Compensation System of Firms Promoting Innovation and Patent System (*)

Research Fellow: Akitoshi MURAMOTO (**)

In this paper, we conducted three analyses or investigations to clarify a desirable compensation system that promotes innovation, especially in terms of cooperation among employees. First, we conduct a literature review on innovation and compensation systems. As a result, psychological literature revealed, mainly in the case of work requiring creativity, that the simple pay-for-performance system can lower the productivity. However, as demonstrated in Manso (2011) and related research, creativity can possibly be further improved by using performance fees designed appropriately. Second, we conducted literature review on teamwork and compensation systems. Traditional economics mainly focused on the advantages of relative performance evaluation, but in recent years, economic research implying that team-based performance evaluation can induce employees' mutual punishment has increased. Third, we conducted analysis based on the theory constructed in this research. In this study, we compared independent performance evaluation with team-based performance evaluation and clarified the condition that team-based performance evaluation is more desirable than independent performance evaluation (bringing higher profit to the employer). We also show that the condition is more likely to be satisfied as the expected revenue from success and the importance of cooperation (increase in success probability caused by cooperation) are larger.

I. Introduction

It is very important for the economic growth of a country that inventions are made actively in the country. Most inventions are made by employees who belong to a firm, etc., and they conduct research as their duties. An invention made by an employee who performs research and development as a duty is called an employee invention. How to design an appropriate compensation system and give appropriate incentives for inventions to employees who do such research and development as their duty is a very important issue for Japanese economic growth. Before legal amendment of Heisei 16, in the Japanese employee invention system, when transferring the right to a patent, etc. to an employer, the employer must pay an appropriate amount of remuneration equal to the benefit from the exclusive license.

Such compulsion seems to have reduced the degree of freedom of the compensation system for employee inventions. Through the amendment of Heisei 16, 27, however, as long as the company has undergone a process such as consultation between employees and employer thoroughly, firms can more freely set payment of compensation for inventions. Under such circumstances, it can be said that firms are confronted with the problem of how to adopt what kind of compensation system

(*) This is a summary of the report published under the 2016FY Industrial Property Research Promotion Project entrusted by the Japan Patent Office.

and promote inventions.

On the other hand, how to give an appropriate incentive thorough an appropriate compensation scheme is one of the main research themes of principal-agent theory, which is one branch of the economics of organization. It can be said that there have been major changes in this theory in two points in recent years. One is whether the desired incentive differs across creative work and simple work. Roughly speaking, regarding simple or routine work, the theory asserted that performance fees increase productivity and many empirical results have supported this. However, in the case of creative work, some studies assert that such a performance fee will rather lower creativity, and new theoretical research, etc. must be conducted to explain such an assertion.

Another factor is teamwork and compensation systems when multiple workers work together. In traditional principal agent theory, many theoretical studies have emphasized the desirability of so-called relative performance evaluation, comparing the performance of multiple workers and paying compensation depending on the comparison.

However, in recent years, theoretical research emphasizing the desirability of team-based performance evaluation has emerged.

In this research, we examine what kind of compensation system is desirable in the employee invention system, while emphasizing the problem of team work among multiple workers. For that purpose, first, we will conduct a literature survey on the above two issues and organize the issues concerning compensation schemes. In Chapter 2, we survey the economic literature on innovation and compensation systems and some psychology literature, and see what kind of compensation system is desirable for innovation. Next, in Chapter 3, we overview the literature on a desirable compensation system when multiple workers work. By doing so, we overview the advantages and disadvantages of relative performance and team-based performance evaluation, respectively.

After overviewing the literature on the compensation system in Chapter 2 and Chapter 3, in Chapter 4, we will construct a new economic model considering both the element of innovation and the element of cooperation between employees. Then, we discuss the desirable compensation system. In our model, two employees engage in research and development. Each employee has his own research. Under these circumstances, each employee makes decisions about two actions. One is decision-making as to whether or not to make effort for his own research. The other is decision-making as to whether or not to support the other employee’s research. Under such circumstance, we compare and examine two performance evaluations. One is an independent performance evaluation. This is a performance evaluation under which employees receive compensation only depending on whether or not their own research succeeded regardless of any other employee’s result. The other is a team-based performance evaluation. Especially in this theoretical analysis, when one or both of the two workers succeed, we consider a compensation

system in which all of the compensation is equally divided between two employees.

