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Employees' Invention Compensation Plan as a Determinant of Patent Quality and Quantity:

Findings of Inventor Survey in Korea*

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Contents

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Abstract

The current paper attempts to explore the employees' inventor compensation plan in Korea using a comprehensive data set of Korean inventor survey in 2009. It aims to empirically examine the effect of the compensation plan on the innovations of Korean inventors. This paper finds that the compensation plan has a positive link with inventors' performance; in particular, the high rate of compensation increases the quality of innovation. Furthermore, this paper extends its discussion to non-monetary compensation types as well as monetary compensation. By examining the inventors' various preferences for invention compensation, we find that the inventors of the private firms with greater preference for monetary compensation produce more patents, whereas those with greater preference for advantages in career produce more valuable patents. Second, inventors employed in public organizations with preferences for self-satisfaction by technical proof are more likely to conduct research on more advanced and challenging technologies. This implies that employees' invention compensation plan has room for further discussion on the types of non-monetary as well as monetary compensation.

Keywords

Inventor survey, employees' invention regulation, monetary compensation, non-monetary compensation, patent

I. Introduction

The invention productivity of inventors is heterogeneous (Harhoff and Hoisl, 2007). In particular, the most crucial inventions tend to be created by a few inventors. Personal factors such as experiences and age may explain the diversity in invention productivity (Harhoff and Hoisl, 2007). Furthermore, institutional factors can also affect productivity. Employees' invention regulation is such an institution that encourages inventors' motivation for inventing and leads to creative inventions (Harhoff and Hoisl, 2007).

As economies grow and technologies become complex, developing new technologies is unfeasible without large-scale research facilities, human resources, or enormous financial support. As a result, most of the inventions are those of employees, whereas few are individual or free inventions. In the case of Korea, the share of employees' inventions has increased. In 2005, the proportion reached 84.6%. Accordingly, the employees' invention system began to draw much attention in Korea.

Korea introduced related provisions in the Patent Law since its enactment in 1961.[1)] Nevertheless, the employees' invention system only started to draw attention in Korea in the 2000s. Many began to recognize that the employees' invention system should necessarily offer inventors more incentives to create more innovations. With such recognition, the Korean patent policy has directed to reinforce the compensation plan for the employees' inventions. The logic behind this move suggests that strengthening the links between compensation and innovative performance increases the effectiveness of inducing inventors' efforts (Zegner and Lazzarini, 2004, p.331). Finally, as of 2006, a new amendment to the

1) The authors consider the Patent Law revised in 1961 as the foundation of the present Patent Law in Korea

Invention Promotion Law integrated all provisions on employee inventions partly stipulated in the Patent Law and the Invention Promotion Law.

However, to our knowledge, no empirical research has been made to examine the effect of the compensation plan on the innovations in Korea. Therefore, we would empirically examine whether the compensation plan has a positive link with inventors' performance, as it has originally intended. Furthermore, the discussion on employees' invention compensation has been restricted to the monetary compensation. Nevertheless, surveys found that inventors also prefer other types of compensation aside from monetary incentives. In this regard, we would address whether other compensation types would be as effective as the monetary form.

The current paper is organized as follows. Section II describes the employees' invention system in Korea. Section III provides a review of related literature. Data and hypotheses are presented in Section IV. Section V presents survey evidence through descriptive analysis. Section VI discusses the variables, model specification, and empirical results. Lastly, Section VII concludes the paper.

II. Employees' Invention Regulation in Korea

Prior to the revision of the Patent Law as of 2006, it included employees' invention-related provisions. The employees' invention-related provisions in the former Patent Law (Article 39 and Article 40) were formerly the foundation for the employees' invention system. The Law stipulated that employee inventions basically belong to the inventors who created them. Further, the Invention Promotion Law (Articles 8-14) stipulated the supplementary details of employee inventions

However, the Laws did not stipulate reasonable criteria for the compensation plan. As a result, several disputes between employer and employees arose in Korea. As Harhoff and Hoisl (2007) pointed out, disputes between employer and employee-inventor could arise due to "delay in payment, intransparent calculation of remuneration, and unfair allocation of remuneration between co-inventors (p.1150)." In Korea, disputes happened because inventors were not compensated. In addition, the related law was not unified because both the Patent Law and the Invention Promotion Law included employees' invention-related provisions. For these reasons, various circles had requested a revision on the employees' invention system.

