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Intrinsic and Extrinsic Motivations of Inventors

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Abstract

This paper theoretically and empirically evaluates the relationship between the strength of inventors' motives and their productivity, and the interaction between intrinsic and extrinsic motivation. For our empirical analyses, we use novel data from a survey of Japanese inventors on 5,278 patents conducted by the Research Institute of Economy, Trade and Industry (RIETI) in 2007 matched with a firm-level survey of remuneration policies for employee inventions conducted by the Institute of Intellectual Property (IIP) in 2005. The RIETI survey contains rich information about inventors, patents, and project characteristics, as well as two new measures of inventor productivity.

Our study first reveals that satisfaction from contributing to science and technology and interest in solving challenging technical problems are highly associated with inventor productivity. Most notably, the science motivation measure has the largest and the most significant correlation with our measures of inventor productivity. Science orientation may be strongly associated with high R&D productivity because early access to scientific discoveries gives inventors an advantage or because interest in science correlates with inventive ability. However, careful analysis using additional measures of knowledge spillovers from academia and a proxy of inventor ability find little support for either explanation. This result makes the third explanation (science orientation) plausible, that is, the above two task motives simply encourage researchers to dedicate themselves to challenging projects.

In order to explore further and based on our interpretation of motivation mentioned above, we present a principal-agent model where the agent selects the type of research projects and exerts effort in the presence of monetary incentives. The model offers the following two empirical implications: (a) firms with many intrinsically motivated employees are less likely to introduce revenue-based pay; and (b) the average value of patents is more positively correlated with the strength of intrinsic motivation in the absence of revenue-based pay than in its presence. Finally, we test the above empirical implications using the matched dataset from the RIETI and IIP surveys and we find little significant support for either prediction. We offer possible explanations for the result.

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I Introduction

Since the seminal work done by Schumpeter (1943), economists have investigated what determines the level of R&D efforts at the organizational level. Although we have accumulated substantial knowledge about how market structure, protection of intellectual property rights, and the existence of positive spillovers affect the level of R&D investment at the firm level, one of the most important resources in technological progress, efforts made by inventors themselves, has not been given enough attention in the literature. Note that most innovators are employed by organizations and much of the rent generated from the invention does not accrue to the inventor himself. This setup is a traditional moral hazard situation in which inventors may exert less efforts than are efficient.

The moral hazard problem in the R&D setting is especially hard to avoid for a number of reasons. First, it is difficult for the management to monitor the process of R&D activities. Since R&D typically requires highly specialized scientific and/or technical knowledge, it is almost inevitable that the management will delegate real decision authority to the researchers about what targets to pursue, what approaches to take, and how much resources to allocate to each step. This means that the management cannot intervene in the day-to-day operation of their R&D projects. Second, the output of R&D is knowledge and technology which will be combined for commercial use. According to the RIETI inventor survey we use, about 80 percent of patented technology in commercial use is utilized conjointly with other patented technology. It is not unusual for more than 100 patents to be bundled together to launch a new product. Therefore, it is a formidable task to evaluate the economic value of each piece of technical knowledge. Third, some discoveries are strategically patented (e.g., for defensive reasons) with little expectation of commercial use while some important technologies and know-how are kept unpatented and secret to avoid disclosure. Therefore, simply counting the number of patents granted may not be a good measure of R&D performance. Fourth, most R&D processes take time and involve considerable uncertainty. It is not uncommon, especially in the pharmaceutical industry, for it to take ten to twenty years for some inventions to start generating significant revenue for the firm. Designing effective incentive contracts is greatly complicated by such time lags and the risk-averse nature of individuals. The difficulty of monitoring and evaluating the performance of R&D employees might impel firms to rely on intrinsic or social motives and to adopt a hands-off management approach that empowers researchers and reinforces their intrinsic motivations.

In this context, it is quite important to understand what factors actually motivate inventors and how they interact each other. Intrinsically motivated behaviors are behaviors which a person engages in to feel competent and self-determining (Deci 1975) and for R&D researchers overcoming obstacles to contribute to the advancement of science fulfills this definition. They are also influenced by extrinsic motives such as career concerns, the desire to enhance their reputations inside and outside their organizations, and the expectation that their performance will affect their research funding and compensation. Social psychologists have long discussed the possible detrimental effect of extrinsic motivation on creativity (see, for example, Amabile 1987). Intrinsic motivation may stimulate creativity by supporting more challenging exploratory work while extrinsic rewards could suffocate creativity by drawing researchers' attention to more incremental approaches. Social psychologists have also examined the interaction between intrinsic and extrinsic motivation and shown some evidence that extrinsic rewards could "crowd-out" intrinsic motivation under certain conditions (see Frey 1997, Deci, Koestner, and Ryan 1999, Frey and Jegen 2001, and Wiersma 1992).

If the "crowding-out" story holds true, striking a balance between intrinsic and extrinsic motivations is a challenging task for the firm. For example, it may be infeasible to encourage individuals to initiate exploratory research relying on intrinsic motives and at the same time motivate the same individuals to exploit the firm's knowledge stock to accelerate incremental process of development and commercialization through extrinsic rewards. The degree to which intrinsic and extrinsic motivations reinforce or weaken each other has various implications for the organizational structure and management of R&D divisions.

The issue of how to design the optimal monetary compensation for inventions is especially important for Japanese firms in the light of recent developments in domestic property rights law. Most Japanese firms offer some form of monetary rewards to employees who successfully develop patented or commercialized technology. Although Japanese patent law requires firms to pay an appropriate amount of monetary compensation to employee-inventors, the law does not specify how much is "appropriate." As a result, the size of reward varies widely from firm to firm. In the past decade, a number of major Japanese firms including Nichia Chemical, Hitachi, Olympus, and Ajinomoto have been sued by their former inventor-employees for not compensating them enough and many of these firms lost their cases. In response to this new legal environment, some firms have introduced additional inventor compensation packages or raised the level of rewards to avoid the risk of legal battles.

In addition, the external labor market for R&D researchers and engineers is becoming increasingly active and their turnover rate has been gradually but steadily rising over the last decade. Competition is pushing innovative firms to offer more generous inventor remuneration to attract and retain talented researchers. We need to investigate whether this trend toward greater extrinsic rewards will benefit or harm R&D productivity in the Japanese firms.

II Prior Literature

Importance of science orientation and intellectual challenge has been discussed by a number of economists such as Arora and Gambardella (1994), Cohen and Levinthal (1989, 1990), Gambadella et al. (2006), Sauermann and Cohen (2010), Stephan (1996), and Stern (2004). Some of these works have found strong correlations between science orientation and R&D productivity, but it has not yet been made clear whether individuals' enthusiasm for science serves to enhance their R&D productivity or if enthusiasm is simply correlated with their ability. The economic significance of intrinsic and social motives recently attracted more attention thanks to the "paradox" of open source software development. Lerner and Tirole (2005) argue that open source contributors enjoy working on a "cool" project, derive ego gratification from peer recognition as well as skill improvement and can advance their careers by attracting offers of employment or venture capital funding.

As noted above, the possibility of extrinsic rewards or intervention “crowding-out” intrinsic motivation has been discussed by many researchers in social psychology. According to Frey (1997), three psychological processes contribute to the crowding-out effect of extrinsic rewards and intervention: individuals feel less responsible and self-determining, their self-esteem suffers from feeling less appreciated for their commitment and competence, and they lose the chance to exhibit their inner motivation.

Although there has been much research in economics on extrinsic rewards such as explicit monetary incentives and promotion, studies rarely considered the role that intrinsic motives play in employee performance with a few exceptions including Kreps (1997), Murdock (2002) and Akerlof and Kranton (2005). Very recently, though, there have been some attempts to explain the substitutability between intrinsic and extrinsic motivation using game-theoretical models. Bénabou and Tirole (2003) argue that information revelation by an informed principal could cause the crowd-out effect. In their model, the principal (manager, teacher, parent) has some private information about the capability of the agent (worker, child) or the difficulty of the task. By choosing certain extrinsic rewards, the principal reveals this private information to the agent (*e.g.,* the principal thinks that the agent lacks sufficient ability to accomplish the task easily or believes the task is more difficult than it looks). This revelation makes the incentive a weak reinforcer in the short run and a negative reinforcer in the long run.

Another related study by Prendergast (2008) introduces the role of sorting based on the preferences of potential employees in the framework of multi-tasking agents. When the firm can contract on outputs, it is best to hire agents who do not have biased preferences. As the precision of output measures deteriorates, the firm relies less on incentives and tries to hire individuals with stronger intrinsic motivation—people who have biased preference for certain aspects of their tasks which leads to the possibility of strife across different parts of the firm. The model has an empirical implication that is very similar to that of the crowd-out effect: the employees are less intrinsically motivated in the firm where strong monetary incentives are offered.

Despite the increasing theoretical works and numerous experimental studies by psychologists, sociologists and economists, there have not been any systematic studies using real-world data. Nor have we seen empirical studies analyzing the impact of extrinsic rewards for R&D workers with the exception is Cohen and Sauermann (2010) who analyze the relationships among income, levels of effort, and innovative outputs for those with science and engineering degrees in the United States.

III Data

We employ data from a survey of 5,091 Japanese inventors on 5,278 patents (187 inventors filled the survey twice on different patents) conducted by the Research Institute of Economy, Trade and Industry (RIETI) in 2007. Roughly 70% of the sample comes from the pool of triadic patents which are simultaneously applied for in Japan, the US and Europe, while roughly 30% come from random sampling of non-triadic patents. Although the pool of triadic patents contains only 3% of all applications submitted to the Japan Patent Office, focusing on this pool allows us to analyze mostly economically valuable patents. In addition, selecting triadic patents enabled us to use citation information provided by the US Patent Office for this portion of respondents. Some inventor and project characteristics as a percentage of the total sample are presented in Tables A-E.

The RIETI survey has two advantages. First, most earlier surveys conducted in Japan were designed for collecting firm-level data and do not allow researchers to test inventor-level, project-level or even business-unit-level hypotheses. The RIETI inventor survey contains rich information about inventor, patent and project characteristics and is perfectly suitable for analyzing the work environments of employee-inventors. Second, the survey offers two new measures of inventor productivity, one "quantitative" and the other "qualitative." The former is the number of patents the project produced or was expected to produce and the latter measure is the economic value of the surveyed patent evaluated on a relative basis by the inventors themselves. These measures, together with patent citation figures—the traditional performance measure for inventions—enable us to analyze hypotheses from multiple dimensions. To be more specific, we have the following two performance measures:

Pat_num : the number of domestic patent grants the project is expected to generate; category variable: 1 (= 1 patent), 2 (2~5), 3(6~10), 4 (11~50), 5 (51~100), 6 (>100).

Pat_val: the inventor's ranking of the economic value of the surveyed patent among other comparable patents in the same technological field concurrently granted in Japan; category variable: 1 (below average), 2 (above average), 3 (top 25 percent), 4 (top 10 percent).

Other important pieces of information that allow us to analyze what inventors care most about are their responses to the survey question, *"How important was each of the following factors as a source of motivation for your invention?"*

1. **SCIENCE**: Satisfaction from contributing to the progress of science and technology.
2. **CHALLENGE**: Satisfaction from solving challenging technical problems.
3. **ORG_PERFORMANCE**: Performance enhancement of your organization
4. **CAREER**: Career advances and better job opportunities.
5. **REPUTATION**: Reputation and prestige.
6. **BUDGET**: Improved research conditions such as more budget.
7. **MONEY**: Monetary rewards.

The 5-point Likert scale is used to answer each question (1 = absolutely unimportant, 5 = very important). We regard the first two motives as intrinsic and the latter five motives as mostly extrinsic. Table 1 shows that there are high correlations between the two intrinsic motives and among the last four extrinsic motives.