In this theory analysis, we compare the profit under the team-based performance evaluation and that under the independent performance evaluation and find the condition such that a team-based compensation system is more profitable for the employer.

In particular, the condition tends to be satisfied when two particular elements are larger. One is management gain which the employer obtains when an employee's research succeeds. Another is the importance of cooperation of workers. The importance of cooperation indicates the degree to which the success rate of research by other employee rises when the employees cooperate. This result is due to the fact that team-based performance evaluation more easily draws out cooperation among employees as opposed to independent performance evaluation. In our model, when employees cooperate, the probability of success of other researchers receiving cooperation increases.

Therefore, if the cooperation of employees is important and increases the success probability by a large amount and the revenue from success is high, team-based performance evaluation tends to be more desirable for the employer.

II. Innovation and Compensation System

In this chapter, we give an overview of economics literature on innovation and compensation systems and some psychology literature. As an employee invention, a relationship in which a user delegates the implementation of labor to a third party (employee) for his own interest is called a principal-agent relationship. A principal is an entity that delegates the implementation of labor, and in the case of employee invention, it is a user. An agent is an entity that is delegated the execution of labor, and in the case of an employee invention, it is an employee. In such a principal-agent relationship, the principal cannot completely observe the behavior of the agent, and it is difficult to completely control the behavior of the agent. Therefore, appropriate reward design is important in order to derive desirable behavior (such as effort) of the agent.

Much literature on traditional principal-agent theory states that it is able to raise the level of effort of employees and therefore productivity by giving compensation linked to the performance of employees. For example, in a dynamic principal-agent model (Rogerson, 1985; Holmstrom and Milgrom 1987; Sanikov, 2008), in which efforts are repetitively performed, if an agent's reward is not tied to the agent's performance, it will result in low effort and low outcome. There are many empirical studies on such performance-linked fees and theoretical results of productivity. Foster and Rosenzweig (1994) conducted research on peasant farmers in the Philippines. Conditional on calorie intake, they compare the case of fixed payment and that of performance based payment. The

result is that weight loss was greater in the case of performance pay. That is, it suggests that workers made more efforts under performance pay. Ehrenbergn and Bognanno (1990) studied professional golf tournament events, showing that the higher the monetary compensation, the better the performance.

In these theoretical studies and empirical studies, analysis focused on situations where only one-dimensional behaviors such as effort or negligence were related to outcomes. These assumptions are appropriate for jobs like repetition, but not necessarily appropriate for innovative work that requires flexibility and creativity.

Actually, pay-for-performance will greatly change performance, depending on whether the job is simple and unchanging repetitive work, or whether it is work that requires flexibility and creativity. This is the result of Glucksberg (1972) and a series of psychological research that follows it. According to the results of their experiments and others, in the case of work requiring simple, repeatable and unaltered responses, pay-for-performance improves outcomes while in the case of work requiring flexibility and creativity, pay-for-performance has a worse outcome.

On the other hand, in recent economic theory, it has been pointed out that trials (experiments) on new methods are important for innovation, and a central tradeoff in innovations has become illuminated. It is exploitation and exploration. Exploitation is the deepening already known technique. Exploration is to pioneer new ways. Manso (2011) studies what kind of compensation system is desirable for employees to not only exploit but also explore and promote innovation. Manso (2011) assumes a situation where an employee is involved in a two-period project. The employee selects in each period either (1) to not take initiative, (2) to exploit, or (3) to explore. To do exploitation here is to take on projects whose success probability is already known. To do exploration is to take on a project whose success probability is not well understood, and after the exploration the employee finds the success probability. A project whose success probability is unknown may actually be a project that provides a higher probability of success than a project whose success probability is known, or it may be a project with low probability of success.