In 2001, revising the Patent Law and its enforcement ordinance was first attempted, but ultimately failed. The attempted revision had included the Article stating that the minimum compensation standard required the payment of 15% of the net income arising from the employees' invention; however, the drafted law was rejected. Later, the employees' invention drew more attention, and a new proposal was worked out. Finally, after the minimum compensation standard was excluded from the new draft, a new amendment to the Invention Promotion Law could have integrated all provisions on employee inventions partly stipulated in the Patent Law and the Invention Promotion Law. As of March 2006, the partially revised Invention Promotion Law was promulgated (Law 7869) and the Law was enforced in September 2006.

The revised Invention Promotion Law was amended to regard any standards for compensation of employee inventions as "reasonable remuneration" if the employer and the employee agreed on such compensation (the Invention Promotion Law Article 15(2)). Prior to the revised Act as of September, 2006, the amount of "reasonable compensation" was unilaterally determined by the court in the case of

compensation disputes between employer and employee-inventor.

Prior to the revision, the former Law (the Patent Law Article 40(2)) only contained the phrase, "the amount of compensation." This implies that the Law only considered the monetary or economic compensation. However, preference of the inventors is not limited to monetary compensation. Obviously, the inventors also tend to prefer non-monetary incentives such as research fellowship programs or career development programs. Thus, the newly revised Invention Promotion Law enabled each firm to voluntarily decide the type of compensation, whether monetary or non-monetary compensation, in overall consideration of the internal circumstances and employees' compensation preference. In other words, when the employers make the compensation criteria in consultation with their employees, they have to decide the type of compensation – either monetary or non-monetary compensation, or both – and determine the criteria for calculating the amount of compensation, etc.

Given that employees' invention regulations aim to not only provide employees with incentives for creative inventions, but also to induce employers' active investment, creating a balance between employer and employee is important. Employers would induce active investment when they can surely obtain and effectively utilize employees' inventions. To this end, the rules aim to reasonably allocate profits between employers who provided R&D investment and facilities, and employees who made creative inventions. The revised Law has newly set up the Article that obliges the inventor to report all inventions to the employer (the Invention Promotion Law, The Article 10). Before the revision, in the case of firms without their own employees' invention plan, those firms were likely to lose core human resources and leak the crucial technology after the completion of work-related inventions, considering employees had no obligation to report this. Now, with the implementation of the revised Law, the employer can easily

recognize the employees' inventions and claim their rights to the inventions made in the course of the employees' normal work.

III. Literature Review

Do employees' invention compensation plans increasingly induce the efforts of employee-inventors and enhance R&D performance? In countries such as Germany, the Employees' Invention Acts have been the subject of controversy, particularly their capacity to properly compensate employees for their creativity and inventions, consequently enhancing the invention productivity and its value by motivating inventors (Harhoff and Hoisl, 2007). Some researchers pointed out that this rule could lower the patent quality by inducing the strategic behaviors of inventors and firms, which may be harmful to innovation incentives (Harhoff and Hoisl, 2007, p.1144).

Nevertheless, Harhoff and Hoisl (2007) positively assessed the German Employees' Invention Act with caution. They noted that the majority of inventors viewed the compensation system positively, but an improvement or reform might also be necessary. Other studies also empirically found that the implementation of monetary incentives tends to induce more innovative output (e.g., Zenger and Lazzarini, 2004, Lerner and Wulf, 2007). There have been attempts to discern the impact of different types of monetary compensation on innovations (Lerner and Wulf, 2007) and to investigate the differential impact of R&D incentives by the firms' size on innovation (Zegner and Lazzarini, 2004).

Owan and Nagaoka (2008) examined the impact of an inventor's motivations on inventor productivity, and the interaction between intrinsic and extrinsic motivations using survey data of Japanese inventors in 2007. They found that both satisfaction derived from contributing to science and

technology and interest in solving challenging technical problems are important determinants of inventor productivity. However, they also found that monetary rewards crowd out the abovementioned motivations.

Lerner and Wulf (2007) investigated the impact of the shifting compensation of corporate R&D heads. They found that more long-term incentives (such as stock options and restricted stocks) were associated with more heavily cited patents, more patents awards, and patents of greater originality. Short-term incentives appeared to be unrelated to measures of innovation. Nonetheless, the current paper is limited to the various types of monetary compensations or incentives. Zegner and Lazzarini (2004) tested for size-related differences in incentives and outcomes using survey responses from a random sample of 352 electronic engineers in the Silicon Valley and Route 128 areas. They noted that small firms enjoyed advantages over large firms that implemented effective, incentive-intensive employment contracts, which lured top engineering talent and induced highly motivated efforts. However, they found more limited support for size-related differences in the resulting incentive outcomes.

