact of l on firm rents. Hence, firm profit decreases in l at high levels of s.

Complementarity has both benefits and costs for the firm. The cost it that compared to the case where the employees are substitutes, the firm loses from its bargaining advantage at the negotiation stage as each employee is less valuable alone than with the other employee. This reduces the firm's outside option in bargaining. The second cost of complementarity is that in case one of the employees fails (SF state of FS state), the total value generated drops to lx from x. Hence making the employees dependent on each other reduces the stand-alone potential of each employee's project, and this is costly both for the employees, in terms of weaker incentives and for the firm, in terms of lower surplus in the SF and FS states. The first benefit of complementarity is the improved effort incentives of the employees, due to higher wages they extract. The second benefit is that where both employees are successful (SS state), the innovations generate a value of sx where $s \geq 1$. Interestingly, even if the increase in the project payoff in the SS state due to complementarity (or synergies), that is, $sx - x$, is lower than the reduction in the project payoffs in the SF or FS state, that is, $x - lx$, the firm still can benefit from complementarity as we show in the remainder of the analysis.

The firm decides the optimal size and the scope (whether to hire substitute or complementary employees) of the firm by evaluating the incentive and rent extraction effects of firm size and scope. The following proposition characterizes the firm's optimal size and scope decision.

Proposition 4 *If $x > \bar{x}$, the firm hires two complementary employees for $s \geq s_1$ and hires only one employee for $s < s_1$. If $x \leq \bar{x}$ the firm hires two complementary employees for $s > S_1$ and* *hires two substitute employees for $s \leq S_2$(where s_1 and S_1 are defined in the appendix).*

For high levels of human capital productivity, that is, for $x > \bar{x}$, the firm hires only one employee if the level of synergies is low, that is, $s < s_2$ This is due to the fact that the firm does not want to dilute strong employee incentives at the benefit of gaining a higher rent extraction ability at the bargaining stage. A high level of x makes the incentive effect of firm size dominate the rent extraction effect of firm size and the firm optimally chooses to hire only one employee. Higher values of s, that is, $s \geq s_2$, mitigates the negative effect of firm size on employee incentives, and the firm hires two employees. The implication of Proposition 4 is that human capital intensive firms stay either small or get bigger only for higher levels of complementarity between the employees. Alternatively, one implication of this results is that, if we interpret complementary employees as employees working as a team, human capital intensive firms benefit from promoting teamwork to enhance employee incentives. This can be interpreted as the firm encouraging a teamwork practice by assigning the employees on different aspects of a given project (product introduction, process innovation etc.). The employees either succeed together and obtain a bargaining advantage in the wage negotiations or fail together compared to the case where each employee is responsible for his performance only (substitute employees).

For lower levels of human capital productivity, that is, for $x \leq \bar{x}$, employee incentives are lower as they are directly proportional to the level of x. The firm is more interested in maximizing its bargaining advantage than providing its employees with stronger incentives by not spreading the firm's resources over two employees. Hence, the firm always hires two employees. For high levels of s, that is, for $s > s_1$, the firm hires two complementary employees and minimizes the distortion in incentives due to a larger firm size. For lower levels of s, that is, for $s \leq s_1$, the firm hires two substitute employees to maximize its bargaining advantage. Note that at low levels of s employee incentives are weaker and the probability of ending up in the SF or FS state is higher. Therefore, the firm chooses substitute employees rather than complementary employees since the payoffs from employee innovations in the SF or FS state is higher with substitute employees than complementary employees (x as opposed to lx).

It is interesting to examine how firm size and scope affect employee welfare. The following proposition establishes the conditions under which employee welfare is positively or negatively affected by the firm's optimal size and scope decision.

Proposition 5 *There are parameter values, that is,* $x > \bar{x}$ *and* $\frac{1}{2}\frac{lx+6k}{x} > s > \frac{2lx+3k-3lk}{x}$*, such that the firm hires two complementary employees rather than 1 employee and each employee is better off compared to the case where the firm hires only one employee.*

Proposition 5 implies that, under certain conditions, expanding firm size with complementary employees is welfare increasing from the employees point of view. For high levels of human capital productivity and high levels of complementary between the employees, each employee is better off with the addition of another complementary employee to the firm.

This result is particularly interesting as it shows that larger (measured by number of employees) firms with complementary employees, pay higher wages and is consistent with an important fact in the empirical literature on firm size and wages. The stylized fact known as the large wage-size effect, shown by Brown and Medoff (1989) documents that larger firms pay higher wages. Our analysis illustrates that this arises as an outcome of hiring complementary employees. A given employee will earn higher wages in a larger firm since he works with complementary employees and extracts higher rents from the firm. On the other hand, larger firms with substitute employees pay lower wages than smaller firms.

An interesting implication of this result is that firms can enhance their employees welfare by hiring complementary employees or assigning employees on complementary tasks and promoting teamwork, especially in human capital intensive industries.

References

[1] Brown, C and J. Medoff, The employer size-wage effect, Journal of Political Economy 97, 1027-1059, 1989.