Figures 1 and 2 illustrate how the inventors' rating of motives does not vary much according to their educational background or employer type. Nonetheless, we can derive a number of notable implications from the graphs. First, the higher level of degree an inventor has, the more he tends to attribute his motivation to advancing science and technology, solving challenging technical problems, enhancing his reputation, and getting more resources (see Figure 1). One caveat is that the differences between PhDs and other degree holders likely reflect differences in the types of organization that employ them as a substantial portion of PhDs work in universities, national laboratories and other non-profit research institutions. As you can see in Figure 2, researchers in those organizations tend to value contributing to science and technology and securing better research conditions more highly than private sector researchers. Second, it is not surprising that self-employed inventors care much more about monetary compensation and less about organizational performance and career development than their employed counterparts. Self-employed researchers can capture a substantial portion of the economic rent generated by their inventions through licensing or commercialization while employee-inventors are typically entitled to a small amount of compensation under the *Patent Law*.

Third, inventors in medium-sized firms seem to have less desire to advance science and technology or earn monetary compensation than inventors in other firms while those in small firms are likely to be less interested in organizational performance and career development. This finding indicates that the relationship between firm size and inventors' motives may not be linear.

IV Empirical Analysis, Part 1

Our multivariate analysis proceeds in two steps in this section. First, we estimate ordered logit models to investigate how the seven motives are associated with inventor productivity measures, controlling for other inventor, technology, project and firm characteristics. The biggest problem in these estimates is self-selection. For example, some unobservable project or firm characteristics may affect both the types of inventors the projects attract and their productivity measures. Since we cannot find any appropriate instruments to resolve this endogeneity issue, we attempt to mitigate the self-selection by estimating the same model with the firm fixed effect. In the second step, we investigate what mechanism lies behind the significant correlation between the measurements of intrinsic motives and our R&D performance measures. We then present a number of hypotheses and examine how well our data support them.

a. What motivates inventors?

First, we estimate two knowledge production functions for the number of patents granted for inventions from a given project (*Pat_num*) and the subjective value of the sampled patent (*pat_val*). The econometric model we use is the following form of the ordered logit model:

$$y^*_i = X_i\beta + Z_i\delta + \varepsilon_i \qquad (7)$$

where y^*_i is the latent variable either for the number of patents (*Pat_num*) or the inventor's own estimate of the value of a patent (*Pat_val*) for each inventor-project pair i, X_i includes various inventor, patent, project, and firm characteristics, Z_i is the inventor's evaluation of the seven motives, and ε_i is the error term. Table 2 shows the results when the dependent variable is the number of patents while Table 3 presents the results when our quality measure—the inventor's evaluation of the worth of a patent—is the dependent variable.

We learn from the first columns of Table 2 and 3 that SCIENCE and CHALLENGE are strongly associated with both measures of inventor productivity. SCIENCE has a higher coefficient than CHALLENGE for the number of patents generated while both have almost equal coefficients for the relative value of patents. The results should not be interpreted as showing the effect of these motives on R&D productivity, however, because the importance of motives is presumably determined endogenously. For example, it is possible that projects closer to the frontiers of science tend to have higher expected values as well as attracting researchers with stronger interests in science or solving challenging problems.

We also find a slight difference between the quantity and quality measures: inventors who say they are highly motivated by a desire to improve their research conditions, such as their funding levels are likely to produce more patents (column 1 in Table 2), while inventors who rate reputation as important are likely to produce more valuable patents (column 1 in Table 3). The former result may imply that in organizations which base research budgets on the amount of inventions produced, inventors will work to increase the number of patents rather than toward producing more valuable inventions. The problem can also be seen as an example of the multi-tasking agency problem analyzed by Milgrom and Roberts (1988) if researchers have to engage in the competing tasks of pursuing quantity and quality. Since the quantity aspect of inventive activities can be objectively and precisely measured by the number of patents obtained and the actual economic value of patents are hard to evaluate, firms tend to rely more on the quantity measure when allocating resources which leads researchers to distort their effort allocation to produce more patents at the cost of lower quality. The correlation between high rating of reputation and the value of invention shown in column 1 in Table 3 has a natural interpretation: employee-inventors who care greatly about their own reputations may focus more on high value projects with longer time horizons. But, it is also possible that inventors who have produced highly valuable inventions care more about maintaining their reputation. Thus, the direction of causality is not so easily determined.

Of course, motivations are not the sole determinants of output. Other inventor and projects characteristics that affect R&D productivity (Nagaoka and Owan 2011) include:

- Amount of human resources allocated. The number of researchers and man-months is significantly associated with both the number of patents generated and their quality.
- Experience. Older and thus more experienced researchers produce more patents and more valuable ones. The same is true of more educated researchers (i.e., PhDs).
- Firm size and project launch departments. Projects in large firms with more than 500 employees and those initiated in R&D units produce more patents but not significantly more valuable patents than projects in smaller firms or in non-R&D business units.
- Groundbreaking opportunity. Projects aimed at developing new business lines or exploiting new emerging technologies generate more patents.

As mentioned earlier, the self-selection problem may be causing the apparent association between the intrinsic motivation and the R&D performance. One possibility is that promising projects may attract more resources including researchers with high intrinsic motivation and technical expertise and thus account for the high ratings of SCIENCE and CHALLENGE. In order to account for the level of a firm's expectations of a project's value, we included an additional input measure, the logarithm of man-months, collected by the RIETI survey. When a firm expects a project to generate a lot of valuable knowledge and inventions, it will allocate many researchers for a long period of time. Therefore the man-month measure should be correlated with a firm's ex ante or interim evaluation of a project. If self-selection is the primary reason behind the significant correlation of SCIENCE and CHALLENGE with R&D productivity, including the man-month measure in the model ought to reduce their coefficients. Column 2 of Table 2 shows that SCIENCE is slightly less associated with the number of patents after including the man-month measure but the decline in the coefficient is rather limited. Furthermore, the change in the coefficient for CHALLENGE is negligible. Column 2 of Table 3 also implies that the strong association between patent value and intrinsic motives is not affected by the inclusion of the man-month measure. These results are not consistent with the conjecture that projects expected to be more valuable attract more researchers with high SCIENCE and CHALLENGE scores.

Another possible source of self-selection is that certain types of firms offer more favorable research environments that attract intrinsically motivated researchers and also raise their R&D productivity. In Column 3 of both Tables 2 and 3, we include three firm characteristics measures—firm age, total sales, and overseas sales ratio—as independent variables.[1] To the extent to which these variables are correlated with a firm's ability to provide a good research environment, we will be able to mitigate the effect of the above form of self-selection. Furthermore, in column 4 of both tables, we use the firm fixed effect to examine how the within-firm variations of motivation variables are associated with the R&D productivity measures. In this way, we can rule out any endogeneity effect caused by unobservable time-invariant firm characteristics. As shown in the tables, the estimated coefficients of SCIENCE and CHALLENGE are robust to the inclusion of firm

[1] We initially included more firm characteristics such as growth rate, R&D intensity, capital intensity, advertising intensity, and female employee ratios, but none of those variables had significant coefficients and are therefore omitted.

characteristics measures or the firm fixed effects, implying that the possible bias in the estimation due to the endogeneity of motivation variables may have limited significance.

b. *Why is SCIENCE highly correlated with inventor productivity?*

Researchers in industries may have an intrinsic preference for contributing to the accumulation of scientific knowledge and for receiving recognition from their peers for discoveries. Stern (2004) calls it "taste" for science. A number of economists have noted that there is a high correlation between the science orientation of an individual and his R&D productivity.[2] There are three explanations for this correlation. First, early access to scientific discoveries may raise a researcher's R&D productivity by encouraging him to explore scientific frontiers to find solutions or by guiding him to technological fields where more by-products and applications are expected. In short, learning from scientific literature and academic communities should improve a researcher's opportunity for serendipitous discovery as well as his absorptive capacity. Second, interest in science may be simply correlated with a researcher's ability. In this case, although the "taste for science" could be a good screening measure for employers, the direct causality between intrinsic motivation and performance becomes superficial. Third, researchers with a strong "taste for science" are more willing to take riskier exploratory approaches and put in long hours to conquer challenges.

[2] See Arora and Gambardella (1994), Cohen and Levinthal (1989, 1990), Gambadella et al.(2006), Rosenberg (1989) , Sauermann and Cohen (2010), Stephan (1996), and Stern (2004).

Note that the high correlation between science orientation and R&D productivity may confound the "learning," "ability," and "motivation" explanations.[3] Rich information in the RIETI survey on research activities and inventors' characteristics help us to distinguish these different explanations. If the "learning" aspect is important, interaction with a scientific community, reading scientific and technical literature, and publishing in academic journals should help to raise inventor productivity. Table 4 shows the estimation results for the same econometric model as in Tables 2 and 3 but with a set of variables indicating the levels of participation in academic research activities and utilization of academic research output. It shows that the data do not offer strong support for the "learning" explanation. First of all, patent value is lower for those with co-inventors from universities. This is inconsistent with the view that cooperation with a scientific community will raise R&D productivity. Second, all variables related to staying current with scientific discoveries except for publishing in academic journals are insignificant in explaining patent value. Third, the coefficient for SCIENCE does not decline much when we add the above variables in estimation. These findings indicate that the "learning" effect explains at most only a portion of the overall relationship between a "taste" for science and R&D productivity, and the effect is especially limited for the patent value.

We next examine whether unobserved ability is generating the apparent correlation between interest in science and R&D performance. In order to do so, we use the information of which schools the inventors graduated assuming that a researcher's educational background signals his innate ability. Table 5 presents the results for estimating the same ordered logit models as before but with

[3] See Rosenberg (1989), Cohen and Levinthal (1989, 1990), and Arora and Gambardella (1994) for similar arguments.

the school fixed effect. The schools which have fewer than three graduates in the dataset are omitted. As you see in Table 5, the estimated coefficients for motivation variables change little after including the school fixed effect implying that unobserved ability is unlikely to be causing the observed relationship between the importance of intrinsic motivation and R&D activity.

Given the analysis so far it would be reasonable to expect that intrinsically motivated individuals are more productive primarily because they are motivated to choose valuable projects and put forth sufficient effort to overcome challenges. Unfortunately, we cannot present strong evidence for this motivation story. Instead, we have developed a principal-agent model which is consistent with this motivation story and derived a number of empirical implications from the model.

V Theoretical Model

In order to illustrate how extrinsic rewards could influence the actions of inventors, we present a very simple principal-agent model where the agent-employee chooses the type of project and the level of efforts. All proofs are in the appendix. Suppose employees must choose between two R&D opportunities that could potentially generate the firm profit *Y*. Project 1 is more exploratory and riskier but could potentially lead to many inventions that can be successfully commercialized. Project 2 is more incremental and safer (i.e., expected to succeed with high probability) but could only result in marginal improvement over the current technology. The principal-firm cannot observe which project each employee chooses. After choosing the project, each employee chooses the level of effort that determines the probability of success. For simplicity, we assume that they choose either high effort, $E = e$, or low effort, $E = 0$. When employees choose $E = e$, Projects 1 and 2 generate profit $Y = Y_1 > 0$ and $Y = Y_2 > 0$ with probability p_1 and p_2, respectively, and $Y = 0$ otherwise. When an employee chooses $E = 0$, the project inevitably fails and $Y = 0$.

Employees enjoy *non-pecuniary personal benefits* with the expected value αuE from executing each project where $u = u_1$ for Project 1 and $u = u_2$ for Project 2. α is the parameter of the strength of intrinsic motivation and varies across employees but cannot be observed by the firm.[4] We assume that α is uniformly distributed between 0 and 1. The assumption that the intrinsic benefits depend on the level of efforts reflects our perception that an intrinsically motivated individual collects some non-pecuniary benefits from engaging in activities because he feels competent and self-determining. Such innate rewards should be greater when he exerts more effort to control the process.

In addition to the intrinsic motive, the firm can provide the employees with monetary incentive $w = w(Y)$. We assume that there is a liquidity constraint with $w \geq 0$ where the minimum wage is normalized at 0 so that $w(0) = 0$. In accordance with the characteristic differences between Project 1 and Project 2 described above, we make the following assumptions.

Assumption 1: $Y_1 > Y_2$, $p_1 < p_2$, $u_1 > u_2$.

