Intrinsic and Extrinsic Motivation for Inventors

Hideo Owan*
Sadao Nagaoka**

May, 2008

Preliminary. Do not quote without permission of the authors.

Abstract

This paper evaluates the sources of inventor motivation, their impacts on inventor productivity, and the interaction between intrinsic and extrinsic motivations using novel data from a survey of Japanese inventors on 5,278 patents conducted by Research Institute of Economy, Trade and Industry (RIETI) in 2007. 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 absorptive capacity of the firm, we cannot find any strong support for this absorptive capacity explanation. To measure the incentive effect of monetary compensation for inventions, we estimate treatment effect models and find some evidence that monetary rewards may be raising the inventor productivity where they are introduced. However, our analyses also suggest that monetary compensation may be "crowding out" taste for science. More specifically, we show that (1) a successful introduction of monetary rewards is less likely where inventors have strong "taste for science", and (2) the effect of "taste for science" on patent value is smaller in the presence of monetary rewards. One interpretation of the result is that inventors who otherwise pursue risky projects aimed at technological leap might shift to safer and predictable projects in the presence of monetary incentives. The "crowd-out" effect found in this paper also implies that the correlation between the R&D productivity and the "taste for science" is caused by its motivational effect rather than simple correlation between the "taste for science" and the inventor ability.

*Professor, Graduate School of International Management, Aoyama Gakuin University, 4-4-25 Shibuya, Shibuya-ku, Tokyo 150-8366 Japan, Fax +81-3-3409-4167,
Email: owan@gsim.aoyama.ac.jp
**Professor, Institute of Innovation Research, Hitotsubashi University, 2-1, Naka, Kunitachi Tokyo 186-8601 Japan, Fax +81-42-580-8410, Email: nagaoka@iir.hit-u.ac.jp

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, or existence of positive spillovers could affect the R&D investment, one of the most important resources in technological progress, efforts made by inventors themselves, have 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 and under-provision of inventor efforts should be concerned. Furthermore, since it is difficult to measure creativity and serendipity of researchers, screening researchers to get right staff is becomes even more difficult task due to adverse selection.

The setting of R&D activity provides three major obstacles for providing researchers with right incentives. First, since R&D typically requires highly specialized scientific and/or technical knowledge, it is almost inevitable for the management to delegate real decision authority to the researchers about what projects to pursue, what approaches to be taken, and how much resources to be allocated to each step. Therefore, it is very hard to monitor the process of R&D activity. Second, the output of R&D is knowledge and technology which will be combined for commercial use. Since an enormous amount of technical knowledge, either patented or not patented, is typically put together for launching a new product or implementing a new process, it is a formidable task to evaluate the economic value of each piece of technical knowledge. Hence, there won't be any appropriate performance measures that can be used to provide right incentives without distortion. Third, most R&D process takes time and involves considerable uncertainty, and thus evaluating and screening researchers for right qualities to enhance R&D productivity is not easy. Therefore, it is inevitable to rely on intrinsic or social motives, to some extent, and a loose control to motivate R&D researchers.

Taking balance between intrinsic and extrinsic motivation, and between control and initiative, however, is a delicate task. As a number of economists have pointed out, technological opportunities and appropriability differ among industries.[1] Furthermore, even in the same industry or for the same firm, technological opportunities and appropriability for R&D projects will vary depending on whether they aim at exploring for new technological seeds or exploiting existing knowledge to reinforce existing business lines[2] This implies that the measurability of R&D performance and the necessity of management control differ across R&D projects.

There have been discussions among social psychologists about the possibility that extrinsic motivation "crowd-out" intrinsic motivation under certain conditions (See Deci et al.1999, Frey and Jegen 2001, Wiersma 1992) Intrinsic motivation may stimulate creativity by supporting riskier and more exploratory works while extrinsic rewards could suffocate creativity by drawing researchers' attention to more incremental and exploitative approaches. If the "crowd-out" story is real, it may be

---

[1] See Levin (1988) and Klevorick et al. (1995) for example.

[2] In the field of organizational economics and strategic management, it has been emphasized that firms need to integrate and build upon its current competencies while simultaneously developing fundamentally new capabilities but not many firms can take balance between the two types of activities (March 1991, Teece, Pisano, & Shuen 1997, Tushman & O'Reilly 1997, Roberts 2004).

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. Therefore, it is important to study the interaction between intrinsic and extrinsic motivation.

The issue of the "crowd-out" possibility is especially important for Japanese firms in the light of recent development in the corporate world of Japan. Most Japanese firms offer some forms of monetary rewards for employees who successfully develop patented or commercialized technology. Although the patent law requires that a patenting firm should pay an appropriate amount of monetary compensation to the employee-inventor, the law does not specify how much is "appropriate." As a result, the size of reward varies from firm to firm. In the past decade, a number of Japanese firms including Nichia Chemical, Hitachi, Olympus, Ajinomoto, etc. have been sued for not compensating their inventors enough. 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 battle. In addition, the labor market for R&D researchers and engineers is becoming increasingly thick nowadays. This also encourages innovative firms to offer more generous inventor compensation schemes to attract talented researchers. We need to evaluate the implications of this recent trend because more monetary compensation may not necessarily stimulate more creativity if it "crowd-out" intrinsic motivation.

II. Literature

Importance of science orientation and intellectual challenge has been discussed by a number of economists. (Arora and Gambardella 1994, Cohen and Levinthal 1989 1990, Gambadella et al. 2006, Rosenberg 1989 , Sauermann and Cohen 2007, Stephan 1996, Stern 2004). Some of these works have found high correlation between science orientation and R&D productivity. But it is not yet clear whether the individual's interest and enthusiasm for science itself raises R&D productivity or such traits are simply correlated with the individual's 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 argues that open source contributors enjoy intrinsic pleasure of working on a "cool" project and ego gratification from peer recognition as well as skill improvement and career advancement (i.e. job offers or access to venture capital in the future).

The "crowd-out" effect of extrinsic rewards has been suggested by some experimental works in social psychology (Deci, Koestner & Ryan 1999, Frey and Jegen 2001, Wiersma 1992) but has never caught much attention of economists. Although there have been many research on monetary incentive schemes in general but few of them consider the role that intrinsic motives play except for a few such as Murdock 2002 and Akerlof and Kranton 2005. There are many empirical works on compensation schemes for blue-color workers, salespeople, top managers, etc. but the study specifically on the compensation for R&D staff is scant (for inventor compensation in Germany, see Harhoff and Hoisl 2007). Our research is intended to fill this gap.