The result of Manso (2011) is that in order to promote exploration and to promote innovation, a compensation scheme that is tolerate of initial failure of the project and remuneration for long-term success are desirable. This is because if the initial failure of the project is severely punished, the employee does not conduct exploration and has an incentive to conduct a project with a well-known success probability, that is, exploitation. On the other hand, if you do not give rewards for success at all, you give employees incentive to not take initiative. Therefore, it is necessary to reward for long-term success.

Ederer and Manso (2013) conducted an economic experiment on the theoretical model of Manso (2011). This experiment was conducted at the computer laboratory of Harvard Business School,

and 379 subjects participated in the experiment. Subjects play games running lemonade shops for 20 periods in this experiment. For each period, subjects make decisions on how to manage lemonade shops. The profit of the lemonade shop changes by changing the price, the lemonade shop location, the lemonade sugar, the amount of sugar in lemonade, the price. Subjects observe the profit of the lemonade shop after each phase of decision making. Subjects were divided into three groups and participated in the experiment. One is a group that receives fixed salaries all the time. The other is a group that gains 50% of the lemonade shop's profit all the time over 20 periods. The third is a group that receives a fixed fee for the first ten periods and receives 50% of profits for the last ten periods. When comparing these three groups, the third group showed the highest productivity. This can be said to be consistent with the theoretical results of Manso (2011). The third group received a fixed salary in the first half, so even if subjects in the group earn poor results early, they do not affect their salary. Therefore, it can be said that this is a tolerant remuneration contract against the initial failure. Also, since the second half is a resulting wage, it gives compensation for long-term success.

Azoulay, Graff-Zivin and Manso (2009) compared the two research grants and demonstrated which of the research is leading to more innovative innovation. One is a research grant from Howard Hughes Medical Institute (HHMI).This research grant is characterized by a long-term (5-year) research subsidy period. Also, at the outset, the review on research is not strict; it is a subsidy for people, not projects. Another subsidy is the R01 subsidy from researcher applications from the National Institute of Health (NIH). This subsidy has a relatively short research assistance period (3 to 5 years) as compared with the former subsidy. Also, the first examination is as severe as the subsequent examination. And subsidies are for projects, not people. The demonstration results of Azoulay, Graff-Zivin and Manso (2009) are as follows. First of all, it can be said that HHMI subsidies are more tolerant of early failure and reward long-term success. And HHMI subsidies create more research that leads to innovative innovation. This result can also be said to be consistent with the theoretical result of Manso (2011).

III. Cooperation among Employees and Compensation System

When there are multiple employees, there are two major performance evaluation systems to evaluate those employees. One is a relative performance evaluation system. This is a performance system that compares the performance of the employees and makes them compete. For example, in a sale of insurance, a compensation system that gives high remuneration according to the order of insurance sales is one relative performance evaluation system, as is a tournament system. Another performance evaluation system is a team-based performance evaluation system. This is a

performance system that pays more compensation not only when individual employees succeed but also when whole teams succeed. Broadly speaking, traditional economics has emphasized the advantages of relative performance evaluation more than team-based performance evaluation. The first drawback of team-based performance evaluation is the free rider problem (Holmstrom, 1982). In the case of team based performance evaluation, it is known that there is an incentive to ride on the efforts of other employees, and tendency for effort incentives to become too small. In addition, compared with team-based performance evaluation, there is a disadvantage in that it is difficult to evaluate the performance of the employee distorted from the firm under relative performance evaluation. In general, if the total performance compensation for employees increases as the performance evaluation increases, there is an incentive for companies to underestimate the performance of their employees. However, considering a relative performance evaluation system that keeps the total bonus amount constant and assigns the total bonus amount according to the ranking of the employees, there is no incentive for undervaluation. This is because even if the number of employees is underestimated, the total number of payment bonuses will not change, only by changing the ranking of the employees. For example, you can commit to giving a bonus of 1 million yen to an employee who receives the best score. In this case, even if the company distorts the evaluation of the employees, the company must finally pay 1 million yen to the employee who was evaluated as in first place. However, in the case of team-based performance evaluation, the firm must pay more bonuses by allowing the team to succeed. Therefore, incentives for companies to underestimate the team's success to save payment bonuses tend to be large.