The employee's utility is linear and additive as a function of intrinsic and extrinsic motives and is defined as follows:

$$U = E[w \mid E] + \alpha uE - E \qquad (1)$$

[4] The benefit may be contingent on Y, but in that case you only need to redefine u as $u = p_i u_i(Y_i) + (1- p_i)\, u_i(0)$ where $u_i(Y)$ is the maximum non-pecuniary intrinsic benefit per unit of effort when the output is Y.

We assume that choosing Project 1 and exerting high effort is efficient for any α, i.e.,

$p_1Y_1 + \alpha u_1 e - e > p_2Y_2 + \alpha u_2 e - e > 0$ for all α.

Assumption 2: $p_1Y_1 > p_2Y_2 > e$.

Assumption 2 is a necessary and sufficient condition for Project 1 to be efficient for all employees. Although there might be a situation where pursuing a safer project is efficient in reality, there is no conflict of interests between the firm and the employee in such a case. In order to focus our attention on misalignment of interests in project selection, we impose Assumption 2. Let $w_1 = w(Y_1)$ and $w_2 = w(Y_2)$. Then, the employee solves the following maximization problem:

$$\text{Max } U = \max\{p_1w_1 + \alpha u_1 e - e, p_2w_2 + \alpha u_2 e - e, 0\} \qquad (2)$$

Note that hiring employees with high α is desirable for the firm because such employees are more likely to exert effort given the same compensation. Since $\alpha u_1 e - e > \alpha u_2 e - e$ for $u_1 > u_2$, no employees choose Project 2 and put forth some effort in it in the absence of monetary incentives, *i.e.*, $w_1 = w_2 = 0$.

Now first we can prove the following lemma.

Lemma 1 *For any pair of* (w_1, w_2)*, there exist* α_1 *and* α_2 *such that* $1 \geq \alpha_1 \geq \alpha_2 \geq 0$ *and the following actions are optimal for the employee:*

(i) *the employee chooses Project 1 and exerts effort if* $\alpha \in (\alpha_1, 1]$

(ii) *the employee chooses Project 2 and exerts effort if* $\alpha \in (\alpha_2, \alpha_1)$

(iii) *the employee chooses not to make any effort if* $\alpha \in [0, \alpha_2)$

Proof is in the Appendix.

The result in Lemma 1 is illustrated in Figure 1. Now, we can state the firm's problem in a simple form.

$$\begin{aligned}
&\underset{w_1,w_2,\alpha_1,\alpha_2}{Max}\ \pi = (1-\alpha_1)p_1(Y_1 - w_1) + (\alpha_1-\alpha_2)p_2(Y_2 - w_2) \text{ s.t.}\\
&\quad p_1 w_1 + \alpha u_1 e - e \geq \max\{p_2 w_2 + \alpha u_2 e - e, 0\} \text{ for } \alpha \in [\alpha_1, 1],\\
&\quad p_2 w_2 + \alpha u_2 e - e \geq \max\{p_1 w_1 + \alpha u_1 e - e, 0\} \text{ for } \alpha \in [\alpha_2, \alpha_1], \text{ and}\\
&\quad 0 \geq \max\{p_1 w_1 + \alpha u_1 e - e,\ p_2 w_2 + \alpha u_2 e - e\} \text{ for } \alpha \in [0, \alpha_2]
\end{aligned} \tag{3}$$

In studying this firm's problem, we consider the following two scenarios:

Case 1: Value of invention is always verifiable.

In this case, the firm can distinguish between Y_1 and Y_2, and therefore chooses w_1 and w_2 (≥ 0) optimally.

Case 2: Value of successful invention is not verifiable.

In this case, when the project succeeds, the firm knows that $Y > 0$ but cannot distinguish between Y_1 and Y_2. Therefore, the firm has to offer the same reward, $w_1 = w_2$, for the successful implementation of either project.

In reality, R&D always has aspects of both Case 1 and Case 2. Many large Japanese firms pay predetermined compensation to inventors for each patent application or patent registration regardless of the expected value of the inventions. Therefore, at least before commercialization or technology licensing occurs, rewards for inventions are not differentiated. Furthermore, even when inventions are commercialized or licensed, inventions with varying technical significance tend to be treated equally because (1) a substantial amount of patents and technical know-how are used in most products, making it is hard to evaluate the economic value of each invention; (2) it often takes many years before an invention is commercially released so its final contribution to the firm's profits can only be estimated after a long period of time; and (3) cross-licensing, which is prevalent among large Japanese firms, often makes it unnecessary to calculate the economic value of each patent in the patent pool (Nagaoka and Kwon 2006). Given the complex, interdependent, and time-variant nature of most inventions, the measurement cost of evaluating the worth of all inventions generated every year would be enormous.

On the other hand, a surge in lawsuits in late 1990s and early 2000s filed by inventors demanding greater compensation prompted many large Japanese firms to be paying inventors based on the profits, sales, or licensing revenue generated by their inventions. Most of these firms' revenue-based remuneration policies primarily target highly valuable inventions with exceptional economic returns in a manner similar to that of Case 1. Therefore, we might see large Japanese firms as shifting from Case 2 to Case 1 by investing in measurement technology. In this theory section, we analyze how different the optimal incentive schemes in Case 1 and Case 2 are. The difference has some implications for how inventor productivity measures are associated with intrinsic motivation and how different these relationships are in Case 1 and Case 2.

In order to simplify the derivation, we impose two more assumptions. Although these assumptions are not innocuous, we can greatly simplify the notation of the propositions and shorten the proofs by ruling out some irrelevant minor cases while maintaining empirical implications relevant for our analysis.

Assumption 3: $u_2 = 0$.

Assumption 4: $w_1 \geq w_2$

Without Assumption 4, the firm will choose $w_1^* < w_2^*$ for sufficiently high u_1 in Case 1 because the firm can pay less to intrinsically motivated employees. This is very unlikely in reality because paying less to intrinsically motivated and productive employees sends the wrong message to the labor market and impedes hiring.

We first analyze Case 1 where there is no constraint on feasible incentive schemes:

Proposition 1 *Suppose the firm can freely choose w_1 and w_2 (Case 1). Then, there are potentially four distinct cases:*

When $u_1 \le \frac{p_1Y_1 - p_2Y_2}{e}$, *the firm will offer* $w_1^* = \frac{e}{p_1}$ *and* $w_2^* = 0$. *Every employee chooses PROJECT 1.*

When $\frac{p_1Y_1 - p_2Y_2}{e} < u_1 < \frac{p_1Y_1 - p_2Y_2}{e} + 2(1 - \frac{p_1}{p_2})$, $\frac{e}{p_2} < w_1^* < \frac{e}{p_1}$ *and* $w_2^* = \frac{e}{p_2}$. *The employees with* $\alpha \in [\frac{1}{2} - \frac{p_1Y_1 - p_2Y_2}{2u_1e}, 1]$ *choose Project 1 while all others choose Project 2.*

When $\frac{p_1Y_1 - p_2Y_2}{e} + 2(1 - \frac{p_1}{p_2}) \le u_1 \le \hat{u}$, $w_1^* = w_2^* = \frac{e}{p_2}$ *where* $\hat{u} \in (\frac{p_2 - 2p_1}{p_2} + \frac{p_1Y_1}{e}, 1 + \frac{p_1Y_1}{e})$ *or* $\hat{u} = +\infty$. *workers with* $\alpha \in [\min\{\frac{p_2 - p_1}{p_2u_1}, 1\}, 1]$ *will choose Project 1 and those with* $\alpha \in [0, \min\{\frac{p_2 - p_1}{p_2u_1}, 1\}]$ *will select Project 2.*

When $u_1 > \hat{u}$, $w_1^* = w_2^* < \frac{e}{p_2}$ *workers with* $\alpha \in [\frac{e + u_1e - p_1Y_1}{2u_1e}, 1]$ *will choose Project 1 and work hard and those with* $\alpha \in [0, \frac{e + u_1e - p_1Y_1}{2u_1e})$ *will not make any efforts regardless of the project they choose.*

Proof is in the Appendix.

Proposition 1 sends a clear message. When the intrinsic benefit of choosing risky and challenging projects is not substantially higher than that for choosing safer and less challenging ones, rewarding only highly valuable successes is optimal in general. When the intrinsic benefit of choosing risky and challenging projects is sufficiently strong, however, the firm can cut back on compensation for discovering valuable inventions because motivating those with strong intrinsic motivation is easier thus requiring less pecuniary rewards. But, reducing the reward leads some portion of workers to stop exerting effort. Then, it becomes optimal to reward those who successfully complete safer and less valuable projects in order to encourage all workers to work hard. Therefore, the greater the potential intrinsic benefit is, the lower the average value of the invention (*i.e.,* more employees will engage in safer projects). In other words, the intrinsic benefit supplants the monetary incentive lowering the overall wage level, which in turn adversely affects the incentives of the employees in project selection.

Next, we will consider Case 2 where the rewards cannot be differentiated based on the profits generated.

Proposition 2 *Suppose the firm cannot verify Y and thus has to offer* $w_1 = w_2 = w$ *(Case 2), then there exists the level of potential intrinsic benefits* $\hat{u} \in (\frac{p_2 - 2p_1}{p_2} + \frac{p_1 Y_1}{e}, 1 + \frac{p_1 Y_1}{e})$ *such that:*

When $e \le \frac{p_2^2 (p_2 - p_1)}{p_1^2 - p_1 p_2 + p_2^2} Y_2$ *or* $u \le \hat{u}$, *the firm will offer* $w^* = \frac{e}{p_2}$. *The workers with* $\alpha \in [\min\{\frac{p_2 - p_1}{p_2 u_1}, 1\}, 1]$ *will choose Project 1 and those with* $\alpha \in [0, \min\{\frac{p_2 - p_1}{p_2 u_1}, 1\}]$ *will select Project 2. Every employee exerts an effort.*

When $e > \frac{p_2^2(p_2 - p_1)}{p_1^2 - p_1 p_2 + p_2^2} Y_2$ *and* $u_1 > \hat{u}$*, the firm will offer* $w^* = \frac{Y_1}{2} + \frac{1-u_1}{2p_1} e < \frac{e}{p_2}$*. The workers with* $\alpha \in [\frac{e + u_1 e - p_1 Y_1}{2u_1 e}, 1]$ *will choose Project 1 and work hard and those with* $\alpha \in [0, \frac{e + u_1 e - p_1 Y_1}{2u_1 e})$ *will not make any efforts regardless of the project they choose.*

Proof is in the Appendix.

Interestingly, the greater the potential intrinsic benefits are, the more employees will choose Project 1, leading to a higher average invention values. This result is in contrast with Proposition 1 where the intrinsic benefit adversely affects the average value of invention. Furthermore, when p_2 is sufficiently greater than p_1 and u_1 is sufficiently small, inducing the employees to choose Project 1 may become impossible.

In Propositions 1 and 2, whether the value of an invention is verifiable or not is given exogenously. In reality, it is more or less endogenous. Suppose the firm can make a costly investment in valuation technology for inventions. If doing so substantially improves efficiency, the firm will invest and offer revenue-based compensation to R&D researchers. Putting Propositions 1 and 2 together, we can determine when firms are more likely to offer revenue-based compensation for inventions. Figures 4 and 5 illustrate the difference in project selection between Cases 1 and 2 offering a few empirical implications.

First, firms which have many employee-inventors with strong intrinsic motivation are less likely to adopt revenue-based compensation policy for inventors. Since many employees are already motivated to choose risky and challenging projects, additional rewards will only affect marginal employees.

Second, the average value of inventions should be more positively correlated with the strength of intrinsic motivation in the absence of revenue-based pay than its presence. Figure 4 illustrates how the share of the workers who choose Project 1 change as the potential intrinsic benefits increase for both Case 1 and Case 2. The figure implies that the importance of intrinsic motivation and the average value of inventions should be negatively associated when the firm has contingent monetary compensation, whereas they are positively associated when monetary rewards for inventions are not revenue-based.