<<Incomplete. To be filled.>>

III. Model for Illustration

In order to illustrate how the "crowding-out" by monetary compensation could take place, we will present a very simple principal-agent model where the agent-employee chooses the type of project and the level of efforts. Suppose employees face two R&D opportunities that could potentially generate the firm profit Y, Project 1 and Project 2. Project 1 is more exploratory and risky but could potentially lead to many projects that will be successfully commercialized. Project 2 is more exploitative and safe and is likely to improve the current product with high probability. 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 no effort $E = 0$. When employees choose $E = e$, Project 1 and 2 generate $Y=Y_1 > 0$ and $Y=Y_2 > 0$ with probability p_1 and p_2, respectively, and $Y=0$ otherwise. When they choose $E = 0$, the project fails for sure with $Y=0$. Employees receive nonpecuniary personal benefits αu from successfully completing each project with $Y > 0$ where $u = u_1$ for Project 1 and $u=u_2$ for Project 2 but get no such benefits in case of failure. α is the parameter of the strength of intrinsic motivation and varies across employees but cannot be observed by the firm. We assume that α is uniformly distributed between 0 and 1. In addition to the intrinsic motive, the firm can provide the employees with monetary incentive $w = w(Y)$. We assume that there is the liquidity constraint with $w \geq 0$ where the minimum wage is normalized at 0. Then, it is immediate that $w(0) = 0$. In accordance with the characteristic differences between Project 1 and Project 2 described above, we assume $Y_1 > Y_2$, $p_1 < p_2$, $u_1 > u_2$.

We assume that choosing Project 1 and exerting high effort is efficient for any α, which is formalized in Assumption 1.

Assumption 1: $p_1(Y_1 + \alpha u_1) - e > p_2(Y_2 + \alpha u_2) - e > 0$ for all α.

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

$$U = E[w + \alpha u \mid E] - E \text{ for } i = 1,2 \qquad (1)$$

Let $w_1 = w(Y_1)$ and $w_2 = w(Y_2)$. Then, the employee solves the following maximization problem:

$$\text{Max } U = \max\{p_1(w_1 + \alpha u_1) - e, p_2(w_2 + \alpha u_2) - e, 0\} \qquad (2)$$

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. We assume that no employees choose Project 2 in the absence of monetary incentive, *i.e.* $w_1 = w_2 = 0$. This is true when the following assumption holds.

Assumption 2: $p_1 u_1 > p_2 u_2$

Under this assumption, we can prove the following lemma.

Lemma 1 *For any pair of* (w_1, w_2) *such that* $w_1 \geq w_2 \geq 0$*, 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 an effort if* $\alpha \in [\alpha_1, 1]$

(ii) *the employee chooses Project 2 and exerts an 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.

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

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

Case 1 (no constraint): the firm can freely choose w_1 and w_2 (≥ 0).

Case 2 (bounded rationality): when the project succeeds, the firm cannot verify *Y*. Therefore,

$w_1 = w_2$

Case 2 is a very realistic situation in R&D. In most new products or processes, a substantial amount of patents and technical know-how are used and therefore it is hard to evaluate the economic value of each invention. Furthermore, it often takes many years before the invention is commercially used and the final contribution to the firm profit can only be estimated after a long period of time. Given the complexity and the interdependent and time-variant nature of most inventions, the measurement cost for evaluating the values of all inventions generated every year would be enormous. Most firms use very objective performance measures of invention such as counts of patent application, patent registration or commercial use, or licensing revenue in determining the monetary compensation for R&D staff. We can prove the following proposition:

Proposition 1 *When the firm can freely choose w_1 and w_2 (case 1), no employee will choose project 2. When* $p_1(Y_1 - u_1) \geq e$*, the firm will succeeds in motivating all employees to exert an effort. When the firm cannot verify Y thus has to offer* $w_1 = w_2 = w$ *(case 2), one of the following two distinct equilibria will prevail:*

(1) The firm will offer $w^* = \min\{\frac{p_1(Y_1 - u_1) + e}{2p_1}, \frac{p_1 u_1 - p_2 u_2}{p_1(u_1 - u_2)} \frac{e}{p_2}, \frac{e - p_1 u_1}{p_1}\}$ *and no worker will choose project 2 and those with* $\alpha \in [\frac{e - p_1 w^*}{p_1 u_1}, 1]$ *will exert an effort;*

(2) The firm will offer $w^{**} = \min\{\frac{p_2(Y_2 - u_2) + e}{2p_2}, \frac{e - p_2 u_2}{p_2}\}$ *and no worker will choose project 1 and those with* $\alpha \in [\frac{e - p_2 w^{**}}{p_2 u_2}, 1]$ *will put forth an effort.*

The latter type of equilibria is more likely to arise when $p_1 u_1 - p_2 u_2 > 0$ *is smaller.*

Proof is in the Appendix.

Note that $\alpha(p_1 u_1 - p_2 u_2)$ is the difference in the strength of intrinsic motivation between project 1 and project 2. The smaller is the difference the likely is for the employee to choose project 2 when he is provided monetary incentives in case 2, because monetary incentives encourage employees to choose less risky project 2 in the case. Unless $p_1 u_1 - p_2 u_2$ is large enough, it is likely that $w^* \leq \frac{p_1 u_1 - p_2 u_2}{p_1(u_1 - u_2)} \frac{e}{p_2}$ binds and the firm offers weak incentive in order not to discourage its employees from taking risky but potentially profitable projects. When $p_1 u_1 - p_2 u_2$ is sufficiently small, it then becomes more profitable to switch to stronger incentives while doing so encourages employees to choose safer but less profitable projects.

To illustrate the crowding-out effect, let us use a numerical example in the rest of the discussion. Consider Y_1 = 10, Y_2 = 4, p_1 =0.3, p_2 =0.7, u_1 =3, u_2 =1, and e = 0.6. Note that they satisfy Assumption 1 and Assumption 2. Then, the employee solves:

Max $U = \max\{0.3(w_1 + 3\alpha) - 0.6, 0.7(w_2 + \alpha) - 0.6, 0\}$

Before solving the firm's optimization problem, first let us show what will happen when the firm offers no monetary incentive. Since Assumption 2 is satisfied, the employee will choose project 1 and exert effort if $0.3(0 + 3\alpha) > 0.6 \Leftrightarrow \alpha > \frac{2}{3}$ and makes no effort otherwise. Therefore, the one third of employees choose Project 1, works hard and generate the profit Y_1 = 10 with the probability 0.3, and the two third of employees makes no effort and produce nothing. Then, the firm's profit is $\pi = 1/3 \times 0.3 \times 10 = 1$. The average utility of employees is $EU = \frac{1}{3} \times 0.3 \times (\frac{5}{6} \times 4) - \frac{1}{3} \times 0.6 = 0.13...$

Now consider Case 1 when there is no constraint. By solving the non-linear programming in (3) for the above numerical example, we can show that the optimal compensation scheme is (w_1, w_2) =(2,0) and all employees choose Project 1 and make efforts. Then the firm's profit is $\pi = 1 \times 0.3 \times (10 - 2) = 2.4$. The average utility of employees is $EU = 0.3 \times (2 + 0.5 \times 4) - 0.6 = 0.6$

Next, consider Case 2 when the firm is constrained to offer $w_1 = w_2 = w$. In this case, we can show that the optimal compensation is $w_1 = w_2 = \frac{6}{7}$ and all employees choose Project 2 and the high effort level. The firm's profit is $\pi = 1 \times 0.7 \times (4 - \frac{6}{7}) = 2.2$. The average utility of employees is $EU = 0.7 \times (\frac{6}{7} + 0.5 \times 1) - 0.6 = 0.35$.