Meanwhile, in recent economic studies, evaluation of team-based performance evaluation is increasing. In particular, under team-based performance evaluation it is often pointed out that cooperation in the team is easy to draw out. Che and Yoo (2000) and Kvaloy and Olsen (2006) developed a theoretical model assuming a situation where multiple employees can work for a long time and observe each other's effort levels. They investigate the shape of the optimal compensation system. As a result, they show that when an employee is patient, under the team-based performance evaluation, incentives for employees to make effort without laziness by mutually punishing lazy workers can be drawn out appropriately. On the contrary, since incentives for such mutual punishment do not work under relative performance evaluation, in the case where the employees are patient, the team-based performance evaluation is better than the relative performance evaluation.

IV. Analysis by Model

1. Model

Up to the preceding chapter, we have reviewed the literature on innovation and compensation systems and on the cooperation between employees and the compensation system, respectively. In this chapter, we will construct a new model and discuss a desirable compensation system in order to think simultaneously about cooperation among employees and innovation problems. In particular, in this section, we compare independent performance evaluation and team-based performance evaluation using a theoretical model and examine which is preferable from the viewpoint of the employer's expected profit. Independent performance evaluation is a performance evaluation in which one's compensation is decided only based on one's own achievements. In team-based performance evaluation, one's compensation is determined by the performance of the whole team.

In the model of this section, we analyze not only the incentives for employees to make effort on their own but also the incentives to cooperate with the research of other employees. We investigate the importance of team work and a desirable compensation system.

In this chapter, we consider the situation where one employer hires two employees (employee 1 and employee 2). Both employees have their own research tasks (task 1 and task 2). Each employee $i = 1,2$ chooses whether to make effort for his own task ($a_i = 1$)or shirk ($a_i = 0$). If he chooses to make effort, he incurs effort cost *c*. Furthermore, he also choose whether to cooperate with the other employee $j(\neq i)$'s task ($b_i = 1$)or not ($b_i = 0$). If he chooses to cooperate, employee i incurs disutility *d*.

Each employee's task will succeed or fail. When the task succeeds, the outcome is written as S. When it fails, the outcome is written as F. The success probability of a task depends on whether employee i makes effort for his own task and whether employee *j* cooperates with i. We assume that when employee i chooses $a_i = a$ and the other employee j chooses $b_j = b$, employee i's task's success probability is $p_a + q_b$, where

$$0 < p_0 < p_1 < 1, \qquad 0 < q_0 < q_1 < 1$$

These inequalities indicate that that the more the employee makes effort and the more the other workers cooperate, the more likely the task will succeed with higher probability. $p_1 - p_0$ is an increment of success probability by one's own effort and $q_1 - q_0$ is that by the other employee's cooperation.

The employer pays compensation depending on the outcomes of tasks. Each compensation

scheme for employee *i* is written as $(\beta^i_{SS}, \beta^i_{SF}, \beta^i_{FS}, \beta^i_{FF})$. For each $\mathrm{KL} = \mathrm{SS}, \mathrm{SF}, \mathrm{FS}, \mathrm{FF}$, β^i_{KL} is the payment employee *i* receives when his/her own task's outcome is *K* and the other employee *j*'s task's outcome is L. For example, β^1_{SF} is the payment employee 1 receives when employee 1's task succeeds and employee 2's task fails. β^2_{FS} is the payment employee 2 receive when employee 2's task fails and employee 1's task succeeds. Hereafter, we assume that payment of compensation is similarly made to employee 1 and employee 2. That is, the payment to employees 1 and 2 are symmetric (i.e., For any K*L*, $\beta^1_{KL} = \beta^2_{KL}$). For simplicity, we drop the subscripts, which indicate employees, and $(\beta^{\mathrm{i}}_{SS}, \beta^i_{\mathrm{SF}}, \beta^i_{\mathrm{FS}}, \beta^i_{FF})$ is simply written as $(\beta_{SS}, \beta_{\mathrm{SF}}, \beta_{\mathrm{FS}}, \beta_{FF})$.