VI Empirical Analysis, Part 2

In order to test the empirical implications obtained in Section V, we turn to an additional data source. In 2005, the Institute of Intellectual Property sponsored a survey conducted by Koichiro Onishi, who collected firm-level panel data on remuneration policies for employee inventions (**IIP firm survey** hereafter).[5] The survey targeted 836 manufacturing firms listed on the first section of the Tokyo Stock Exchange as of March 31, 2005. Among the targeted firms, 360 firms responded to the questionnaire (response rate: 43.1%). We use the data for 347 firms after excluding two firms that had not obtained any patents in the past 15 years and 11 firms that refused to answer some major questions. These data have two advantages. First, they contain rich information on remuneration

[5] I thank Koichiro Onishi for generously sharing his proprietary data.

policies implemented at large Japanese firms including types of remunerations (filing/registration-based vs. revenue-based).[6] Second, the survey questionnaire asked each firm about the details of its remuneration policies in 1990 and when and what changes were made between 1990 and 2005. We can therefore construct panel data of evolving remuneration policies for 347 major Japanese firms.

Our first prediction is about the relationship between the incidence of revenue-based remuneration and the strength of intrinsic motivation. We define *ppay* as the incidence of revenue-based pay and *ppay_1mil* as the incidence of such policies with payout limits over ¥1 million. The latter variable is introduced to rule out the compensation policies whose payout is so low that they provide little incentive to choose risky and challenging projects. We also use the SCIENCE variable (the importance of satisfaction from contributing to the progress of science and technology as a source of motivation) as a proxy for the overall strength of intrinsic motivation. Then, our empirical prediction can be expressed as Corr(*ppay*, SCIENCE) < 0. To test this hypothesis, we estimate the probit model using *ppay* or *ppay_1mil* as the dependent variable.

The results are in Table 6. All models imply that larger firms (measured by the number of employees), firms with more technical capability (measured by the size of patent stock), and firms in industries with more lawsuits related to inventor remuneration are more likely to introduce revenue-based compensation. Although our focal variable SCIENCE is negatively associated with the incidence of revenue-based pay, the coefficient is not significant.

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[6] Other information collected includes types of revenue measures (sales vs. licensing vs. transfer), types of patents (domestic vs. foreign), payout limits, frequency of payouts, etc.

Table 7 shows the result for our second hypothesis. Unlike the theoretical prediction, the average value of patent is no more positively associated with the strength of science orientation in the absence of revenue-based pay than its presence. The coefficients for SCIENCE in two subsamples (i.e. *ppay_1mil*=0 and *ppay_1mil*=1) are not significantly different.

The above results raise the question of why we do not find strong support for our theory. There are several possible reasons. First, it may be the case that a typical Japanese firm does not design its compensation policy for employee inventions as an incentive scheme but rather to comply with Section 35 of Japan's *Patent Law* that requires appropriate remuneration for employee inventions. Owan and Onishi (2010) offer some evidence for this argument. Second, the IIP survey tells us that many Japanese firms reformed their invention remuneration policies after the period when most of the inventions targeted in the RIETI survey were discovered (in general, a few years before those patent applications were submitted, which means roughly between 1990-2000) . Note that inventions remuneration policies in the IIP survey are matched with the estimated year of inventions. This means that, if these changes were to improve the efficiency of the policies, the old ones we used in our analysis may be far from efficient. Third, our survey targets only research projects that generated patents and is likely to pick more successful projects because those that produced many patents are more likely to be included in the dataset by its design. Therefore, our sample may include mostly those projects where the "distortion" in project selection is relatively limited causing sample selection biases on the coefficient estimates. . Fourth, it may be the case that firms have sufficient instruments to avoid conflicts of interest in project selection, which is a central issue in our theory.

VII Conclusion

Our study reveals that two intrinsic motives--satisfaction from contributing to science and technology "taste for science", and interests in solving challenging technical problems "taste for challenge"--are more important determinants for the inventor productivity than any other motives. Although it is sometimes argued that hiring those with strong science orientation can increase the learning capacity of the firm, we cannot find any strong support for this learning capacity explanation. We neither find the evidence for the possibility that the inventors with strong intrinsic motivation are likely to have higher innate capability thus creating the correlation between the importance of intrinsic motivation and the R&D productivity.

The study also explores for the possible linkage between monetary compensation and intrinsic motivation. Our theoretical model implies that monetary compensation which generally induces more efforts may "distort" the selection of a project away from the set of "challenging" and potentially more desirable projects (*i.e.* the employees who otherwise are more inclined to choose riskier projects encouraged by their intrinsic benefits may choose safer projects that give the employees a better chance of getting the reward). The model offers two testable empirical implications. First, firms which have many employee-inventors with strong intrinsic motivation are less likely to adopt revenue-based compensation policy for inventors. Second, the average value of inventions is more positively correlated with the strength of intrinsic motivation in the absence of revenue-based pay than its presence. The reason for the second implication is that the hazard and degree of project selection distortion, which reduces the average value of inventions, is smaller as the potential intrinsic benefits get greater when the value of the invention is not verifiable but such relationship could be reversed when the value of the invention is verifiable.

In order to test these hypotheses, we combined the RIETI inventor survey with the IIP firm survey, which contains detailed information about the invention remuneration policies instituted by large Japanese firms. Our empirical analysis failed to support the above implications. There are a number of possible explanations. First, the assumption of optimal contracting may be unrealistic because firms often adopt invention remuneration policies simply to comply with the Japan's Patent Law and the data collected are in the period when a majority of firms were reforming their policies substantially (thus, less likely to be perceived as optimal). Second, our data collection method may have systematically selected more successful projects which were less likely to be affected by distortion in project selection.

Further investigation of possible interaction between intrinsic motivation and monetary incentives for R&D employees is desirable given that there has been little empirical research on the productivity impact of incentives at the individual level in the R&D function. The topic is especially important in Japan where a rapid increase in the payout of invention remuneration has been observed in 2000s after the revision of Section 35 of Patent Law.

Appendix

Proof of Lemma 1

Lemma 1 can be restated in the following format:

For any pair of (w_1, w_2), there exist α_1 and α_2 such that $1 \geq \alpha_1 \geq \alpha_2 \geq 0$ and

(i) $p_1 w_1 + \alpha u_1 e - e > \max\{p_2 w_2 + \alpha u_2 e - e, 0\}$ for any $\alpha \in (\alpha_1, 1]$

(ii) $p_2 w_2 + \alpha u_2 e - e > \max\{p_1 w_1 + \alpha u_1 e - e, 0\}$ for any $\alpha \in (\alpha_2, \alpha_1)$

(iii) $0 > \max\{p_1 w_1 + \alpha u_1 e - e, p_2 w_2 + \alpha u_2 e - e\}$ for any $\alpha \in [0, \alpha_2)$.

Suppose inequality (i) holds for a certain α. Then for any $\alpha' > \alpha$, (i) is satisfied because $u_1 > u_2$. Let $\alpha_1 = \inf\{\alpha \mid \text{(i) is satisfied}\}$. Then inequality (i) holds for any $\alpha \in (\alpha_1, 1]$ but not for any $\alpha \in [0, \alpha_1]$. If (i) does not hold for any α, let $\alpha_1 = 1$. Since no α satisfies $\alpha \in (1, 1]$, the condition (i) still holds. Similarly, suppose inequality (iii) holds for α. Then for any $\alpha' < \alpha$, (iii) is satisfied. Let $\alpha_2 = \sup\{\alpha \mid (\text{iii}) \text{ is satisfied}\}$. Then inequality (iii) holds for any $\alpha \in [0, \alpha_2)$ but not for any $\alpha \in [\alpha_2, 1]$. Again, let $\alpha_2 = 1$ when no α satisfies (iii).

Since inequalities (i) and (iii) do not hold at the same time except when both are satisfied with equality, $\alpha_2 \leq \alpha_1$. If $\alpha_2 < \alpha_1$, for any $\alpha \in (\alpha_2, \alpha_1)$, $p_1 w_1 + \alpha u_1 e - e < \max\{p_2 w_2 + \alpha u_2 e - e, 0\}$ and $0 < \max\{p_1 w_1 + \alpha u_1 e - e, p_2 w_2 + \alpha u_2 e - e\}$, which imply that $p_2 w_2 + \alpha u_2 e - e > \max\{p_1 w_1 + \alpha u_1 e - e, 0\}$. This concludes the proof. ■

Proof of Proposition 1

First, it is immediate to prove that offering $w_2 > \frac{e}{p_2}$ is suboptimal because paying $w_2 = \frac{e}{p_2}$ is sufficient to induce all workers to work hard (i.e. $\max\{p_1 w_1 + \alpha u_1 e - e, p_2 w_2 - e\} \geq 0$) while paying more will simply encourage more workers to choose Project 2 over Project 1.

Next, when $w_1 < \frac{e}{p_1}$, offering $w_2 = \frac{e}{p_2}$ strictly dominate $w_2 < \frac{e}{p_2}$. To show this, suppose $w_1 < \frac{e}{p_1}$ and $w_2 < \frac{e}{p_2}$. Then,

$p_1 w_1 + \alpha u_1 e - e \geq \max\{p_2 w_2 - e, 0\} = 0$ for any $\alpha \in (\frac{e - p_1 w_1}{u_1 e}, 1]$, and

$0 > \max\{p_1 w_1 + \alpha u_1 e - e, p_2 w_2 - e\}$ for any $\alpha \in [0, \frac{e - p_1 w_1}{u_1 e})$ except when $\frac{e - p_1 w_1}{u_1 e} \geq 1$, in which case no worker works hard.

This implies that $\alpha_1 = \alpha_2 = \min\{\frac{e - p_1 w_1}{u_1 e}, 1\}$ where α_1 and α_2 are the thresholds defined in Lemma 1. Note that the workers with $\alpha \in [0, \frac{e - p_1 w_1}{u_1 e})$ here do not make any efforts. By offering $w_2 = \frac{e}{p_2}$, the firm can induce those workers to choose Project 2 and exert an effort without affecting the share of those who choose Project 1. Therefore, we can conclude that offering $w_2 = \frac{e}{p_2}$ is optimal when $w_1^* < \frac{e}{p_1}$.

When $w_1^* = \frac{e}{p_1}$, all workers choose Project 1and exert efforts regardless of the level of w_2 as long as $w_2 \leq \frac{e}{p_2}$. Hence, we need to maximize the firm profit given $w_2 = \frac{e}{p_2}$:

$$\pi = (1 - \alpha_1) p_1 (Y_1 - w_1) + \alpha_1 p_2 (Y_2 - w_2)$$
$$= (1 - \frac{e - p_1 w_1}{u_1 e}) p_1 (Y_1 - w_1) + \frac{e - p_1 w_1}{u_1 e} p_2 (Y_2 - \frac{e}{p_2})$$

The optimal wage should satisfy the first-order condition:

$$\frac{\partial \pi}{\partial w_1} = \frac{p_1^2}{u_1 e}(Y_1 - w_1) - \frac{p_1 p_2}{u_1 e}(Y_2 - \frac{e}{p_2}) - p_1 (1 - \frac{e - p_1 w_1}{u_1 e})$$
$$= \frac{p_1^2}{u_1 e}[Y_1 - \frac{p_2}{p_1} Y_2 + \frac{e}{p_1} - \frac{(u_1 - 1)e}{p_1} - 2w_1] \geq 0 \quad (= 0 \text{ if } w_1^* < \frac{e}{p_1})$$

It is easily seen that the second-order condition holds. Therefore,

$w_1^* = \min\{\frac{Y_1}{2} - \frac{p_2}{p_1}\frac{Y_2}{2} + \frac{e}{2p_1} - \frac{(u_1-1)e}{2p_1}, \frac{e}{p_1}\}$. This concludes the proof. ■

When $u_1 \le \frac{p_1Y_1 - p_2Y_2}{e}$*, the firm will offer* $w_1^* = \frac{e}{p_1}$ *and* $w_2^* = 0$*. Every employee chooses Project 1.*

When $\frac{p_1Y_1 - p_2Y_2}{e} < u_1 < \frac{p_1Y_1 - p_2Y_2}{e} + 2e(1 - \frac{p_1}{p_2})$*,* $\frac{e}{p_2} < w_1^* < \frac{e}{p_1}$ *and* $w_2^* = \frac{e}{p_2}$*. The employees with* $\alpha \in [\frac{1}{2} - \frac{p_1Y_1 - p_2Y_2}{2u_1e}, 1]$ *choose Project 1 while all others choose Project 2.*

When $\frac{p_1Y_1 - p_2Y_2}{e} + 2(1 - \frac{p_1}{p_2}) \le u_1 \le \hat{u}$*,* $w_1^* = w_2^* = \frac{e}{p_2}$ *where* $\hat{u} \in (\frac{p_2 - 2p_1}{p_2} + \frac{p_1Y_1}{e}, 1 + \frac{p_1Y_1}{e})$ *or* $\hat{u} = +\infty$*. Workers with* $\alpha \in [\min\{\frac{p_2 - p_1}{p_2u_1}, 1\}, 1]$ *will choose Project 1 and those with* $\alpha \in [0, \min\{\frac{p_2 - p_1}{p_2u_1}, 1\}]$ *will select Project 2.*

When $u_1 > \hat{u}$*,* $w_1^* = w_2^* < \frac{e}{p_2}$ *Workers with* $\alpha \in [\frac{e + u_1e - p_1Y_1}{2u_1e}, 1]$ *will choose Project 1 and work hard and those with* $\alpha \in [0, \frac{e + u_1e - p_1Y_1}{2u_1e})$ *will not make any efforts regardless of the project they choose.*

Proof of Proposition 2

We will solve constrained optimization for two ranges of wage level: (1) $w \ge \frac{e}{p_2}$, and (2) $w < \frac{e}{p_2}$.