Suppose the employees who work hard in this example are surveyed and asked which motive is more important. Assume that they would choose "intrinsic motives" if $w < \alpha u$ and "extrinsic motives" if $w > \alpha u$. I summarize the percentage of people who choose each answer in the following table for each of the cases discussed.

	% of workers who work hard.	% of hard workers who choose risky projects	% of workers who choose "Intrinsic Motives"	% of workers who choose "Extrinsic Motives"
No monetary rewards	33%	100%	100%	0%
Case 1	100%	100%	50%	50%
Case 2	100%	0%	17%	83%

This numerical example has three implications. First, monetary compensation in general should encourage the employees in the R&D units who otherwise will not work hard to put forth more efforts thus there will be more inventions. Second, when the values of inventions are not verifiable, however, offering monetary compensation encourages the employees in the R&D units to choose safer but less valuable inventions. This distortion will be greater the higher is the compensation. Third, intrinsic motives play much lower role when the values of inventions are not verifiable than otherwise.

IV. Data

I 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 Research Institute of Economy, Trade and Industry (RIETI) in 2007. Roughly 70% of the sample come from the pool of triadic patents, the patents applied to all patent offices in Japan, 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 Japan Patent Office, focusing on this pool allows us to analyze mostly economically valuable patents. In addition, we could use citation information provided by the US Patent Office for this portion of respondents. Some inventor and project characteristics as a percentage of total sample are presented in Table A-E.

There are three advantages with the survey. 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 new inventor survey contains rich information about inventor, patent and project characteristics and is perfectly suitable for analyzing work environments for employee-inventors. Second, survey questions replicate many of those in the PATVAL-EU survey and researchers involved coordinated with counterparts in the US who conducted a similar survey on US patents allowing us to compare the nature of invention and the pattern of discoveries among three developed areas. Third, the survey offers two new measures of inventor productivity-one is “quantitative” measure and the other is “qualitative” measure. The former is the number of patents the project is expected to generate and the latter measure is the economic value of the surveyed patent evaluated on the relative basis. Together with citation measures, traditional performance measures for invention, they enable us to analyze hypotheses from multiple dimensions. To summarize,

Size_pat : the size of domestic patent grants the research is expected to generate (6 point scale)

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 (4 point scale)

Important pieces of information that we could obtain from the inventor survey in order to analyze the motivation for inventors are the answers to the survey question "How important was each of the following factors as a source of motivation for your invention?":

- **SCIENCE**: Satisfaction from contributing to the progress of science and technology.
- **CHALLENG**: Satisfaction from solving challenging technical problems.
- **ORG_PERFORMANCE**: Performance enhancement of your organization
- **CAREER**: Your career advances.
- **REPUTATION**: Your own reputation.
- **ENVIRONMENT**: Improved research conditions such as more budget.
- **MONEY**: Monetary rewards.

The 5 point Likert scale is used to answer the questions (1=absolutely unimportant – 5=very important).

Figure 1 and 2 illustrate how the inventors' assessments of the above seven motives differ among inventors with different educational degrees and those working in different organizations. These graphs seem to suggest that what motivate inventors do not vary much across educational backgrounds and across types of organizations that employ them. Nonetheless, we can derive a number of notable implications from the graphs. First, as an inventor has a higher educational degree, he tends to see contribution to science and technology, solving challenging technical problems, reputation, and getting more resources as more important in motivating himself (see Figure 1). One caveat is that the differences between Ph.D.s and other degree holders are likely to reflect the difference in the types of organization that employ them. A substantial portion of Ph.D.s work in universities, national laboratories and other non-profit research institutions. As you can see in Figure 2, researchers in those organizations tend to see contribution to science and technology and better research environment more highly than those in industries. Second, self-employed inventors care much more about monetary compensation and rate organizational performance and career development less important than those employed, which might be rather obvious. Self-employed can capture substantial portion of economic rent generated by the invention through licensing or commercialization while employee-inventors are typically entitled to a small monetary compensation required to be paid under the patent law.

Thirdly, inventors in medium-sized firms seem to be less motivated by contribution to science and technology and monetary compensation than other firms while those in small firms are likely to be less interested in organizational performance and career development. This finding might imply that the possible relationship between firm size and the strengths of motives may not be linear.

V. Analyses

Our multivariate analyses proceeds in multiple steps. First, I estimate ordered logit models to investigate how seven motives are associated with inventor productivity measures controlling other inventor, technology, project and firm characteristics. Second, being aware that seven motives are likely to be endogenously determined, we estimate ordered logit models to examine how inventor, technology, project and firm characteristics are associated with the effectiveness of seven motives. In order to test the hypotheses from past studies and our model presented earlier, we focus on the two motives, SCIENCE and MONEY, in the rest of the analyses in the rest of the analyses. In the third step, we attempt to investigate what mechanism plays behind the strong correlation between SCIENCE and inventor performance measures by modifying the analyses presented in the first step. In the fourth step, we focus on the incentive effect of monetary compensation and estimate treatment effect model to deal with the endogeneity problem. Finally, we examine whether monetary compensation “crowd out” intrinsic motives such as “taste for science”. We re-estimate the above ordered logit models that have R&D performance measures as dependent variables separately between the two groups of inventions: those that were effectively motivated by monetary rewards and those that were not.

a. *What motivates inventors?-a first look.*

First, we estimate two knowledge production functions for the number of patents granted for inventions from the project (*size_pat*) 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 for the number of patents (*size_pat*) or the inventor's self-evaluated value of a patent (*valued2*) for inventor-project pair i, X_i is the inventor/project characteristics including technology class dummies, Z_i is the inventor's evaluation of seven motives, and ε_i is the error term.

We learn from Table 2 that SCIENCE and CHALLENGE are closely associated with both measures of inventor productivity although SCIENCE and CHALLENGE are highly correlated as can be seen in Table 1. Especially, SCIENCE has the largest coefficient among all for both quantity and quality measures. The results should not be interpreted as the effect of these motives, however, because the causality may be the opposite (e.g. project with high expected value may attract those with "strong tastes for science or challenge").

We also find a slight difference between the quantity and quality measures: inventors who think that the research conditions and resources they receive are important sources of motivation are likely to produce more patents while inventors who rate reputation as important are likely to produce more valuable patents. The former result may imply that in an organization where resources the researchers receive are dependent on the amount of inventions they produce the researchers may shift their efforts toward increasing the number of patents rather than toward producing more valuable inventions. This finding is consistent with our discussion in Section III where our model implies that extrinsic motivation may crowd out intrinsic motivation. The problem can also be seen as multi-tasking agency problems analyzed by Milgrom and Roberts (1988) if researchers have to engage in two competing tasks: producing patents and ensuring the quality of the invention. 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 the patents are hard to evaluate, firms tend to rely more on the quantity measure in deciding on resource allocation and researchers distort their effort allocation to produce more patents and the quality aspect may be neglected. The latter result in turn implies that when employee-inventors care about his own reputation what matters is the quality of work thus putting more effort to improve the value of his invention.

Table 2 has a number of other interesting but reasonable implications, some of which are discussed in Nagaoka and Owan (2008). For example, inventors in large firms, in R&D units, working to develop new business line and/or working to commercialize new scientific or technological discoveries are likely to produce more patents but not more valuable ones.

b. How are motives formed?