When compensation is paid according to $\beta \equiv (\beta_{SS}, \beta_{\mathrm{SF}}, \beta_{\mathrm{FS}}, \beta_{FF})$, where employee 1 takes action $(\mathrm{a}_1, \mathrm{b}_1)$, and employee 2 takes action as $(\mathrm{a}_2, \mathrm{b}_2)$, employee 1's expected payoff is the expected compensation minus effort cost and cooperation cost, which is written as follows.

$$
\begin{aligned}
&\mathrm{u}(\mathrm{a}_1, \mathrm{b}_1, \mathrm{a}_2, \mathrm{b}_2 : \beta) \\
&= \beta_{\mathrm{SS}}(p_{a1} + q_{b2})(p_{a2} + q_{b1}) + \beta_{SF}(p_{a1} + q_{b2})(1 - p_{a2} - q_{b1}) \\
&\quad + \beta_{\mathrm{FS}}(1 - p_{a1} - q_{b2})(p_{a2} + q_{b1}) + \beta_{FF}(1 - p_{a1} - q_{b2})(1 - p_{a2} - q_{b1}) \\
&\quad - \mathrm{c}\, a_1 - d b_1
\end{aligned} \tag{1}
$$

We can similarly compute the expected payoff for employee 2. Each employee chooses actions to maximize his own expected payoff given the shape of $\beta \equiv (\beta_{SS}, \beta_{\mathrm{SF}}, \beta_{\mathrm{FS}}, \beta_{FF})$ and the other employee's action.

As mentioned above, this chapter compare two compensation systems. The first one is independent performance evaluation. Under independent performance evaluation, an employee receives a certain amount of compensation depending only on his own task's outcome. Therefore, this compensation system can be written as follows.

For a certain amount of compensation B,

$$\beta_{SS} = \beta_{SF} = B, \quad \beta_{FS} = \beta_{FF} = 0. \tag{2}$$

The other compensation system is a team-based performance evaluation system. Under this performance evaluation system, employees evenly split the total bonus for the total success of the team. This compensation system can be written as follows. For a certain amount of compensation B,

$$\beta_{SS} = B\,, \beta_{SF} = \beta_{FS} = \frac{B}{2}, \beta_{FF} = 0. \tag{3}$$

Hereafter, we focus on an equilibrium such that two employees takes the same action profile. That is, we assume $(a_1, b_1) = (a_2, b_2)$ on equilibrium.

The employer's expected payoff is the expected revenue from the successes of tasks minus expected total payment to employees. We assume that the employer obtain the revenue R per each task's success. Therefore, when the employee's actions on equilibrium is $(a_1, b_1) = (a_2, b_2) = (a, b)$, the expected revenue from one task is $(p_a + q_b)R$ so, the total expected revenue, which is from two tasks, is given as,

$$2(p_a + q_b)R.$$

On the other hand, the total expected payment to the employees is represented as

$$\begin{aligned} &2\{\, \beta_{SS}(p_a + q_b)(p_a + q_b) + \beta_{SF}(p_a + q_b)(1 - p_a - q_b) \\ &\quad + \beta_{FS}(1 - p_a - q_b)(p_a + q_b) + \beta_{FF}(1 - p_a - q_b)(1 - p_a - q_b)\,\}. \end{aligned} \tag{4}$$