<u>When $w \ge e/p_2$:</u>

All employees work hard on either Project 1 and Project 2. The threshold between the two groups is $\alpha_1 = \min\{\frac{p_2 - p_1}{u_1}\frac{w}{e}, 1\}$. Note that paying more than $w = \frac{e}{p_2}$ simply reduces the share of the employees who choose Project 1 over Project 2 without any merit for the employers. Therefore, the best choice in this case is $w^* = \frac{e}{p_2}$ and thus $\alpha_1 = \min\{\frac{p_2 - p_1}{p_2u_1}, 1\}$. The firm profit is

$$\pi = (1 - \frac{p_2 - p_1}{p_2 u_1}) p_1 (Y_1 - \frac{e}{p_2}) + \frac{p_2 - p_1}{p_2 u_1} p_2 (Y_2 - \frac{e}{p_2}) \text{ if } u_1 > \frac{p_2 - p_1}{p_2}$$

$$p_2 (Y_2 - \frac{e}{p_2}) \text{ if } u_1 \le \frac{p_2 - p_1}{p_2}$$

When $w < e / p_2$:,

No employee will choose Project 2. In this case, the share of the employees who choose not to work is $\alpha_1 = \alpha_2 = \frac{e - p_1 w}{u_1 e}$ for $w > \frac{1-u_1}{p_1} e$ and $\alpha_1 = \alpha_2 = 1$ for $w \le \frac{1-u_1}{p_1} e$ where α_1 and α_2 are the thresholds defined in Lemma 1. The firm profit is $\pi = (1 - \frac{e - p_1 w}{u_1 e}) p_1 (Y_1 - w)$ if $w > \frac{1-u_1}{p_1} e$ and 0 otherwise. By solving the maximization problem, we obtain $w^* = \max\{\min\{\frac{Y_1}{2} + \frac{1-u_1}{2p_1} e, \frac{e}{p_2}\}, 0\}$.

When $w^* < \frac{e}{p_2} \Leftrightarrow \frac{Y_1}{2} + \frac{1-u_1}{2p_1} e < \frac{e}{p_2} \Leftrightarrow u_1 > \frac{p_2 - p_1}{p_2} + \frac{p_1 Y_1}{e} - \frac{p_1}{p_2}$, we can easily show $w = \frac{Y_1}{2} + \frac{1-u_1}{2p_1} e > \frac{1-u_1}{p_1} e$ (thus $\alpha_1 = \alpha_2 < 1$) and the firm profit is $\pi = \frac{1}{u_1 e} (\frac{p_1 Y_1}{2} + \frac{u_1 - 1}{2} e)^2$.

Now, we compare the maximal profit levels between (1) $w \ge \frac{e}{p_2}$, and (2) $w < \frac{e}{p_2}$.

When $u_1 \le \frac{p_2 - p_1}{p_2}$, no wage $w < \frac{e}{p_2}$ can induce the worker to make an effort, because $\frac{1-u_1}{p_1} e \ge \frac{e}{p_2} > w$, which implies $\alpha_1 = \alpha_2 = 1$ from the above discussion. Therefore, the optimal wage is $w^* = \frac{e}{p_2}$.

When $\frac{p_2 - p_1}{p_2} < u_1 \le \frac{p_2 - p_1}{p_2} + \frac{p_1 Y_1}{e} - \frac{p_1}{p_2}$, $\frac{\partial \pi}{\partial w} \ge 0$ for $w < \frac{e}{p_2}$ and

$\lim_{w \to \frac{e}{p_2}} \pi = (1 - \frac{p_2 - p_1}{p_2 u_1}) p_1 (Y_1 - \frac{e}{p_2}) < (1 - \frac{p_2 - p_1}{p_2 u_1}) p_1 (Y_1 - \frac{e}{p_2}) + \frac{p_2 - p_1}{p_2 u_1} p_2 (Y_2 - \frac{e}{p_2})$. Once again, from the above results, any $w < \frac{e}{p_2}$ is strictly inferior to $w^* = \frac{e}{p_2}$.

When $u_1 > \frac{p_2 - p_1}{p_2} + \frac{p_1 Y_1}{e} - \frac{p_1}{p_2}$, let us denote the profits derived for (1) $w \ge \frac{e}{p_2}$ and (2) $w < \frac{e}{p_2}$ above by $\pi^1(u_1)$ and $\pi^2(u_1)$. Namely,

$$\pi^1(u_1) = (1 - \frac{p_2 - p_1}{p_2 u_1}) p_1 (Y_1 - \frac{e}{p_2}) + \frac{p_2 - p_1}{p_2 u_1} p_2 (Y_2 - \frac{e}{p_2})$$
$$\pi^2(u_1) = \frac{1}{u_1 e}(\frac{p_1 Y_1}{2} + \frac{u_1 - 1}{2} e)^2$$

We can easily show that $\pi^1(u_1)$ is increasing and concave in u_1 while $\pi^2(u_1)$ is increasing and convex in u_1 up to $u_1 = 1 + \frac{p_1 Y_1}{e}$ where w^* is set at zero, beyond which the profit levels off at $\pi^2(1 + \frac{p_1 Y_1}{e}) = \frac{(p_1 Y_1)^2}{p_1 Y_1 + e}$. Therefore, if $\pi^1(1 + \frac{p_1 Y_1}{e}) \geq \pi^2(1 + \frac{p_1 Y_1}{e})$, $\pi^1(u_1) \geq \pi^2(u_1)$ for all u_1 and the optimal wage is always $w^* = \frac{e}{p_2}$. On the other hand if $\pi^1(1 + \frac{p_1 Y_1}{e}) < \pi^2(1 + \frac{p_1 Y_1}{e})$, there exists $\hat{u}$ such that $\pi^1(\hat{u}) = \pi^2(\hat{u})$ and the optimal wage is $w^* = \frac{e}{p_2}$ for $u < \hat{u}$ but $w^* = \frac{Y_1}{2} + \frac{1 - u_1}{2 p_1} e$ for $u > \hat{u}$. It is straightforward to show that $\pi^1(1 + \frac{p_1 Y_1}{e}) < \pi^2(1 + \frac{p_1 Y_1}{e})$ if and only if $e > \frac{p_2^2 (p_2 - p_1)}{p_1^2 - p_1 p_2 + p_2^2} Y_2$. This concludes the proof. ■

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Table A   Educational Background

Education Level	Freq.	Percent
High School or lower	432	8.25
Technical School or 2-year College	283	5.4
Bachelor	2,283	43.59
Master	1,627	31.06
PhD	613	11.7
Total	5,238	100

Inventors who are surveyed twice are counted twice.

Table B   Gender

Gender	Freq.	Percent
Men	5,179	98.42%
Women	83	1.58%
Total	5,262	100%

Table C   Affiliation

Employer Type	Freq.	Percent
Large firms (>500 employees)	4,231	80.3%
Medium firms (101-500 employees)	472	9.0%
Small firms (≤100 employees)	271	5.1%
Higher education institutions	108	2.1%
National research labs	26	0.5%
Municipal research labs	10	0.2%
Non-for-profit organizations	6	0.1%
Other government agencies	4	0.1%
Self-employed	114	2.2%
Others	25	0.5%
Total	5,267	100.0%

Table D Stage of Research

	Freq.	Percent
Basic Research	1,109	21.1%
Applied Research	1,967	37.5%
Development	3,455	65.8%
Technical Service	459	8.7%
Others	93	1.8%
Total	5,250	100.0%

Total does not sum up to 100% because some projects span multiple stages

Table E Business Function

	Freq.	Percent
Independent R&D units	3,353	67.6%
R&D function attached to operational units	727	14.6%
R&D units of unknown affiliation	80	1.6%
Production	311	6.3%
Software development	149	3.0%
Other function	343	6.9%
Total	4,963	100.0%

Table 1 Correlation Among Motivational Factors

	Science	Challenge	Org. Performance	Career	Reputation	Environment	Money
Science	1						
Challenge	0.4346	1					
Org. Performance	0.1009	0.1365	1				
Career	0.2334	0.177	0.3243	1			
Reputation	0.2982	0.1953	0.2491	0.5897	1		
Environment	0.3183	0.1672	0.2649	0.4644	0.5229	1	
Money	0.1864	0.1058	0.1635	0.4146	0.4514	0.4627	1