[2] Rotemberg, J. J., and G. Saloner, Benefits of Narrow Business Strategies, *American Economic Review*, 84, 1330-1349, 1994.

[3] Schoar, A., The Effect of Diversification on Firm Productivity, Journal of Finance, 62 (6), 2379-2403, 2002.

[4] Stole, L. and Z. H. Zwiebel, Intrafirm Bargaining Under Nonbinding Contracts, *Review of Economic Studies*, 63, 375-410, 1996a.

[5] Stole, L. and Z. H. Zwiebel, Organizational Design and Technology Choice under Intrafirm Bargaining, *American Economic Review*, 86, 195-222 1996b.

5 Appendix

Proof of Proposition 1.

Direct comparison of p^* (3) and p_1^{S*} (9) reveals that $p^* > p_1^{S*}$ for all parameter values.

Proof of Proposition 2. Comparing the firm's profits with two substitute employees, given in (11), to that with only one employee, given in (4), reveals that $\pi_F^{S*}(2) > \pi_F^*(1)$ for $x < 3\left(\frac{1}{2}\sqrt{5} - \frac{1}{2}\right)k$ and $\pi_F^*(1) \geq \pi_F^{S*}(2)$ for $x \geq 3\left(\frac{1}{2}\sqrt{5} - \frac{1}{2}\right)k$.

Proof of Proposition 3. Direct comparison of $p_1^{C*} = \frac{(3lx)}{2(3k-sx+2lx)}$ to $p_1^{S*} = \frac{4x}{3x+8k}$ reveals that $p_1^{C*} > p_1^{S*}$ if and only if $s > \frac{1}{8}\frac{7lx-24lk+24k}{x}$. Comparing $p_1^{C*} = \frac{(3lx)}{2(3k-sx+2lx)}$ to $p^* = \frac{x}{2k}$ gives that $p_1^{C*} > p^*$ if and only if $s > \frac{-3lk+3k+2lx}{x}$.

Proof of Lemma 1. Taking the partial derivative of $\pi_{E1}^{C*} = \frac{9}{8}\frac{kl^2x^2}{(3k-sx+2lx)^2}$ with respect to x yields that $\frac{\partial\pi_{E1}^{C*}}{\partial x} = \frac{27}{4}k^2l^2\frac{x}{(3k-sx+2lx)^3}$. From (16), we have that $3k - sx + 2lx > 0$, under which $\frac{\partial\pi_{E1}^{C*}}{\partial x} = \frac{27}{4}k^2l^2\frac{x}{(3k-sx+2lx)^3} > 0$.

Taking the partial derivative of $\pi_{E1}^{C*} = \frac{9}{8}\frac{kl^2x^2}{(3k-sx+2lx)^2}$ with respect to k yields that $\frac{\partial\pi_{E1}^{C*}}{\partial k} = -\frac{9}{8}l^2x^2\frac{3k+sx-2lx}{(3k-sx+2lx)^3}$. From (3), we have that $2k > x$. Since $s \geq 1$ and $l \leq 1$, we have that $3k + sx > \frac{3x}{2} + x > 2lx$. Hence, the numerator of $\frac{\partial\pi_{E1}^{C*}}{\partial k}$ is always positive. We have that the denominator is always positive from (16), yielding $\frac{\partial\pi_{E1}^{C*}}{\partial k} = -\frac{9}{8}l^2x^2\frac{3k+sx-2lx}{(3k-sx+2lx)^3} < 0$.

Taking the partial derivative of $\pi_{E1}^{C*} = \frac{9}{8}\frac{kl^2x^2}{(3k-sx+2lx)^2}$ with respect to s yields that $\frac{\partial\pi_{E1}^{C*}}{\partial s} = \frac{9}{4}kl^2\frac{x^3}{(3k-sx+2lx)^3} > 0$ as we have that $3k - sx + 2lx > 0$.

Taking the partial derivative of $\pi_{E1}^{C*} = \frac{9}{8}\frac{kl^2x^2}{(3k-sx+2lx)^2}$ with respect to l yields that $\frac{\partial\pi_{E1}^{C*}}{\partial l} = \frac{9}{4}klx^2\frac{sx-3k}{(3k-sx+2lx)^3}$. $\frac{\partial\pi_{E1}^{C*}}{\partial l} > 0$ if and only if $s < 3\frac{k}{x}$.

Proof of Lemma 2. Taking the partial derivative of firm profits, $\pi_F^{C*} = \frac{3}{4}\frac{l^2x^2(-sx+2lx+6k)}{(3k-sx+2lx)^2}$, with respect to x gives that $\frac{\partial\pi_F^{C*}}{\partial x} = \frac{3}{4}l^2x\frac{x^2(s-2l)^2+9k(4k-sx+2lx)}{(3k-sx+2lx)^3}$. From the proof of

Lemma x, we know that the denominator of $\frac{\partial\pi_F^{C*}}{\partial x}$ is positive. The numerator is also always positive as $4k - sx + 2lx > 3k - sx + 2lx > 0$, giving $\frac{\partial\pi_F^{C*}}{\partial x} > 0$.