The present paper empirically examines the impact of employees' invention compensation plan on inventors' innovation output. Further, it extends the discussion to the non-monetary types of compensation to test their impact on inventors' innovative performance. Ultimately, it aims to assess how the plan has been actually operated and to provide policy implications. In sum, this paper analyzes the following: (1) the impacts of employees' invention compensation plan on inventors' patent; (2) the impacts of the different preferences of the inventors across compensation types on their patent.

IV. Data and Hypotheses

The data were collected from the inventor survey of Korea conducted in 2009 (Ryu et al, 2009). In the survey, we asked the first inventors to select the most important employee patent among their patent applications in 2005 or 2006. Thus, one inventor replied to one questionnaire. Unless the first inventor was a main contributor to the patent, the second inventor or the inventor with the most contributions was allowed to answer the questionnaire. The survey questionnaire primarily benchmarked the PatVal-EU Survey[2] questionnaire.

<Table 1> Distribution of total responses

		Organizations				
		Large firms	Small firms	Univ.	PRI	Total
Tech. Class	I Electrical Engineering	192	87	53	73	405
	[Share (%)]	[18.0%]	[8.2%]	[5.0%]	[6.8%]	[38.0%]
	II Instrument	41	32	20	31	124
	[Share (%)]	[3.8%]	[3.0%]	[1.9%]	[2.9%]	[11.6%]
	III Chemistry	52	55	66	40	213
	[Share (%)]	[4.9%]	[5.2%]	[6.2%]	[3.7%]	[20.0%]
	IV Mechanical Engineering	117	53	26	50	246
	[Share (%)]	[11.0%]	[5.0%]	[2.4%]	[4.7%]	[23.1%]
	V Others	22	40	8	9	79
	[Share (%)]	[2.1%]	[3.7%]	[0.7%]	[0.8%]	[7.4%]
	Total	424	267	173	203	1,067
	[Share (%)]	[39.7%]	[25.0%]	[16.2%]	[19.0%]	[100.0%]

Note: The classification of industry follows the IPC-Technology Concordance Table, WIPO.

2) The PatVal-EU survey was a large scale survey of inventors located in France, Germany, Italy,

We selected a stratified sample of the inventors in proportion to the each stratum of technology class-organization. The stratified sample was drawn from the inventors' population who applied for patents during the 2005-2008 periods. As a result, the inventors of the firms accounted for 78.2%; particularly, large firms accounted for as high as 60.5%. On the other hand, the share of inventors from small and medium-sized enterprises (SMEs), universities, and public research institutes (PRI) was very low. In particular, many of the large firm inventors mostly belong to specific firms, thereby requiring us to reduce a potential bias against such specific firms. Considering the above reason, we increased the share of SMEs, universities, and PRI by 65%, and reduced the share of large firms to about 35% as shown in <Table 1>. The final responses totaled 1,067.

After the revision of the Invention Promotion Law in 2006, many Korean firms implemented compensation plans for employee inventions to comply with this Law. To evaluate the impact of the compensation plan, we set up a simple hypothesis that states that patents are positively affected by the employees' invention compensation plan (Hypothesis I).

Hypothesis I: The implemented compensation plan increases inventors' patents.

Furthermore, another hypothesis can be established, indicating that the simple existence of the compensation plan would not provide such incentives to generate qualitatively excellent patents for inventors. Rather, the high compensation rate would be more effective in inducing valuable patents (Hypothesis II). Under such compensation plan, inventors can be more compensated if their patents make higher profits. Therefore, the

the Netherlands, Spain and the United Kingdom. It was conducted in 2003. The objective of the PatVal-EU survey was to "collect information on the economic value of the European patents, and on other aspects about the innovation process and its output that is not available from other sources (Giuri et al, 2007)"

inventors are encouraged to produce more valuable patents with an expectation of higher compensation.

Hypothesis II: The higher the compensation rate, the higher the value of patents.

One important consideration is that even as all inventors in the sample produced the patents, they are employed by different types of organizations. There are fundamental differences between the methods in which firms in the private sector and public research institutes or universities operate. Thus, employees' compensation for inventors may have differential effects in organizations with different innovation environments. For this reason, we test the above hypothesis by the organizations that the inventors belong to.