Figure 1 Average Motivation Ratings by Educational Level

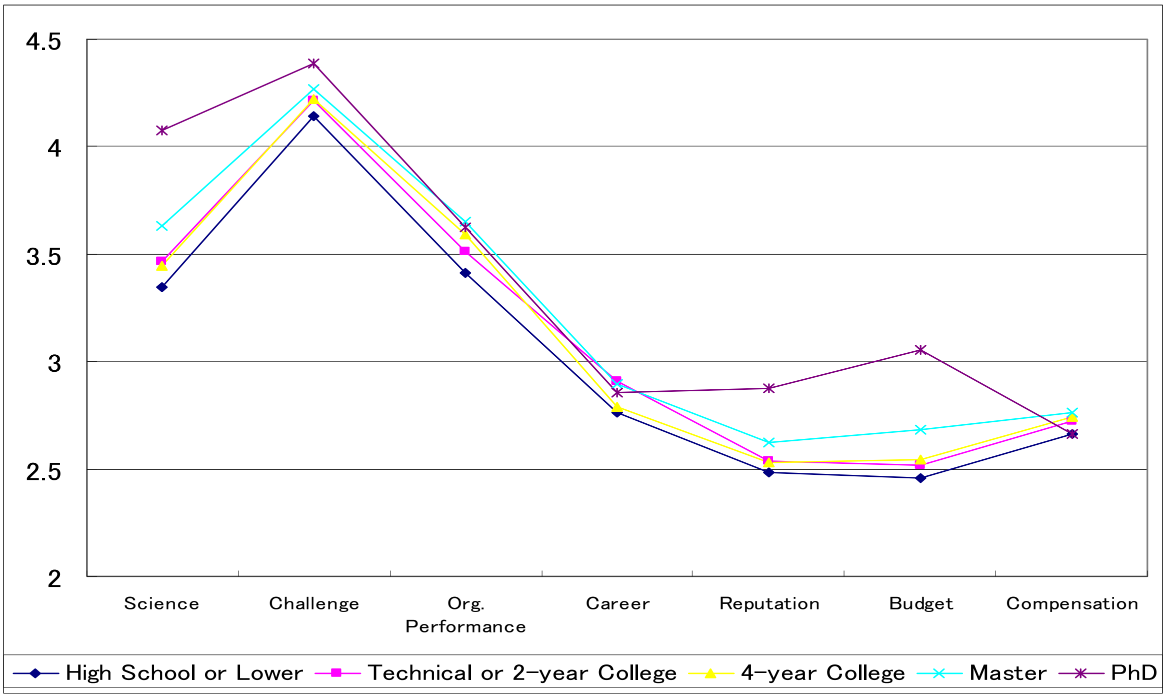

Figure 2 Average Motivation Ratings by Organizational Type

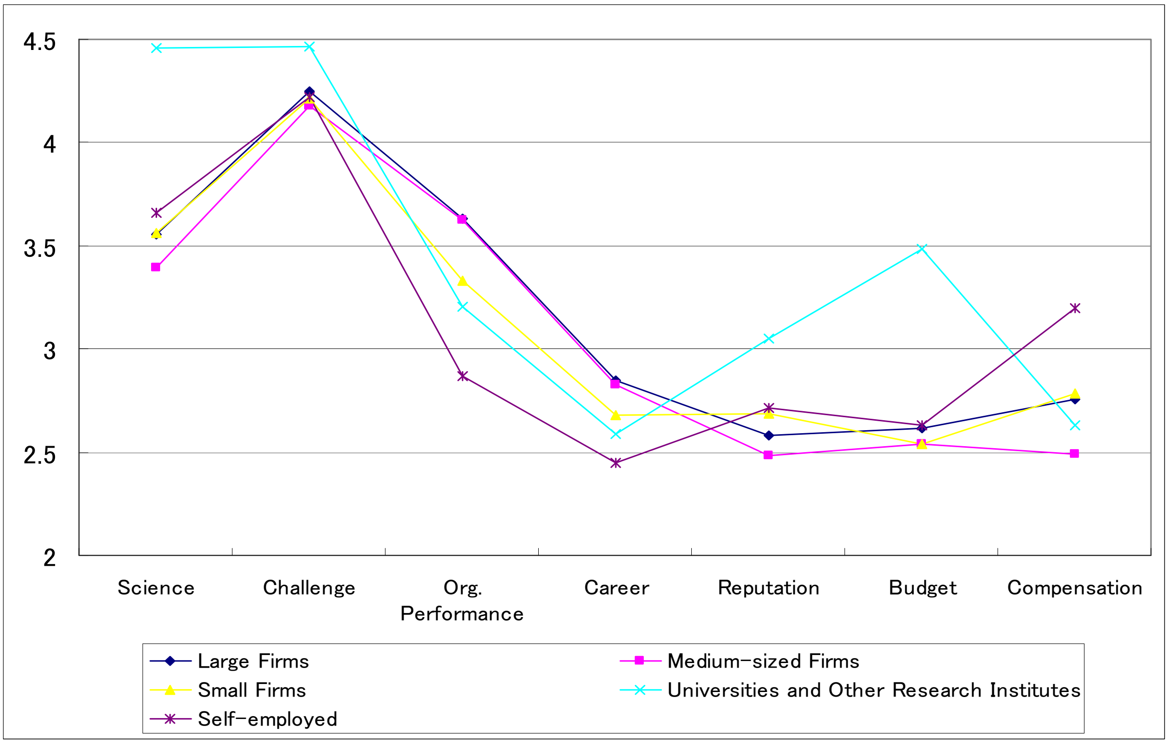

Table 2 Ordered Logit Regression for the Number of Patents Generated

		Dependent variable: Pat_num (# of patents expected)											
		Base			With man-month indicator			With firm characteristics			With firm fixed effect		
Independent variables		Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.
Project size	ln(# of inventors)	0.210	***	0.050	-0.005		0.052	0.016		0.061	0.093		0.074
	ln(# of applicants)	-0.262	**	0.126	-0.276	**	0.128						
Basic inventor characteristics	Female	0.289		0.245	0.255		0.275	0.382		0.318	0.346		0.330
	ln(age)	0.837	***	0.143	0.833	***	0.145	0.767	***	0.178	1.084	***	0.205
Educational background	High school diploma	-0.089		0.114	-0.031		0.117	-0.173		0.143	0.061		0.168
	Two-year college	0.112		0.121	0.204	*	0.122	0.215		0.164	0.254		0.180
(base: college graduates)	Master's degree	0.261	***	0.070	0.278	***	0.070	0.192	**	0.082	0.184	**	0.092
	PhD	0.387	***	0.105	0.366	***	0.106	0.212	*	0.127	0.435	***	0.140
Organization	Private firm (250 < emp ≤ 500)	-0.456	***	0.121	-0.491	***	0.126						
(base: private firm w. employment > 500)	Private firm (100 < emp ≤ 250)	-0.630	***	0.143	-0.613	***	0.151						
	Private firm (emp ≤ 100)	-0.332	**	0.150	-0.396	***	0.152						
	Universities	-0.775	***	0.266	-0.730	***	0.264						
Function	R&D unit in business	-0.363	***	0.117	-0.277	**	0.120	-0.482	***	0.145	-0.534	***	0.167
(base: independent R&D)	Production	-0.638	***	0.185	-0.496	***	0.190	-0.407		0.256	-0.478	*	0.264
	Software development	-0.294	**	0.126	-0.198		0.127	-0.297	*	0.163	-0.388	**	0.178
Objective	Reinforcing non-core business	-0.085		0.081	-0.115		0.081	-0.162	*	0.095	-0.104		0.108
(base: reinforcing core business)	Developing new business	0.446	***	0.074	0.396	***	0.073	0.383	***	0.088	0.467	***	0.098
	Expanding technological base	-0.083		0.117	0.003		0.120	0.077		0.150	-0.027		0.158
Nature	Seeds-oriented	0.247	***	0.070	0.214	***	0.070	0.143	*	0.084	0.290	***	0.092
(base: needs-oriented)	Exploration for seeds	0.096		0.094	0.133		0.096	0.190		0.120	0.313	**	0.127
Firm characteristics	ln(firm age)							0.183		0.162			
	ln(sales)							0.124	***	0.023			
	Overseas sales ratio							0.439	**	0.190			
Man-months	ln(man-month)				0.449	***	0.026	0.433	***	0.030	0.507	***	0.034
Sources of motivation	**Science**	**0.182**	***	**0.032**	**0.154**	***	**0.033**	**0.154**	***	**0.040**	**0.180**	***	**0.044**
	Challendge	**0.120**	***	**0.043**	**0.108**	**	**0.044**	**0.085**		**0.053**	**0.107**	*	**0.058**
	Org_perfromance	**0.042**		**0.032**	**0.009**		**0.033**	**-0.022**		**0.040**	**-0.039**		**0.045**
	Career	**-0.013**		**0.035**	**-0.009**		**0.035**	**-0.024**		**0.043**	**-0.005**		**0.048**
	Reputation	**0.033**		**0.037**	**0.013**		**0.037**	**0.003**		**0.045**	**-0.001**		**0.051**
	Budget	**0.109**	***	**0.035**	**0.109**	***	**0.035**	**0.130**	***	**0.041**	**0.114**	**	**0.047**
	Money	**0.010**		**0.034**	**0.019**		**0.034**	**-0.012**		**0.040**	**-0.015**		**0.044**
Firm fixed effect		No			No			No			Yes		
# of observations	.	4723			4699			3339			3500		
Log pseudolikelihood		6087.28			-5858.92			-4194.88			-4203.73		
Pseudo R^2		0.0574			0.087			0.0845			0.1383		

Note: All models control for application year and technology class (US subcategories) fixed effects. The following control variables are not reported in the table: status (employed, self-employed, student), organizational types other than firms and universities, stages (basic, applied, or development), invention types (product or process).

Table 3 Ordered Logit Regression for the Relative Economic Value of Patents

		Dependent variable: Pat_val (# of patents expected)											
		Base			With man-month indicator			With firm characteristics			With firm fixed effect		
Independent variables		Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.
Project size	ln(# of inventors)	0.270	***	0.056	0.183	***	0.057	0.246	***	0.067	0.216	**	0.085
	ln(# of applicants)	0.075		0.151	0.073		0.151						
Basic inventor	Female	-0.326		0.277	-0.341		0.293	0.097		0.284	-0.159		0.327
characteristics	ln(age)	0.663	***	0.173	0.682	***	0.174	0.736	***	0.214	0.793	***	0.253
Educational	High school diploma	0.291	**	0.122	0.329	***	0.123	0.193		0.147	0.141		0.185
background	Two-year college	-0.018		0.154	0.027		0.152	0.113		0.200	0.209		0.231
(base: college	Master's degree	0.062		0.080	0.049		0.081	0.072		0.095	0.053		0.112
graduates)	PhD	0.432	***	0.125	0.393	***	0.125	0.271	*	0.152	0.470	***	0.175
Organization	Private firm (250 < emp ≤ 500)	0.043		0.140	0.023		0.142						
(base: private firm w.	Private firm (100 < emp ≤ 250)	-0.144		0.201	-0.144		0.205						
employment > 500)	Private firm (emp ≤ 100)	0.495	***	0.183	0.452	**	0.187						
	Universities	-0.428		0.274	-0.419		0.274						
Function	R&D unit in business	0.004		0.147	0.039		0.149	0.000		0.189	0.087		0.207
(base: independent	Production	0.144		0.211	0.176		0.214	0.303		0.271	0.216		0.274
R&D)	Software development	0.090		0.147	0.127		0.150	0.065		0.183	0.381	*	0.222
Objective	Reinforcing noncore business	-0.236	**	0.099	-0.238	**	0.099	-0.339	***	0.119	-0.343	**	0.144
(base: reinforcing	Developing new business	0.042		0.086	0.005		0.087	-0.062		0.103	-0.058		0.120
core business)	Expanding technological base	-0.315	**	0.132	-0.257	*	0.134	-0.387	**	0.175	-0.402	**	0.185
Nature	Seeds-oriented	0.031		0.082	0.014		0.082	0.017		0.100	-0.066		0.113
(base: needs-oriented)	Exploration for seeds	0.021		0.104	0.027		0.106	-0.034		0.131	-0.050		0.146
Firm characteristics	ln(firm age)							0.216		0.172			
	ln(sales)							-0.057	**	0.026			
	Overseas sales ratio							-0.259		0.215			
Man-months	ln(manmonth)				0.188	***	0.027	0.167	***	0.033	0.206	***	0.036
Sources of	**Science**	**0.295**	*******	**0.039**	**0.289**	*******	**0.040**	**0.249**	*******	**0.047**	**0.308**	*******	**0.054**
motivation	**Challenge**	**0.273**	*******	**0.054**	**0.271**	*******	**0.055**	**0.239**	*******	**0.065**	**0.430**	*******	**0.077**
	Org_perfromance	**-0.016**		**0.041**	**-0.030**		**0.041**	**0.011**		**0.052**	**-0.055**		**0.058**
	Career	**0.038**		**0.043**	**0.036**		**0.043**	**0.002**		**0.055**	**0.007**		**0.063**
	Reputation	**0.123**	*******	**0.044**	**0.116**	*******	**0.045**	**0.114**	******	**0.057**	**0.106**		**0.065**
	Budget	**-0.010**		**0.041**	**-0.011**		**0.041**	**0.026**		**0.049**	**0.025**		**0.055**
	Money	**0.020**		**0.040**	**0.024**		**0.040**	**0.037**		**0.048**	**0.065**		**0.054**
Firm fixed effect		No			No			No			Yes		
# of observations	.	3454			3433			2431			2599		
Log pseudolikelihood		-4177.02			-4125.94			-2909.29			-2835.66		
Pseudo R^2		0.0616			0.0679			0.0577			0.1421		

Note: All models control for application year and technology class (US subcathegories) fixed effects. The following control variables are not reported in the table: status (employed, self-employed, student), organizational types other than firms and universities, stages (basic, applied, or development), invention types (product or process).