If the compensation scheme is independent performance evaluation (i.e., (2) holds) or, team-based performance evaluation (i.e., (3) holds), by substitution (2) or (3) to (4),
(4) can be transformed as follows:

$$\begin{aligned} &2\{\, \beta_{SS}(p_a + q_b)(p_a + q_b) + \beta_{SF}(p_a + q_b)(1 - p_a - q_b) \\ &+ \beta_{FS}(1 - p_a - q_b)(p_a + q_b) + \beta_{FF}(1 - p_a - q_b)(1 - p_a - q_b)\,\} \\ &= 2(p_a + q_b)B. \end{aligned}$$

Therefore, in this case, the employer's expected profit can be represented as

$$2(p_a + q_b)R - 2(p_a + q_b)B. \tag{5}$$

2. Independent Performance Evaluation Versus Team-Based Performance Evaluation

In this section, we investigate the condition under which team-based performance evaluation is more desirable than independent performance evaluation.

The following proposition holds.

Proposition 1

The condition under which the profit under team-based performance evaluation is greater than that under independent performance evaluation is as follows.

(i)If $\frac{c}{p_1-p_0} > \frac{d}{q_1-q_0}$

$$R > \frac{c}{(p_1-p_0)(q_1-q_0)}(2p_1+2q_1) + \frac{2c}{p_1-p_0}$$

(ii)If $\frac{c}{p_1-p_0} \leq \frac{d}{q_1-q_0}$

$$R > \frac{2d(2p_1+q_1)}{(q_1-q_0)^2} + \frac{c(2p_1+q_0)}{(p_1-p_0)(q_1-q_0)}$$

Proposition 1 is illustrated as Figure I.