Furthermore, Korea's Inventors' Survey investigated both inventors' preferences for a series of compensation types for employees' inventions. The inventors were asked to check their preference for (1) monetary compensation, (2) advantages in careers reflected in promotion, performance, and evaluation, (3) privilege/reputation, (4) improvement in organizational performance, (5) self-satisfaction by technical proof, and (6) improvement in working environment (through compensation for employers). We use this question in examining the potential impact of different compensation types, that is, both monetary and non-monetary compensations. We would extend the discussion on the potential impact of the different types of compensation on innovative activities. If the preference for self-satisfaction with technical proof is more strongly associated with innovations, then the inventors would be more encouraged by the compensation plan to meet their preferences and induce them to innovate. The preferences for the compensation types would differ by organizations, given that the characteristics of the inventors and the environment for innovation likewise differ. We examine the compensation

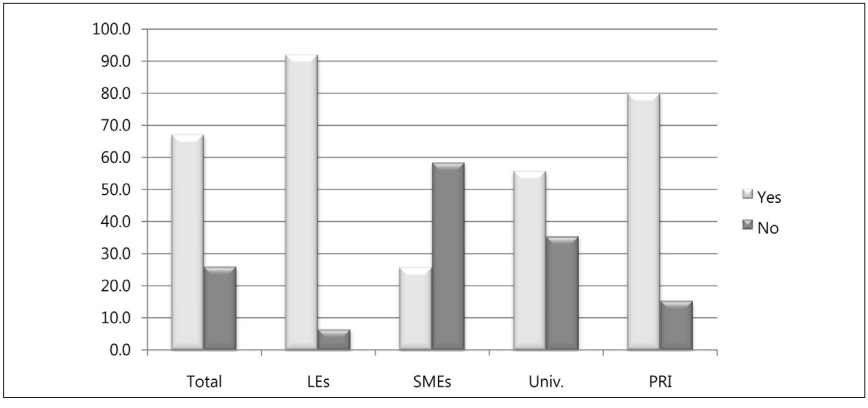
types that are more suitable to the organizations by referring to the inventors' preferences and how such various types affect the innovative activities. Thus, we establish the following hypothesis:

Hypothesis III: The compensation types that have effective impacts on patents will differ by the organizations the inventors belong to.

V. Descriptive Analysis: Survey Evidence

In addition to the questions that examine employees' invention compensation plan, inventor survey in Korea also inquired about the inventors' characteristics. The inventors who responded to the survey in 2009 were characterized as follows. The inventors had a high educational level–on average, 94% of the inventors in the sample had a university degree; 35.7% of these inventors pursued doctoral or postdoctoral studies. The distribution of PhDs largely varied across the types of organizations and technology fields. At the time of the survey, the average age of the inventors was 40 years. Inventors whose ages ranged from 30 to 40 years were most actively

<Figure 1> Employees' invention compensation plan (by organization)



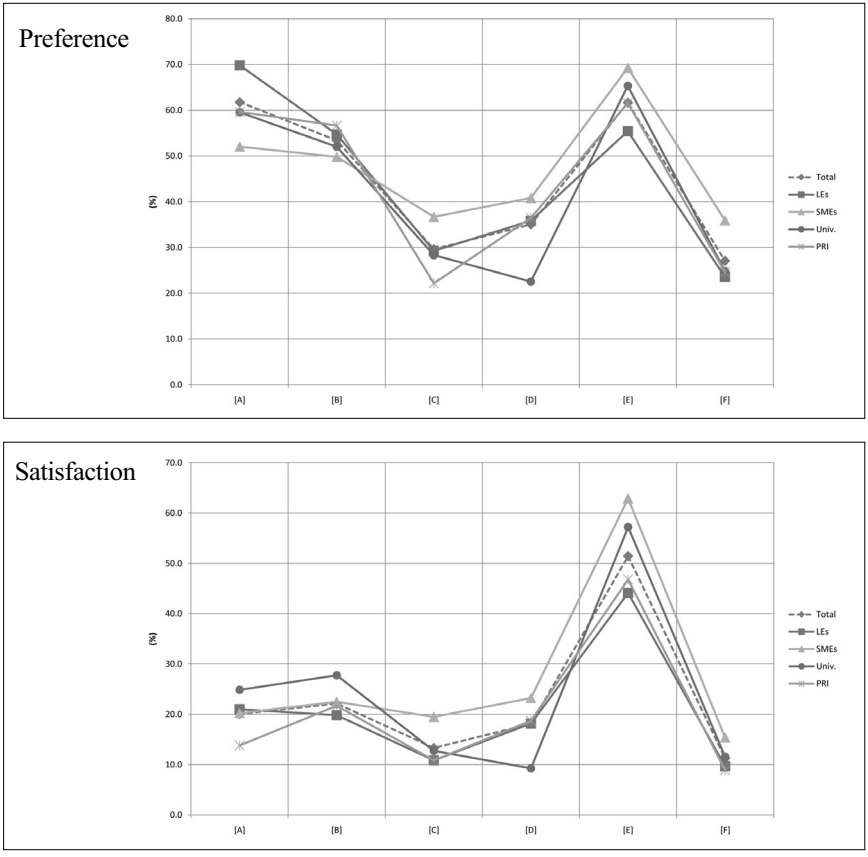
engaged in inventions. The mobility of the inventors was infrequent. Up to 73.6% of the inventors had never experienced turnover.