Table 4 R&D Productivity and the Utilization of Academic Research Output

Ordered logit model	Dependent variable	**Pat_num (# of patents expected)**						**Pat_val (relative economic value)**					
		Base			With academic activities			Base			With academic activities		
Independent variables		Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.
Project size	ln(# of inventors)	-0.005		0.052	-0.021		0.053	0.183	***	0.057	0.164	***	0.059
	ln(# of applicants)	-0.276	**	0.128	-0.334	**	0.133	0.073		0.151	0.016		0.158
Basic inventor	Female	0.255		0.275	0.226		0.282	-0.341		0.293	-0.452		0.292
characteristics	ln(age)	0.833	***	0.145	0.806	***	0.149	0.682	***	0.174	0.592	***	0.181
Educational	High school diploma	-0.031		0.117	-0.040		0.123	0.329	***	0.123	0.361	***	0.129
background	Two-year college	0.204	*	0.122	0.113		0.124	0.027		0.152	0.010		0.158
(base: college	Master's degree	0.278	***	0.070	0.233	***	0.071	0.049		0.081	0.007		0.082
graduates)	PhD	0.366	***	0.106	0.237	**	0.110	0.393	***	0.125	0.235	*	0.129
Organization	Private firm (250 < emp £ 500)	-0.491	***	0.126	-0.484	***	0.132	0.023		0.142	0.049		0.149
(base: private firm	Private firm (100 < emp £ 250)	-0.613	***	0.151	-0.575	***	0.154	-0.144		0.205	-0.102		0.216
with emp > 500)	Private firm (emp £ 100)	-0.396	***	0.152	-0.288	*	0.154	0.452	**	0.187	0.478	**	0.190
	Universities	-0.730	***	0.264	-0.741	***	0.275	-0.419		0.274	-0.612	**	0.303
Function	R&D unit in business	-0.277	**	0.120	-0.210		0.137	0.039		0.149	-0.085		0.170
(base: independent	Production	-0.496	***	0.190	-0.387	*	0.201	0.176		0.214	0.091		0.228
R&D)	Software development	-0.198		0.127	-0.130		0.144	0.127		0.150	0.085		0.170
Objective	Reinforcing noncore business	-0.115		0.081	-0.098		0.083	-0.238	**	0.099	-0.262	***	0.100
(base: reinforcing core	Developing new business	0.396	***	0.073	0.377	***	0.075	0.005		0.087	-0.002		0.088
business)	Expanding technological base	0.003		0.120	0.010		0.123	-0.257	*	0.134	-0.282	**	0.139
Nature	Seeds-oriented	0.214	***	0.070	0.205	***	0.071	0.014		0.082	0.005		0.084
(base: needs-oriented)	Exploration for seeds	0.133		0.096	0.146		0.098	0.027		0.106	0.064		0.110
Interactions with	Independent R&D unit				0.065		0.082				-0.064		0.094
academic communities	Co-inventors from universities				-0.330	*	0.197				0.069		0.208
	Collaboration with universities				0.155		0.135				-0.045		0.150
(for getting ideas)	Importance of science literature				0.019		0.028				-0.026		0.034
	Importance of universities				0.064	*	0.035				0.032		0.038
(for implementing	Importance of science literature				0.032		0.026				0.004		0.032
ideas)	Importance of universities				-0.010		0.035				-0.029		0.038
	Published the discovery in journals				0.348	***	0.084				0.728	***	0.097
Man-month	ln(manmonth)	0.449	***	0.026	0.430	***	0.027	0.188	***	0.027	0.165	***	0.028
Sources of motivation	**Science**	**0.154**	*******	**0.033**	**0.127**	*******	**0.034**	**0.289**	*******	**0.040**	**0.278**	*******	**0.041**
	Challenge	**0.108**	******	**0.044**	**0.094**	******	**0.045**	**0.271**	*******	**0.055**	**0.262**	*******	**0.056**
	Org_perfromance	**0.009**		**0.033**	**0.017**		**0.034**	**-0.030**		**0.041**	**-0.026**		**0.042**
	Career	**-0.009**		**0.035**	**-0.005**		**0.036**	**0.036**		**0.043**	**0.051**		**0.044**
	Reputation	**0.013**		**0.037**	**-0.005**		**0.038**	**0.116**	*******	**0.045**	**0.094**	******	**0.046**
	Budget	**0.109**	*******	**0.035**	**0.084**	******	**0.036**	**-0.011**		**0.041**	**-0.017**		**0.042**
	Money	**0.019**		**0.034**	**0.013**		**0.034**	**0.024**		**0.040**	**0.030**		**0.041**
# of observations	.	4699			4545			3433			3319		

Note: All models control for application year and technology class (US subcategories) fixed effects. The following control variables are not reported in the table: status (employed, self-employed, student), organizational types other than firms and universities, stages (basic, applied, or development), invention types (product or process).

Table 5 R&D Productivity Estimation Controlling for Inventor Ability

Ordered logit model	Dependent variable	Pat_num (# of patents expected)						Pat_val (relative economic value)					
		Base (restricted to college graduates or higher)			With FE dummies for college the inventor graduated			Base (restricted to college graduates or higher)			With FE dummies for college the inventor graduated		
Independent variables		Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.
Project size	ln(# of inventors)	-0.019		0.055	-0.024		0.059	0.198	***	0.061	0.220	***	0.064
	ln(# of applicants)	-0.322	**	0.137	-0.319	**	0.145	0.056		0.161	0.059		0.179
Basic inventor	Female	0.302		0.289	0.279		0.314	-0.380		0.327	-0.248		0.384
characteristics	ln(age)	0.832	***	0.161	0.754	***	0.172	0.740	***	0.188	0.869	***	0.206
Educational	Master's degree	0.282	***	0.070	0.247	***	0.078	0.047		0.081	0.149		0.095
background	PhD	0.366	***	0.108	0.374	***	0.120	0.398	***	0.125	0.498	***	0.141
Organization	Private firm (250 < emp £ 500)	-0.563	***	0.134	-0.603	***	0.145	0.063		0.162	0.077		0.180
(base: private firm	Private firm (100 < emp £ 250)	-0.531	***	0.173	-0.587	***	0.191	-0.075		0.236	-0.112		0.261
with emp > 500)	Private firm (emp £ 100)	-0.461	***	0.170	-0.410	**	0.188	0.121		0.194	0.131		0.214
	Universities	-0.737	***	0.267	-0.709	**	0.277	-0.543	**	0.276	-0.568	**	0.285
Function	R&D unit in business	-0.240	*	0.144	-0.177		0.157	0.044		0.180	-0.006		0.197
(base: independent	Production	-0.504	**	0.218	-0.466	*	0.239	0.212		0.238	0.193		0.276
R&D)	Software development	-0.097		0.142	-0.129		0.152	0.109		0.166	0.119		0.184
Objective	Reinforcing non-core business	-0.165	*	0.089	-0.171	*	0.093	-0.255	**	0.108	-0.278	**	0.115
(base: reinforcing core	Reinforcing other existing business	-0.073		0.161	-0.114		0.167	-0.105		0.193	-0.172		0.209
business)	Developing new business	0.396	***	0.078	0.387	***	0.082	-0.028		0.092	-0.015		0.097
	Expanding technological base	-0.006		0.127	-0.082		0.135	-0.287	**	0.144	-0.310	**	0.158
Nature	Seeds-oriented	0.185	**	0.074	0.213	***	0.079	-0.036		0.087	-0.070		0.092
(base: needs-oriented)	Exploration for seeds	0.187	*	0.104	0.180		0.111	0.023		0.116	0.016		0.126
Man-months	ln(manmonth)	0.470	***	0.028	0.478	***	0.029	0.186	***	0.029	0.179	***	0.031
Sources of motivation	**Science**	**0.141**	*******	**0.036**	**0.138**	*******	**0.038**	**0.288**	*******	**0.042**	**0.291**	*******	**0.045**
	Challendge	**0.125**	*******	**0.048**	**0.120**	******	**0.050**	**0.258**	*******	**0.059**	**0.248**	*******	**0.064**
	Org_perfromance	**0.008**		**0.036**	**0.004**		**0.038**	**-0.077**	*****	**0.044**	**-0.053**		**0.047**
	Career	**0.011**		**0.038**	**0.003**		**0.039**	**0.047**		**0.047**	**0.050**		**0.050**
	Reputation	**0.013**		**0.040**	**0.017**		**0.042**	**0.114**	******	**0.047**	**0.122**	******	**0.051**
	Budget	**0.106**	*******	**0.038**	**0.106**	*******	**0.040**	**-0.010**		**0.043**	**-0.031**		**0.047**
	Money	**0.016**		**0.037**	**0.028**		**0.039**	**0.030**		**0.043**	**0.033**		**0.045**
# of observations	.	4103			3949			3034			2927		
Log pseudolikelihood		-5158.07			-4906.34			-3662.48			-3444.46		
Pseudo R^2		0.0889			0.1006			0.0662			0.0891		

Note: All models control for application year and technology class (US subcategories) fixed effects. The following control variables are not reported in the table: status (employed, self-employed, student), organizational types other than firms and universities, stages (basic, applied, or development), invention types (product or process).