Table 3 compares seven motives in how they are associated with inventor, project, and firm characteristics in order to understand how these motivators might be formed.

First, inventors working in large groups care more about organizational performance and resources they receive. It is understandable because large-group projects are likely to be strategically important for the employers and the project outcome will significantly affect the firm performance and the resources the inventors receive in the future. Second, older inventors, presumably having more decision authority, highly rate challenge and research conditions as more important than their younger ones.

Third, inventors who work to develop a new business line or to reinforce core businesses more highly rate science, challenge, career advancement, and reputation as more important motives than those working for non-core businesses. Fourth, SCIENCE is a primary motivation driver for those working on exploratory themes (associated with new technology base, basic research, commercialization of new seeds, and exploration of technological seeds). Finally, organizational performance matters more for inventors when firms have large tangible fixed assets – hence failure in R&D may result in large adjustment cost (Chan, Nickerson and Owan 2007).

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

A number of economists pointed out that researchers in industries may have 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. As Stern argues, there are three reasons why some firms prefer hiring researchers with taste for science and allow them to pursue individual research agenda. First, early access to scientific discoveries may raise his R&D productivity by guiding him to the area where there are many commercialization opportunities or by simply improving his absorptive capacity (call it "absorptive capacity" explanation). Second, "taste" for science is likely to be correlated with the researcher's ability and thus could be a reliable screening measure for the firms which need highly talented researchers (call it "screening" explanation). Third, researchers with "taste" for science are willing to trade off wage premium with good research environment. One possibly more important reason, however, is that people with strong "taste" for science might be simply more motivated and work hard as our model suggests.

Note that high correlation between science orientation and R&D productivity confounds the "absorptive capacity" "screening," and "motivation" effects.[3] Rich information in the inventor survey on research activities might help us to distinguish the first explanation from the last two. If the "absorptive capacity" explanation is true, cooperation with scientific community, reading scientific and technical literature, and publishing in academic journals should help to raise inventor productivity. Table 4 shows that the data do not offer strong support for this view. First of all, patent value is lower for those with co-inventors from universities. This is inconsistent with the view that cooperation with scientific community will raise R&D productivity. Second, all variables related to activities to learn scientific discoveries except for "publish in academic journals" become insignificant in explaining patent value. Third, the coefficient for Science does not decline much as

[3] See Rosenberg (1889), Cohen and Levinthal (1989, 1990), and Arora and Gambardella (1994) for similar arguments.

we add the above variables in estimation. These findings may indicate that the “absorptive capacity” effect may explain only a portion, if any, of overall relationship between “taste” for science and R&D productivity, and the effect is especially limited for patent value. Later we will try to distinguish between “ability” and “motivation” explanation.

d. *Which firms are more likely to adopt effective monetary rewards?*

Earlier analyses do not seem to suggest that monetary compensation has a significant impact on inventor productivity as a motive or is significantly correlated with project or firm characteristics (See Table 2&3). This immediately raises a question whether the purposes of monetary rewards for invention are limited to conforming to the patent law (i.e. pay “appropriate compensation” to inventors) and attracting talented researchers.

But, remember that monetary rewards only work when the firm offers them. The inventor survey, however, does not ask which firms offered monetary incentives. As a result, low value of MONEY may result from either no provision of monetary rewards or lack of response to existing ones. Another yet more serious problem is that a firm’s decision to adopt monetary incentives for inventors is likely to be influenced by unobserved firm characteristics that affect the value of invention, which is a typical self-selection problem that could cause significant bias in estimation (e.g. competitive market situation, state of product pipeline, or quality of researchers may affect the firm’s decision whether to adopt substantial monetary compensation or not).

In order to overcome this endogeneity problem, we estimate the inventor productivity measures and the importance of monetary rewards simultaneously. To use treatment effect models as our econometric strategy, we construct the dummy variable INCENTV: =1 if inventor thinks monetary rewards were an important motivator (i.e. MONEY = 4 or 5). Theoretically, INCENTV =1 only when the firm offers some form of monetary rewards AND they succeed to motivate the inventor.

The econometric model we use is the maximum likelihood estimation of treatment effect models for category variables:

$$\begin{aligned} y^*_i &= X_i\beta_1 + \delta\, incentv_i + \varepsilon_{1i} \\ incentv^*_i &= Z_i\beta_2 + \varepsilon_{2i} \end{aligned} \qquad (7)$$

where y^*_i is the latent variable for the number of patents (*size_pat*) or the inventor's self-evaluated value of a patent (*pat_val*) for inventor-project pair *i*, X_i is the inventor/project/firm characteristics including SCIENCE dummies, Z_i includes some variables in X_i *plus* instruments, and ε_{1i} and ε_{2i} are the error terms that are possibly correlated..

We use four instruments, debt asset ratio, parent company ownership, foreign ownership, and importance of corporate secrecy constructed from the responses to the survey.[4] The liquidity problem due to high debt asset ratio might constrain the firm's compensation policy as well as parent companies and foreign shareholders when their presence is high. If corporate secrecy is important,

[4] The last instrument "importance of corporate secrecy" is the score given by the inventor for "corporate secrecy" to the question "How important is each of the following strategy to commercialize this invention successfully?"

the firm will not patent all relevant technology thus unlikely encourage inventors to patent through monetary rewards.

Table 5 shows the results for the INCENTV equations to see what determines the firm's decision to offer substantial monetary rewards. Since the package of monetary incentives for patented inventions normally is the same for all researchers in the same firm, their INCENTV variables should be highly correlated. In order to examine how firm characteristics affect the adoption of substantial monetary incentive, we also estimate the logit regression model for grouped data with some additional firm-level data.

The results are mostly reasonable and we do not see significant differences across different model specifications. Older firms, larger firms, and firms that compete more in global markets are more likely to adopt effective monetary rewards. Firms with high debt asset ratio are less likely to adopt generous monetary incentives as we expected. Firms with high female employee ratio are more likely to offer such incentives. Since firms with many female workers are typically pressed to cut back long work hours, such firms may be more likely to shift toward meritocracy where performance evaluation does not depend on work hours. Such system may offer more monetary incentives for R&D performance. But, it is also likely that female employee ratio is simply correlated with some unobserved industry characteristics that affect the decisions on inventor compensation. One last but very importance point is that firms are less likely to introduce substantial monetary incentives when the “taste for science” of employees is strong. This result is consistent with our model presented earlier.

e. *Are monetary incentives ineffective?*

<<The R&D performance equation in the treatment effect model should be re-estimated thus the discussion is omitted.>>

f. *Do monetary incentives “crowd-out” intrinsic motivation?*

Our model in Section III implies that the effect of “taste for science” on patent value should be smaller in the presence of monetary rewards because even those with relatively strong “taste for science” will shift toward safer projects and those with little “taste for science” will work harder to get the reward. A similar result cannot be obtained for its effect on the number of patents generated. In order to test this hypothesis, we conducted the ordered logit model estimations similar to those in Section a separately between the two cases: INCENTV=0 and INCENTV=1.