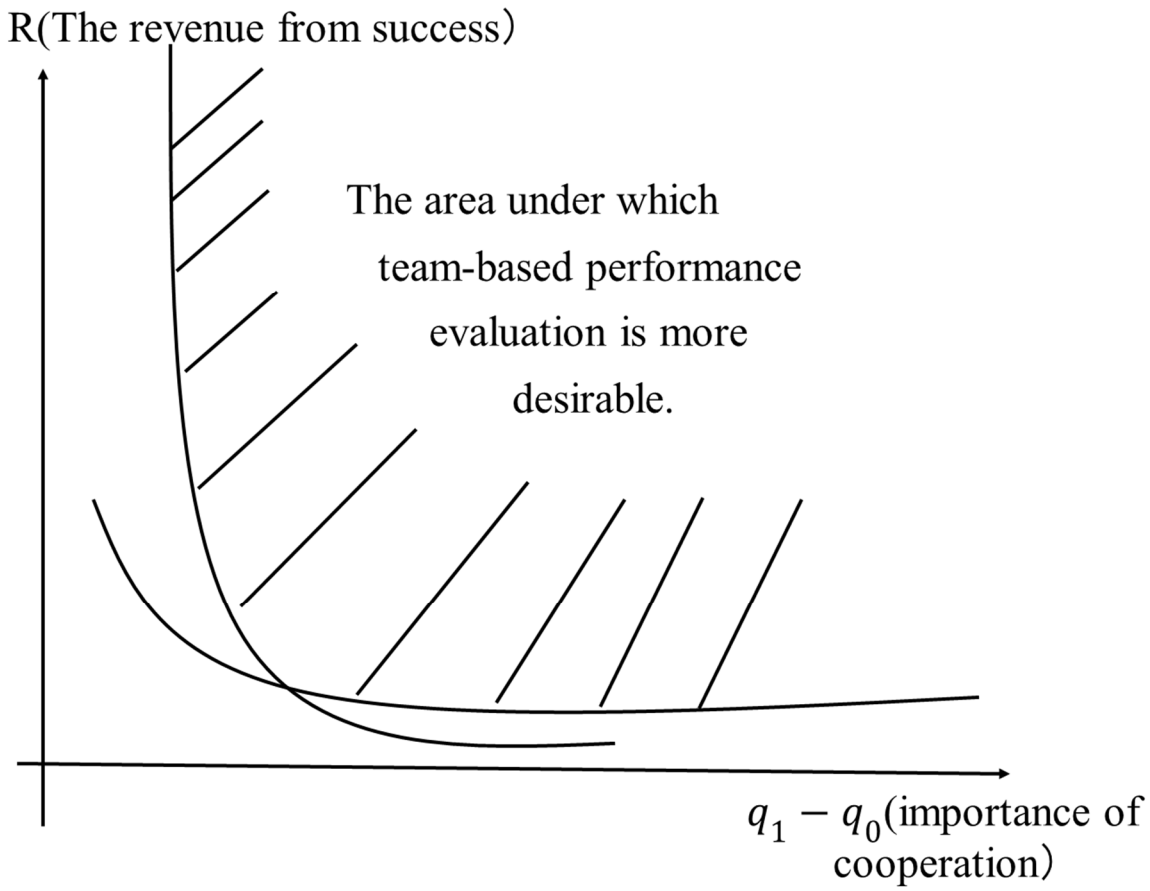

Figure I

Corollary 1

Team-based performance evaluation tends to be more desirable than independent performance evaluation when the revenue from the invention R is large. Team-based performance evaluation

tends to be more desirable than independent performance evaluation when the increment of the success probability of invention $q_1 - q_0$ *is large.*

VI. Conclusion

In this paper, we conducted three analyzes or investigations to clarify a desirable compensation system that promotes innovation, especially in terms of cooperation among employees. The first was literature review on innovation and compensation systems. As a result, psychological literature revealed, mainly in the case of work requiring creativity, simple pay-for-performance can lower productivity. However, as demonstrated in Manso (2011) and related research, it is possible to further improve creativity by using appropriately designed performance fees. The second was literature review on teamwork and compensation systems. Traditional economics mainly focused on the advantages of relative performance evaluation, but in recent years, economic research implying that team-based performance evaluation can induce employees' mutual punishment has increased. The third was analysis based on the theory constructed in this research. In this study, we compared independent performance evaluation with team-based performance evaluation and clarified the condition that team-based performance evaluation is more desirable than independent performance evaluation (bringing higher profit to the employer). And we showed that the condition is more likely to be satisfied as the expected revenue from success and the importance of cooperation (increase in success probability caused by cooperation) are larger.

References

Azoulay, P., Graff Zivin, J. S., & Manso, G. (2011). Incentives and creativity: evidence from the academic life sciences. *The RAND Journal of Economics,* 42(3), 527-554.

Boning, B., Ichniowski, C., & Shaw, K. (2001). Opportunity counts: Teams and the effectiveness of production incentives (No. w8306). *National Bureau of Economic Research*.

Che, Y. K., & Yoo, S. W. (2001). Optimal incentives for teams. *American Economic Review*, 91(3), 525-541.

Ederer, F., & Manso, G. (2013). Is pay for performance detrimental to innovation?. *Management Science*, 59(7), 1496-1513.

Ederer, F., & Manso, G. (2011). Incentives for innovation: Bankruptcy, corporate governance, and compensation systems. *Handbook of Law, Innovation, and Growth*, 90-111.

Ehrenberg, R. G., & Bognanno, M. L. (1990). The incentive effects of tournaments revisited: Evidence from the European PGA tour. *Industrial & Labor Relations Review*, 43(3), 74S-88S.

Foster, A. D., & Rosenzweig, M. R. (1994). A test for moral hazard in the labor market: Contractual arrangements, effort, and health. *The Review of Economics and Statistics*, 76(2), 213-227.

Glucksberg, S. (1962). The influence of strength of drive on functional fixedness and perceptual recognition. *Journal of Experimental Psychology*, 63(1), 36.

Holmstrom, Bengt (1982). Moral hazard in teams. *The Bell Journal of Economics*, 13(2), 324-340.

Kvaløy, O., & Olsen, T. E. (2006). Team incentives in relational employment contracts. *Journal of Labor Economics*, 24(1), 139-169.

Manso, G. (2011). Motivating innovation. *The Journal of Finance*, 66(5), 1823-1860.

Weitzman, M. L. (1979). Optimal search for the best alternative. *Econometrica,* 47(3), 641-654.