Figure 3 Employees' Choice of Project and Effort

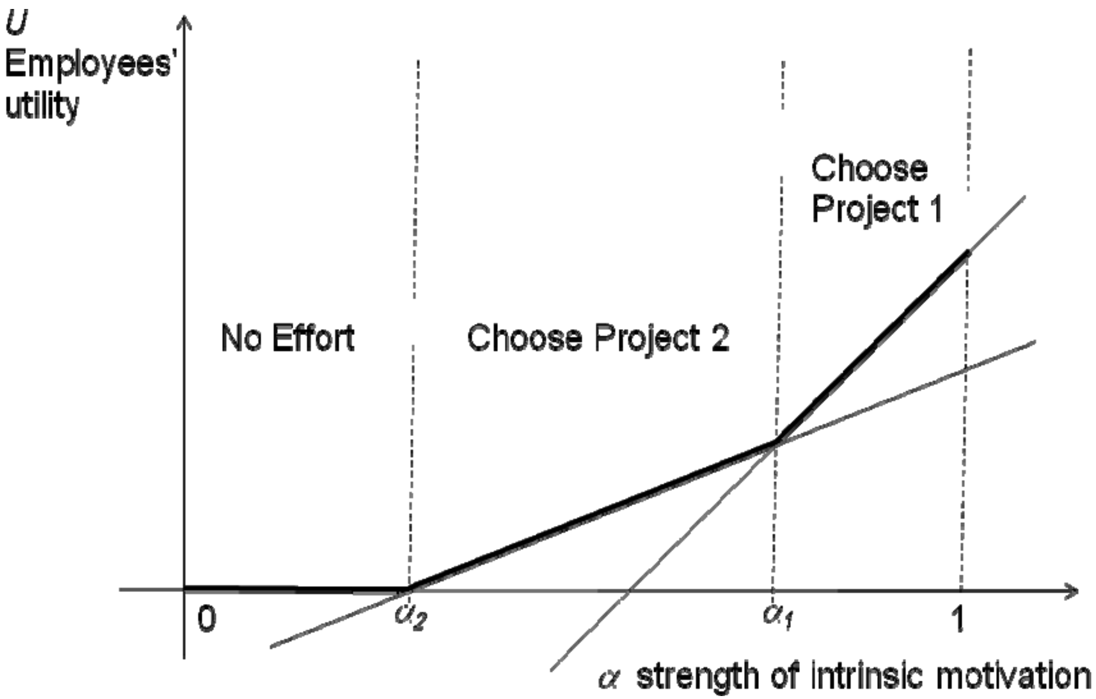

Figure 4 Project Choice under Revenue-Based vs. Non-Revenue-Based Pay

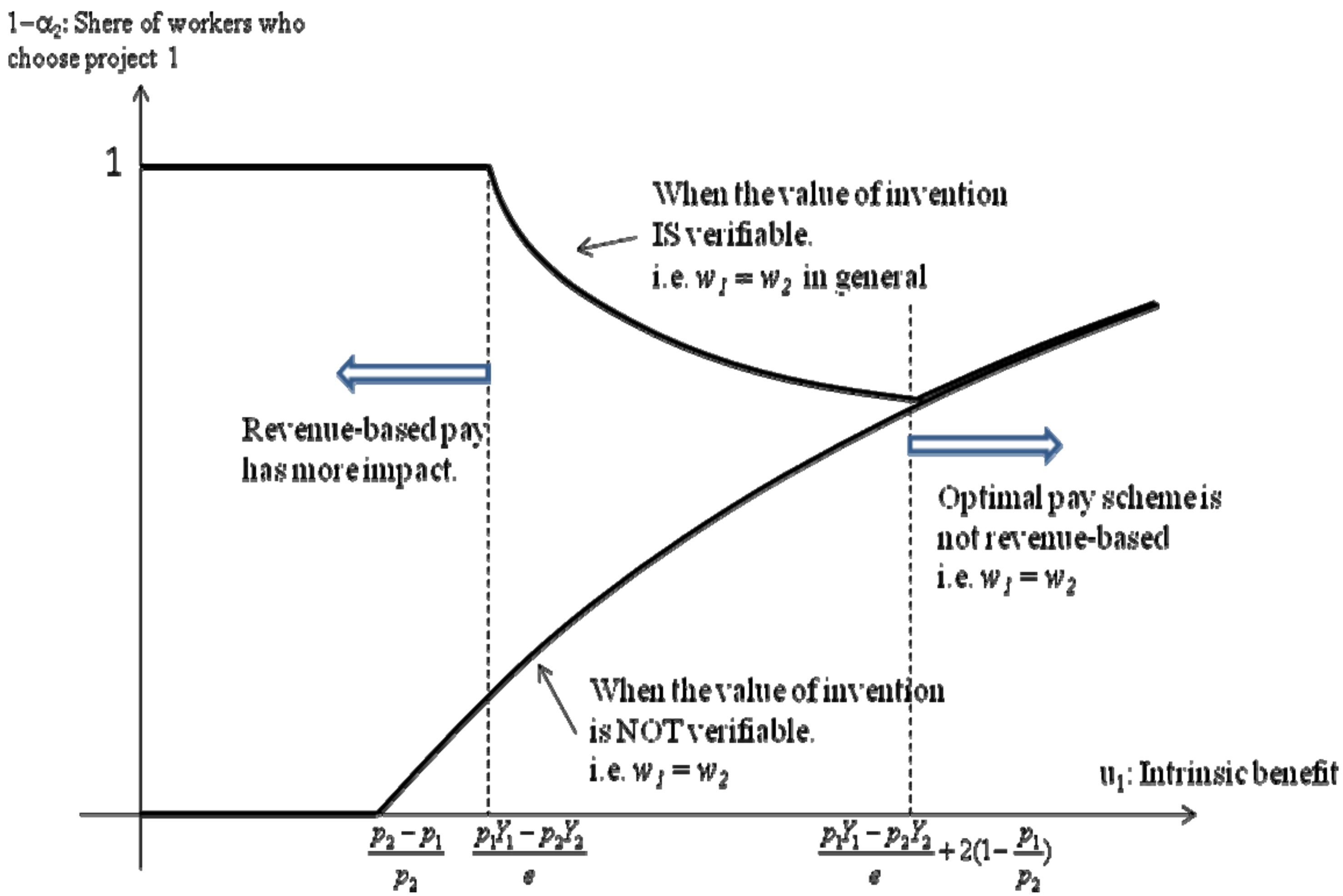

Figure 5 Average Success Rate under Revenue-Based vs. Non-Revenue-Based Pay

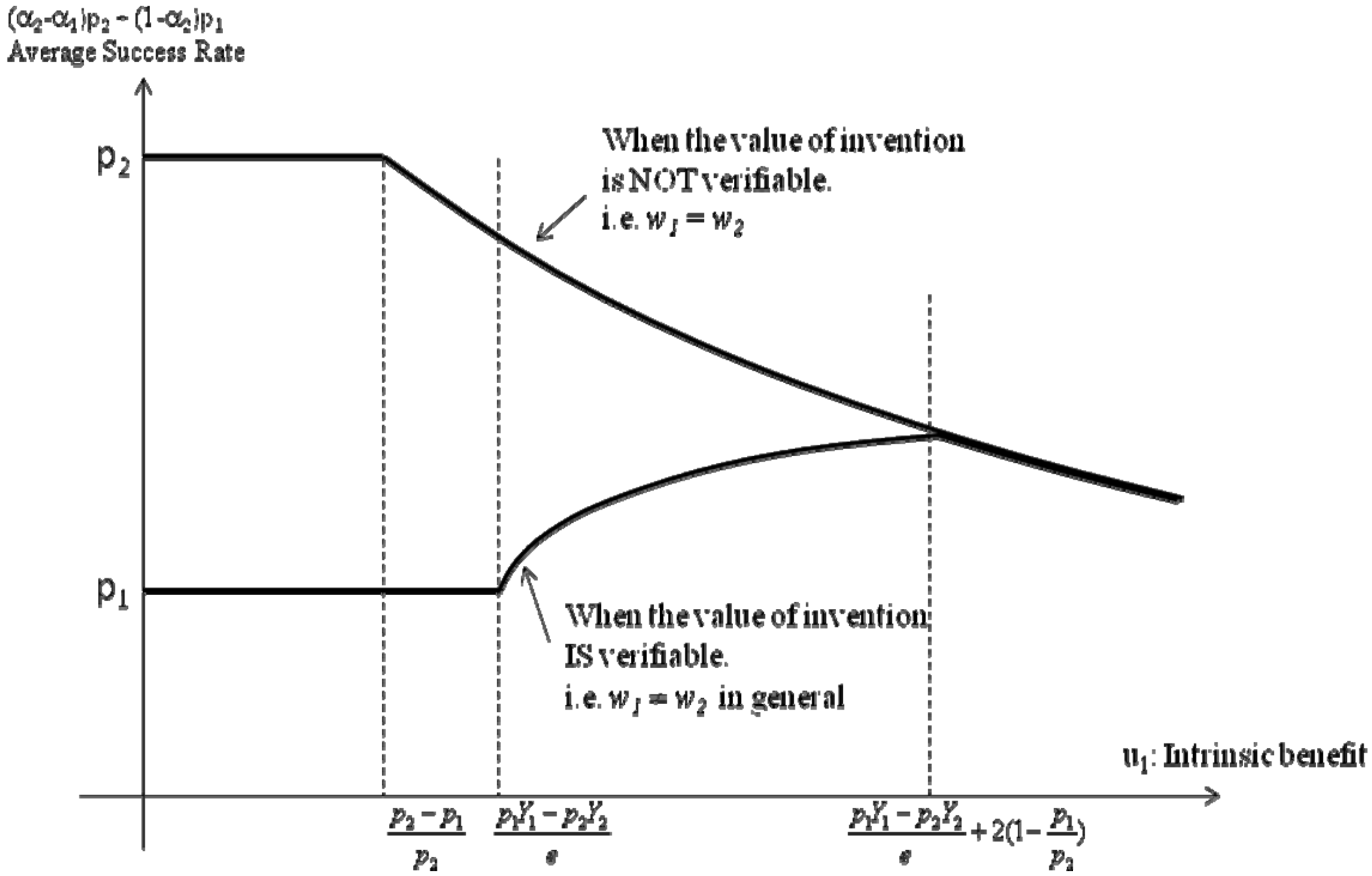

Table 6 Intrinsic Motivation and Incidence of Revenue-based Pay

Probit Model

Dependent Variable	ppay Incidence of revenue-based pay		ppay Incidence of revenue-based pay		ppay_1mil No or higher-than-¥1million limit for payment		ppay_1mil No or higher-than-¥1million limit for payment	
ln(# of employees)	0.5971	***	0.6021	***	0.3088	***	0.3070	***
	(0.1161)		(0.1146)		(0.1007)		(0.0999)	
ln(patent stock)	0.1671	***	0.1664	***	0.0289		0.0306	
	(0.0552)		(0.0551)		(0.0430)		(0.0430)	
# of lawsuit cases	0.5083	***	0.5154	***	0.3410	***	0.3411	***
	(0.1069)		(0.1076)		(0.0880)		(0.0874)	
Sources of motivation								
Science	**-0.0644**		**-0.0521**		**-0.0103**		**-0.0060**	
	(0.0448)		**(0.0432)**		**(0.0347)**		**(0.0399)**	
Challenge			(0.0101)				-0.0090	
			(0.0583)				(0.0484)	
Org_perfromance			(0.0233)				-0.0044	
			(0.0623)				(0.0365)	
Career			-0.0450				0.0277	
			(0.0468)				(0.0431)	
Reputation			-0.1256	**			-0.0980	**
			(0.0589)				(0.0421)	
Budget			0.1293	**			0.0704	*
			(0.0612)				(0.0421)	
# of observations	1848		1840		1939		1930	
Log pseudolikelihood	-480.606		-471.475		-928.488		-920.061	
Pseudo R^2	0.3872		0.3952		0.2735		0.2756	

Note: All models include application year and technology class (US subcathegories) fixed effects.
Standard errors are clustered by applicant firm (in parentheses).

Table 7 Intrinsic Motivation and Revenue-Based Pay Schemes

Ordered logit model	Dependent variable	Size_pat (# of patents expected)						Pat_value (relative economic value)					
	Sample: substantial revenue-based reward	**Yes**			**No**			**Yes**			**No**		
Independent variables		Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.	Coefficient		S.E.
Basic inventor characteristics	Female	1.163	**	0.465	-1.216		0.822	-0.459		0.411	0.131		0.695
	ln(age)	1.236	***	0.312	0.793	*	0.427	1.468	***	0.293	0.751	*	0.400
Educational background	High school diploma	0.077		0.302	0.740		0.616	0.679	**	0.332	0.334		0.404
	Two-year college	0.003		0.221	0.941	***	0.359	0.379		0.237	0.115		0.308
(base: college graduates)	Master's degree	0.231		0.224	1.127	***	0.354	0.519	**	0.240	0.351		0.311
	PhD	0.414		0.286	1.149	***	0.382	0.702	**	0.303	0.430		0.375
Function	Belong to R&D unit	0.781	***	0.175	-0.035		0.248	0.116		0.171	0.555	**	0.261
Objective	Reinforcing existing business	-0.514	***	0.131	-0.432	**	0.194	-0.126		0.130	-0.098		0.175
(base: developing new business)	Expanding technological base	-0.759	***	0.257	-0.684	*	0.349	-0.825	***	0.238	-0.311		0.327
	Others	1.093		0.695	-2.141	***	0.627	-0.534		1.043	-1.340	***	0.496
Nature	Seeds-oriented	0.229	*	0.137	0.248		0.200	-0.244	*	0.140	0.616	***	0.186
(base: needs-oriented)	Exploration for seeds	0.107		0.176	0.913	***	0.296	0.007		0.188	0.023		0.269
Stages	Basic	0.037		0.163	0.663	***	0.203	0.108		0.167	0.452	**	0.215
(base: development only)	Applied	0.298	**	0.131	0.359	**	0.169	0.325	***	0.123	0.421	**	0.176
	Development	0.062		0.145	0.570	***	0.188	0.255	*	0.130	0.466	**	0.196
	Technical Service	-0.010		0.210	0.178		0.259	0.153		0.249	0.948	***	0.271
Firm characteristics	ln(sales)	0.158	***	0.052	0.233	***	0.080	-0.038		0.050	0.067		0.063
	ln(patent stock)	-0.135	***	0.046	0.046		0.088	0.042		0.048	0.014		0.073
Project size	ln(# of inventors)	-0.009		0.029	-0.037		0.046	0.114	***	0.034	0.050		0.041
	ln(manmonth)	1.566	***	0.143	1.200	***	0.201	0.462	***	0.130	0.440	**	0.178
Sources of motivation	**Science**	**0.254**	*******	**0.059**	**0.071**		**0.081**	**0.373**	*******	**0.054**	**0.294**	*******	**0.075**
# of observations	.	1299			721			1299			722		
Log pseudolikelihood		-1639.41			-916.49			-1861.29			-1014.98		
Pseudo R^2		0.1043			0.1081			0.0652			0.0693		

Note: All models control for application year and technology class (US subcathegories) fixed effects.

substantial revenue-based reward means revenue-based compensation with no or higher-than-\1milion limit for annual payment