The results in Table 7 are consistent with our hypothesis. The coefficient for SCIENCE in the estimate for the value of patent is substantially lower and insignificant when INCENTV=1 while the same coefficients for the estimate for the number of patents are almost equivalent in size. Similarly, the coefficient for PhD, the indicator of PhD holders who presumably have more intrinsic motivation, decline substantially from a significantly positive number to a negative one in the estimate for the patent value when INCENTV switches from 0 to 1. The results imply that monetary incentives do “crowd-out” intrinsic motivation.

Finally, note that the existence of the “crowd-out” effect suggests that the correlation between the R&D productivity and the “taste for science” is caused by its motivational effect rather than simple correlation between the “taste for science” and the inventor ability. Our model in Section II demonstrates that intrinsic motives actually motivate individuals but extrinsic rewards substitute intrinsic motives, which is fully consistent with our empirical results. The “ability” explanation does not account for the “crowd-out” unless more able employees are less responsive to monetary rewards.

VI. 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 absorptive capacity of the firm, we cannot find any strong support for this absorptive capacity explanation. To measure the incentive effect of monetary compensation for inventions, we estimate treatment effect models and find some evidence that monetary rewards may be raising the inventor productivity where they are introduced. However, our analyses also suggest that monetary compensation may be “crowding out” taste for science. More specifically, we show that (1) a successful introduction of monetary rewards is less likely where inventors have strong “taste for science”, and (2) the effect of “taste for science” on patent value is smaller in the presence of monetary rewards. One interpretation of the result is that inventors who otherwise pursue risky projects aimed at technological leap might shift to safer and predictable projects in the presence of monetary incentives. The “crowd-out” effect found in this paper also implies that the correlation between the R&D productivity and the “taste for science” is caused by its motivational effect rather than simple correlation between the “taste for science” and the inventor ability.

Appendix

Proof of Lemma 1 Lemma 1 can be restated in the following format:

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

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

(ii) $p_2(w_2 + \alpha u_2) - e \geq \max\{p_1(w_1 + \alpha u_1) - e, 0\}$ (A.2), for any $\alpha \in [\alpha_2, \alpha_1]$

(iii) $0 \geq \max\{p_1(w_1 + \alpha u_1) - e, p_2(w_2 + \alpha u_2) - e\}$ (A.3), for any $\alpha \in [0, \alpha_2]$.

Suppose inequality A.1 holds for α. Then for any $\alpha' > \alpha$, A.1 is satisfied from Assumption 2. Let $\alpha_1 = \inf\{\alpha \mid (\text{A.1}) \text{ is satisfied}\}$. Then inequality A.1 holds for any $\alpha \in [\alpha_1, 1]$ but not for any $\alpha \in [0, \alpha_1)$. Next, suppose inequality A.3 holds for α. Then for any $\alpha' < \alpha$, A.3 is satisfied. Let $\alpha_2 = \sup\{\alpha \mid (\text{A.3}) \text{ is satisfied}\}$. Then inequality A.3 holds for any $\alpha \in [0, \alpha_2]$ but not for any $\alpha \in (\alpha_2, 1]$.

Since inequalities A.1 and A.3 do not hold at the same time, $\alpha_2 \leq \alpha_1$. If $\alpha_2 < \alpha_1$, for any $\alpha \in [\alpha_2, \alpha_1]$, $p_1(w_1 + \alpha u_1) - e < \max\{p_2(w_2 + \alpha u_2) - e, 0\}$ and $0 < \max\{p_1(w_1 + \alpha u_1) - e, p_2(w_2 + \alpha u_2) - e\}$, which imply that $p_2(w_2 + \alpha u_2) - e \geq \max\{p_1(w_1 + \alpha u_1) - e, 0\}$. This concludes the proof.

References

Akerlof,G.A.&Kranton,R.E.2005.”Identity and the economics of organizations,” *Journal of Economic Perspectives*,19(1):9-32.

Deci, E. L., Koestner, R.,&Ryan, R. M.1999. “A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation,” *Psychological Bulletin*, 125(6):627-668.

Frey, B. S.&Jegen, R. 2001. “Motivation crowding theory,” *Journal of Economic Surveys*, 15(5):589-611.

Gambardella, A., Harhoff, D.,&Verspagen, B. 2006. “The value of patents,” Working Paper.

Gibbons, R. 1998. “Incentives in organizations,” Journal of Economic Perspectives, 12(4):115-132.

Lazear ,E. P. 2000. “Performance pay and productivity,” *American Economic Review*, 90(5):1346-1361.

Lerner, J. &Tirole, J.2005. “The Economics of Technology Sharing:Open Source and Beyond,” *The Journal of Economic Perspectives*, 19(2):99.

Murdock, K. 2002. “Intrinsic motivation and optimal incentive contracts,” *Rand Journal of Economics*, 33(4):650-671.

Nelson, R. R. 1959. “The simple economics of basic scientific research,” *Journal of Political Economy*, 67(3):297-306.

Prendergast, C. 1999. “The provision of incentives in firms,” *Journal of Economic Literature*, 37(1):7-63.

Schumpeter, J. A. 1943. *Capitalism, socialism,and democracy*. London,:G. Allen&Unwin Itd.

Stephan, P. E. 1996. “The economics of science,” *Journal of Economic Literature*, 34(3):1199-1235.

Stern, S. 2004. “Do scientists pay to be scientists?” *Management Science*, 50(6):835-853.

Teece, D. J. 2003. “Design issues for innovative firms:Bureaucracy ,incentives and industrial structure.” In A. D. Chandler &P. Hagstrom& O. Solvell(Eds.), *The dynamic firm: the role of technology, strategy, organization and regions:* Oxford University Press.

Wiersma, U. J. 1992. “The effects of extrinsic rewards in intrinsic motivation: A meta-analysis,” *Journal of Occupational and Organizational Psychology*, 65:101-114.