Taking the partial derivative of firm profits, $\pi_F^{C*} = \frac{3}{4}\frac{l^2x^2(-sx+2lx+6k)}{(3k-sx+2lx)^2}$, with respect to k gives that $\frac{\partial\pi_F^{C*}}{\partial k} = -\frac{27}{2}l^2x^2\frac{k}{(3k-sx+2lx)^3}$. It is immediate to see that

$\frac{\partial \pi_F^{C*}}{\partial k} < 0$ since $3k - sx + 2lx > 0$.

Taking the partial derivative of firm profits, $\pi_F^{C*} = \frac{3}{4}\frac{l^2x^2(-sx+2lx+6k)}{(3k-sx+2lx)^2}$, with respect to s gives that $\frac{\partial \pi_F^{C*}}{\partial s} = \frac{3}{4}l^2x^3\frac{9k-sx+2lx}{(3k-sx+2lx)^3}$. It follows that $3k - sx + 2lx > 0$ implies $\frac{\partial \pi_F^{C*}}{\partial s} > 0$.

Finally, taking the partial derivative of firm profits, $\pi_F^{C*} = \frac{3}{4}\frac{l^2x^2(-sx+2lx+6k)}{(3k-sx+2lx)^2}$, with respect to k gives that $\frac{\partial \pi_F^{C*}}{\partial k} = \frac{3}{2}x^2l\frac{x^2(s-l)(s-2l)+9k(2k+lx-sx)}{(3k-sx+2lx)^3}$. It is straightforward to show that $\frac{\partial \pi_F^{C*}}{\partial k} > 0$ if and only if $s < \frac{\frac{3}{2}lx+\frac{9}{2}k-\frac{1}{2}\sqrt{(l^2x^2+18lxk+9k^2)}}{x}$.

Proof of Proposition 4. Notew first that, from Proposition 2, we have that $\pi_F^{S*} > \pi_F^*(1)$ if and only if $x \leq \bar{x}$. Let then $x \geq \bar{x}$.In this case, comparing firm profit with one employee given in (4) to that with two complementary employees given in (18) yields that $\pi_F^*(1) = \frac{x^2}{4k} > \pi_F^{C*} = \frac{3}{4}\frac{l^2x^2(-sx+2lx+6k)}{(3k-sx+2lx)^2}$ if and only if $P_1 \equiv 4x^4s^2 + \left(-8x^3\left(3k+2lx\right) + 12kl^2x^3\right)s + 4x^2\left(3k+2lx\right)^2 - 12kl^2x^2\left(2lx+6k\right) > 0$. Note that P_1 is a convex parabola in s with two roots s_1 and s_2 where $s_1 < s_2$ and

$$
\begin{aligned}
s_1 &\equiv \frac{3k - \frac{3}{2}l^2k + 2lx - \frac{3}{2}\sqrt{(4l^2k^2 + l^4k^2)}}{x}, \\
s_2 &\equiv \frac{3k - \frac{3}{2}l^2k + 2lx + \frac{3}{2}\sqrt{(4l^2k^2 + l^4k^2)}}{x}.
\end{aligned}
$$

We have from (16) that $s < \frac{1}{2}\frac{lx+6k}{x}$. It is straightforward to show that $s_2 > \frac{1}{2}\frac{lx+6k}{x}$, implying that $\pi_F^*(1) = \frac{x^2}{4k} > \pi_F^{C*}$ only when $s < s_1$.

Let now $x < \bar{x}$. In this case, comparing firm profit with two complementary employees given in (18) to that with substitute employees given in (18) yields that $\pi_F^{C*} = \frac{3}{4}\frac{l^2x^2(-sx+2lx+6k)}{(3k-sx+2lx)^2} > \pi_F^{S*}(2) = \frac{3x^2(x+6k)}{4(x+3k)^2}$ if and only if $P_2 \equiv -x^4\left(x+6k\right)s^2 + \Big(-l^2x^3\left(x+3k\right)^2 + 2x^3\left(x+6k\right)\left(3k+2lx\right)\Big)$ $s + l^2x^2\left(2lx+6k\right)\left(x+3k\right)^2 - x^2\left(x+6k\right)\left(3k+2lx\right)^2 > 0$. Note that P_2 is a concave parabola in s with two roots S_1 and S_2 where

$$S_1 \equiv \frac{2(x+6k)(3k+2lx) - l^2(x+3k)^2 - \sqrt{l^2(x+3k)^2\left(12k(x+6k) + l^2(x+3k)^2\right)}}{2(x+6k)x},$$

$$S_2 \equiv \frac{2(x+6k)(3k+2lx) - l^2(x+3k)^2 + \sqrt{l^2(x+3k)^2\left(12k(x+6k) + l^2(x+3k)^2\right)}}{2(x+6k)x}.$$

We have from (16) that $s < \frac{1}{2}\frac{lx+6k}{x}$. It is possible to show that $S_2 > \frac{1}{2}\frac{lx+6k}{x}$, implying that $\pi_F^{C*} > \pi_F^{S*}(2)$ only when $s > S_1$.

P**roof of Proposition 5**. To be completed.