Figure 1. Employees' Choice of Project and Effort

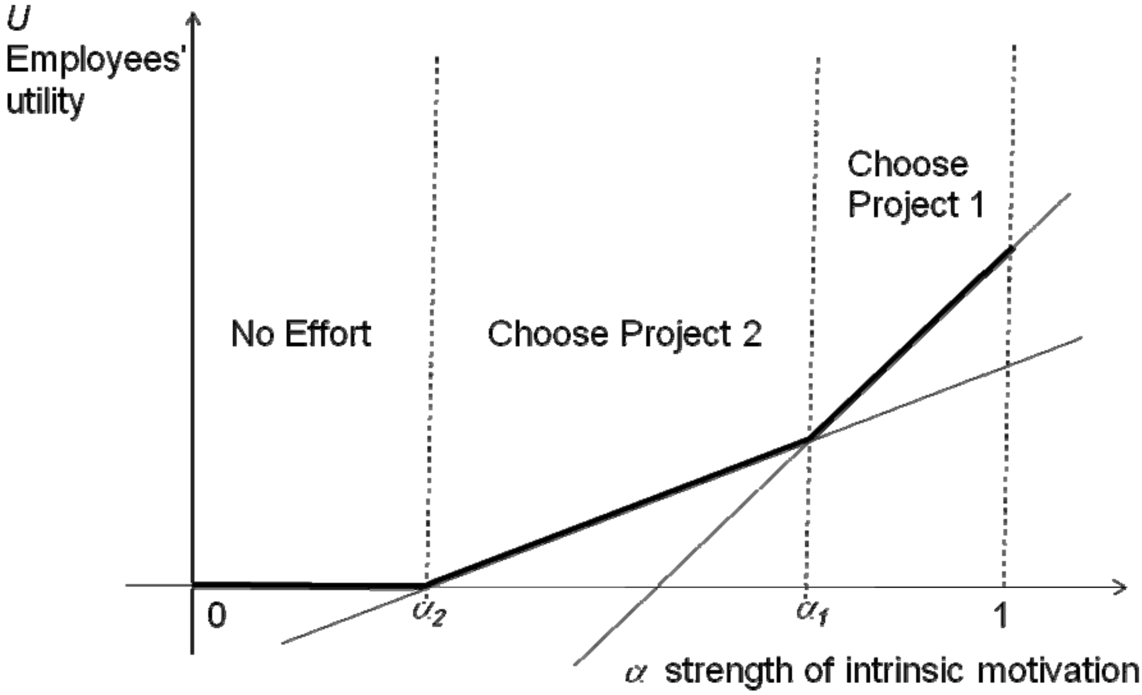

Figure 2. Average Responses by Educational Level

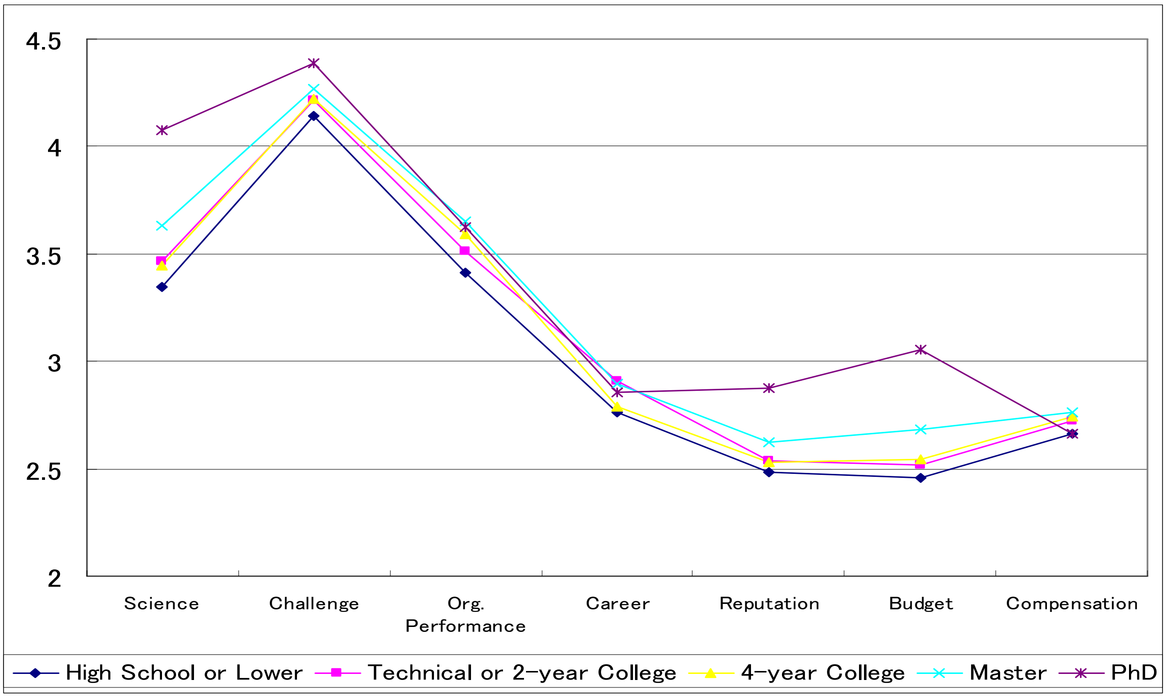

Figure 3 Average Responses by Organizational Type

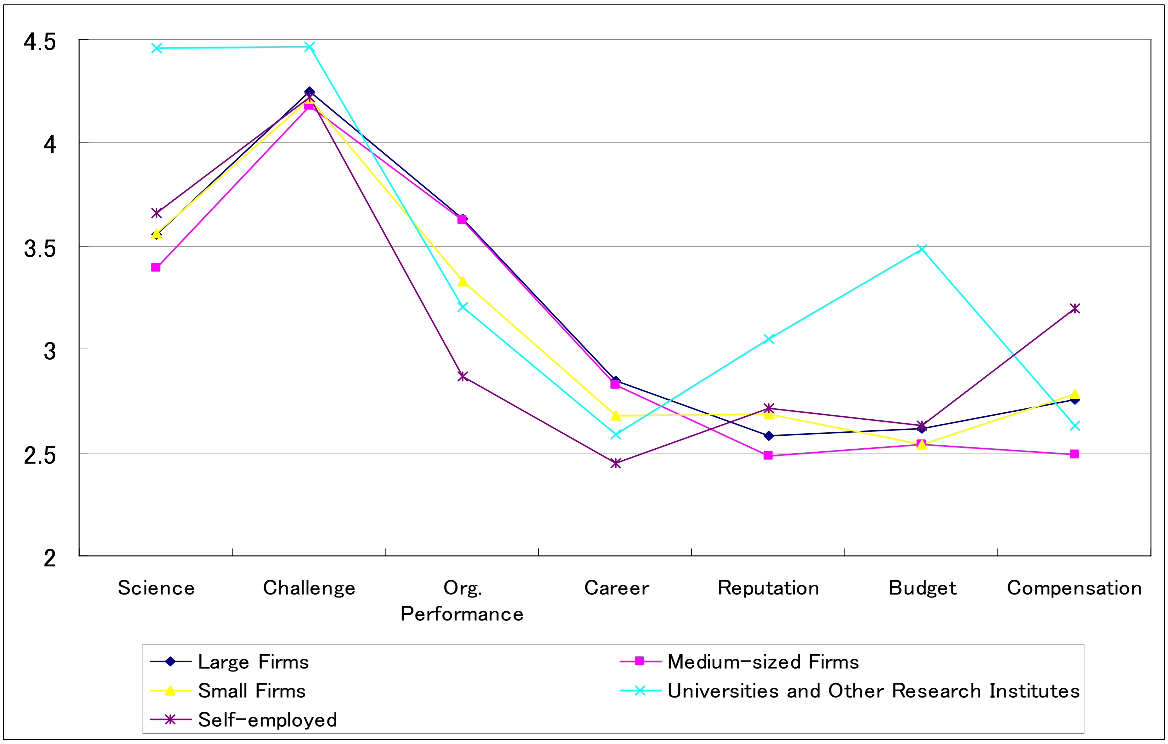

Table A Educational Background

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	Freq.	Percent
Large firms (empoyment>501)	4,231	80.3%
Mediam-sized firms (101<employment£500)	472	9.0%
Small firms (employment£100)	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 but its nature is unknown	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

Table 2 Ordered Logit Regression

Independent variables	Dependent variable	Size_pat (# of patents expected) Coefficient	S.E.	Pat_value (relative economic value) Coefficient	S.E.
Project size	# of inventors	0.0715***	0.016	0.090***	0.019
	# of applicants	-0.092	0.056	0.039	0.066
Basic inventor	Female	0.253	0.239	-0.275	0.302
characteristics	Age	0.021***	0.006	0.016**	0.007
	Tenure	0.001	0.006	0.003	0.007
Educational	High school diploma	-0.091	0.118	0.199	0.130
background	Two-year college	0.087	0.123	-0.066	0.153
(base: college grad)	Master degree	0.248***	0.071	0.089	0.080
	Ph.D	0.312***	0.108	0.436***	0.127
Affiliation	Big firm	0.508***	0.087	-0.163	0.106
	Belong to R&D unit	0.506***	0.086	-0.016	0.105
Objective	New business line	0.577***	0.088	0.165	0.106
(base: reinforcing	Reinforcing core business	0.081	0.075	0.120	0.090
non-core business)	Reinforcing technology base	-0.180	0.129	-0.239	0.151
Scope	Basic research	0.239***	0.078	0.185**	0.093
	Applied research	0.260***	0.062	0.192***	0.070
	Technical service	-0.161*	0.097	0.127	0.124
Motivation	Seeds oriented	0.291***	0.072	-0.004	0.084
(base: needs-oriented)	Exploration of seeds	0.077	0.097	0.055	0.110
Type of invention	Product	-0.097	0.074	-0.229***	0.089
	Method	-0.311***	0.080	-0.262***	0.094
Sources of	Science	0.186***	0.033	0.279***	0.039
motivation	Challenge	0.108**	0.043	0.268***	0.055
	Org_performance	0.046	0.033	0.002	0.042
	Career	0.009	0.036	0.032	0.045
	Reputation	-0.005	0.038	0.120***	0.045
	Benefit	0.111***	0.036	0.020	0.042
	Money	0.025	0.034	-0.015	0.041
# of observations		4,483		3,274	
Prob > χ^2		0.000		0.000	
Pseudo R^2		0.058		0.054	

*, ** and *** indicate significance levels of 10%, 5%, and 1% respectively. Dummies for US technology classes are not reported.

Table 3 Ordered Logit Regressions

Dependent variables: motivational factors

	Science	**Challenge**	**Org. Perf.**	**Career**	**Reputat'n**	**Environ't**	**Money**
# of inventors	0.006	-0.028	**0.076*** **	0.026	0.022	**0.068*** **	-0.021
Age	0.019*	**0.027*** **	-0.005	-0.004	0.006	**0.030*** **	-0.013
High school graduate	-0.011	-0.191	**-0.390** **	**0.386*** **	-0.036	0.107	-0.204
Ph.D	0.282*	-0.004	0.079	-0.005	0.218	0.072	-0.111
R&D division	**0.536*** **	**0.324** **	0.008	**0.244** **	**0.233** **	**0.529*** **	0.107
New business line	**0.392*** **	0.246*	-0.010	**0.316*** **	**0.229** **	**0.367*** **	0.130
Core business	**0.407*** **	**0.304*** **	0.174*	**0.215** **	**0.279*** **	-0.017	0.103
New technology base	**0.330** **	-0.039	**-0.439*** **	-0.047	-0.067	0.176	0.047
Basic research	**0.668*** **	**0.432*** **	0.043	0.050	-0.034	**0.307*** **	-0.045
Comm. of new seeds	**0.467*** **	0.044	-0.027	0.107	0.162*	0.172*	0.139
Explor. of tech seeds	**0.336** **	0.242*	-0.189	0.035	0.145	0.008	0.017
Firm size =ln(sale)	**0.084*** **	0.029	0.024	**0.059** **	0.024	**0.067** **	**0.081*** **
Capital Intensity	-0.337	-0.251	**0.976** **	0.376	0.060	0.159	-0.681*

The similar control variables as used in Table 3 plus financial information from other sources are included but most of those without significant coefficients are omitted. ***, **, and * indicate significant level at 1%, 5%, and 10%, respectively.

Table 4 Ordered Logit Estimates of Inventor Productivity

Dependent Variable	Size_pat		Dom_pat_value	
	(1)	**(2)**	**(3)**	**(4)**
Number of inventors	0.0737***	0.0639***	0.0910***	0.0745***
	(0.0156)	(0.0157)	(0.0187)	(0.0192)
Age	0.0217***	0.0220***	0.0166***	0.0152**
	(0.0056)	(0.0058)	(0.0063)	(0.0066)
PhD	0.2962***	0.1325	0.4319***	0.2348*
	(0.1075)	(0.1100)	(0.1257)	(0.1283)
Working in a big firm	0.5121***	0.4858***	-0.1765***	-0.1880*
	(0.0861)	(0.0884)	(0.1044)	(0.1083)
Belong to R&D division	0.4311***	0.3833***	0.0036	0.0316
	(0.1051)	(0.1063)	(0.1231)	(0.1260)
New business line	0.5890***	0.5454***	0.2039*	0.2206**
	(0.0874)	(0.0889)	(0.1050)	(0.1059)
Basic research	0.2537***	0.1762**	0.2064**	0.1395
	(0.0774)	(0.0800)	(0.0921)	(0.0930)
Applied research	0.2701***	0.2238***	0.2136***	0.1881***
	(0.0610)	(0.0620)	(0.0697)	(0.0707)
Motivation: Science	**0.2548***	**0.1931***	**0.3938***	**0.3696***
	(0.0298)	**(0.0310)**	**(0.0343)**	**(0.0365)**
Co-inventors from universities, etc.		-0.5176***		0.1453
		(0.1936)		(0.2522)
Cooperation with universities, etc.		0.4519***		0.0892
		(0.1281)		(0.1500)
Importance of science literature in getting idea		0.1084***		-0.0020
		(0.0193)		(0.0231)
Published the discovery in journals		0.4077***		0.7693***
		(0.0842)		(0.0978)
Pseudo R-squared	0.0546	0.0616	0.0475	0.0571
# of Observations	4522	4453	3306	3244

Other independent variables omitted include number of applicants, gender, tenure, and other educational background of surveyed inventor, types of employers, and other project characteristics. Robust standard errors are in the parentheses. *, ** and *** indicate significance levels of 10%, 5%, and 1% respectively.

Table 5 What firms introduce monetary rewards that are effective?

		Logit for grouped data Dep. Var.: Incentv			Treatment effect model (endogenous dummy var.) Dep. Var.: Incentv Maximum Likelihood Est.					
					2nd stage dep. var.: lnnum_pat			2nd stage dep.var.: econ_val_dom		
		Number of obs = 3586 Wald chi2(11) = 59.18 Prob > chi2 = 0.0000 Log pseudolikelihood = -1937.69 Pseudo R2 = 0.0156			Number of obs = 3056 Wald chi2(61) = 712.43 Prob > chi2 = 0.0000 Log pseudolikelihood = -6209.86			Number of obs = 2235 Wald chi2(61) = 621.59 Prob > chi2 = 0.0000 Log pseudolikelihood = -4077.90		
	Variable	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
Firm age	fage	0.011	0.006	*	0.007	0.004	*	0.012	0.005	***
Asset	lnasset	0.118	0.043	***	0.048	0.026	*	0.040	0.029	
Patent & utility model	ln1patutil	-0.023	0.030		0.001	0.018		0.008	0.021	
Science (normalized)	m_sci	-0.514	0.103	***	-0.252	0.031	***	-0.274	0.034	***
Instrumental variables for treatment effect model										
Debt asset ratio	debtasset	0.075	0.237		-0.301	0.170	*	-0.317	0.159	**
Foreign ownership	fo	0.000	0.001		0.000	0.000		0.000	0.000	
Parent company ownership	parent	0.000	0.000		0.000	0.000		0.000	0.000	
Corporate secrecy in other firms	oth_corp_secr				-0.092	0.077		-0.007	0.086	
Other variables used in logit for grouped data										
Sales abroad	abroad	0.687	0.210	***						
Female employee ratio	female_ratio	1.118	0.405	***						
Importance of first mover advantage	r_d_fma	0.224	0.120	*						
Importance of corporate secrecy	corp_secr	0.057	0.098							

Note. * significant at 10%, ** significant at 5%, *** significant at 1%

Robust standard errors are reported.

Table 6 Treatment Effect Model (Maximum Likelihood Estimation)

		Treatment effect model (structural equation) Maximum Likelihood Estimation					
		Dep. Var.: lnnum_pat			Dep.Var.: pat_val		
		Number of obs = 3056 Wald chi2(61) = 712.43 Prob > chi2 = 0.0000 Log pseudolikelihood = -6209.86			Number of obs = 2235 Wald chi2(61) = 621.59 Prob > chi2 = 0.0000 Log pseudolikelihood = -4077.90		
	Variable	Coef.	Std. Err.		Coef.	Std. Err.	
# of inventors	n_inventors	0.038	0.012	***	0.046	0.013	***
Female (=1)	gender	0.156	0.151		0.136	0.162	
Age	age	0.008	0.005		0.007	0.005	
Tenure	tenure	0.005	0.005		0.005	0.005	
High school grad	high	-0.230	0.087	***	0.038	0.084	
Two-year college grad	col2	0.014	0.092		0.115	0.092	
Master	master	0.130	0.050	***	0.093	0.044	**
PhD	phd	0.202	0.088	**	0.226	0.074	***
Firm age	fage	0.000	0.004		-0.004	0.003	
Asset	lnasset	0.076	0.034	**	-0.033	0.024	
Patent & utility model	ln1patutil	-0.007	0.019		0.002	0.018	
Working in R&D unit	blng_RD	0.311	0.062	***	0.073	0.051	
New business	new_business	0.405	0.077	***	0.128	0.057	**
Core business	core_business	0.120	0.052	**	0.154	0.051	***
New technology base	long_tech	0.088	0.092		-0.018	0.089	
Basic research	basic_r	0.171	0.059	***	0.116	0.053	**
Development	develpmnt	0.098	0.056	*	0.043	0.047	
Technical service	tech_srvc	-0.005	0.066		0.020	0.063	
Product	product	-0.068	0.057		-0.147	0.050	***
Method	method	-0.165	0.063	***	-0.159	0.058	***
Science (normalized)	m_sci	0.206	0.029	***	0.236	0.029	***
Monetary Incentive	**Incentv**	1.563	0.134	*******	1.522	0.120	*******

Note. * significant at 10%, ** significant at 5%, *** significant at 1%
Robust standard errors are reported.

Table 7 Are Science and Money substitutes?

		Ordered Logit Estimation											
		Dep. Var.: size_pat						Dep.Var.: pat_val					
		Incentv==1			**Incentv==0**			**Incentv==1**			**Incentv==0**		
		Number of obs = 708 Wald chi2(61) = 165.75 Prob > chi2 = 0.0000 Log pseudolikelihood = -943.23 Pseudo R2 = 0.0748			Number of obs = 2425 Wald chi2(62) = 329.14 Prob > chi2 = 0.0000 Log pseudolikelihood =-3132.43 Pseudo R2 = 0.0493			Number of obs = 532 Wald chi2(60) = 1101.12 Prob > chi2 = 0.0000 Log pseudolikelihood = -639.60 Pseudo R2 = 0.0740			Number of obs = 1757 Wald chi2(62) = 195.42 Prob > chi2 = 0.0000 Log pseudolikelihood =-2127.29 Pseudo R2 = 0.0420		
	Variable	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
# of inventors	n_inventors	0.038	0.012	***	0.068	0.022	***	0.123	0.055	**	0.097	0.026	***
Female (=1)	gender	0.156	0.151		0.404	0.332		0.654	0.646		0.229	0.355	
Age	age	0.008	0.005		0.015	0.009	*	0.041	0.028		0.008	0.012	
Tenure	tenure	0.005	0.005		0.006	0.009		0.003	0.028		0.011	0.011	
High school grad	high	-0.230	0.087	***	-0.342	0.170	**	-0.095	0.413		0.193	0.183	
2-y college grad	col2	0.014	0.092		0.219	0.169		-0.079	0.562		0.051	0.214	
Master	master	0.130	0.050	***	0.210	0.098	**	0.406	0.225	*	0.140	0.116	
PhD	**phd**	**0.202**	**0.088**	**	**0.381**	**0.147**	***	**-0.042**	**0.370**		**0.627**	**0.187**	***
Firm age	fage	0.000	0.004		0.005	0.006		0.003	0.014		0.000	0.007	
Asset	lnasset	0.076	0.034	**	0.145	0.040	***	0.019	0.096		-0.071	0.046	
Patent & utility model	ln1patutil	-0.007	0.019		-0.014	0.029		0.000	0.077		0.026	0.032	
Working in R&D unit	blng_RD	0.311	0.062	***	0.650	0.126	***	0.405	0.324		0.130	0.155	
New business	new_business	0.405	0.077	***	0.563	0.120	***	0.205	0.312		0.289	0.148	*
Core business	core_business	0.120	0.052	**	0.153	0.100		0.487	0.291	*	0.248	0.123	**
New technology base	long_tech	0.088	0.092		-0.132	0.192		0.277	0.473		-0.177	0.233	
Basic research	basic_r	0.171	0.059	***	0.332	0.110	***	0.249	0.271		0.261	0.136	*
Development	develpmnt	0.098	0.056	*	0.204	0.094	**	-0.040	0.217		0.137	0.107	
Technical service	tech_srvc	-0.005	0.066		0.062	0.136		0.069	0.320		0.036	0.167	
Product	product	-0.068	0.057		-0.129	0.101		-0.615	0.251	**	-0.256	0.119	**
Method	method	-0.165	0.063	***	-0.269	0.108	**	-0.924	0.258	***	-0.134	0.124	
Science (normalized)	**m_sci**	**0.206**	**0.029**	***	**0.191**	**0.051**	***	**0.097**	**0.130**		**0.245**	**0.059**	***

Note. * significant at 10%, ** significant at 5%, *** significant at 1%
Robust standard errors are reported.