Regarding employees' invention compensation plans, the survey asked the inventors whether their organizations have implemented their own employees' invention compensation plans. The results are shown in <Figure 1>. A total of 67% of the inventors indicated that their organizations have implemented employees' invention compensation plans. However, the ratio of implementation of such plans varied across the type of organizations. In the case of large firms, 92% implemented the plans. On the other hand, in the case of SMEs, only 25.7% implemented the plans, indicating the SMEs' urgent need to implement a compensation plan for inventors. In the case of the public sector, 79.9% of public research institutes and 55.7% of universities have their own compensation plans for employees' inventions. This figure can be taken at face value. However, the inventors may also be possibly unaware of the employees' invention compensation plans, which, in fact, have been implemented already. This implies that the inventors are still insufficiently informed about the related compensation plans in their organizations.

Secondly, the survey asked about the preference for and satisfaction with the compensation types. The compensation types include (1) monetary compensation, (2) advantages in careers, which are reflected in promotion, performance, and evaluation, (3) privilege/reputation, (4) improvement in organizational performance, (5) satisfaction with technical solution, and (6) improvement in working environment (through compensation for employers). <Figure 2> shows Korean inventors' preferences and level of satisfaction across compensation types for inventions. The preferences for and level of satisfaction with the compensation types did not significantly vary across the types of organizations that employ the inventors. The inventors across organizations highly preferred monetary compensation.

However, their satisfaction with monetary compensation was not as high as their preference for monetary compensation. Up to 61.8% of the respondents preferred monetary compensation,[3] 61.7% preferred self-satisfaction in technical proof, and 53.4% signified their preference for advantages in

<Figure 2> Preference for and satisfaction with employees' invention compensation plan



Note: [A] Monetary compensation, [B] Advantages in careers, [C] privilege/reputation, [D] improvement in organizational performance, [E] self satisfaction by technical proof, [F] improvement in working environment (through compensation for employers)

3) Choo et al. (2008) also found that Korean inventors prefer the monetary compensation type the most. Advantages in their careers ranked second.

their careers through promotion, performance, or evaluation. On the other hand, the respondents were less likely to prefer privilege/ reputation (29.6%), improvement in organizational performance (29.6%), and improvement in working environment (by compensating employers) (27.1%).

However, their level of satisfaction was significantly different from their preferences. A total of 51.5% of the respondents were satisfied or very much satisfied with self-satisfaction with technical proof; 22.1% with advantages in their careers; 20.1% with monetary compensation; 18.1% with improvement in organizational performance; 13.3% with privilege/reputation; and 11.2% with improvement in working environment.

The difference in self-satisfaction with technical proof between satisfaction and preference was found to be the least, indicating that inventors were significantly motivated by and satisfied with observing their own technical ideas, whether these ideas were realized or not. On the other hand, the largest gap between preference and satisfaction appeared in monetary compensation and advantages in careers. The gaps were 41.7% and 31.3%, respectively, indicating that the actual compensations were not high enough to satisfy the inventors despite the strong preferences for monetary compensation and advantages in careers. Thus, the system has a potential to discourage motivations for inventions, different from the original intent to provide incentives for creative inventions. Examples include discontent among inventors and the potential compensation disputes between employers and inventors.

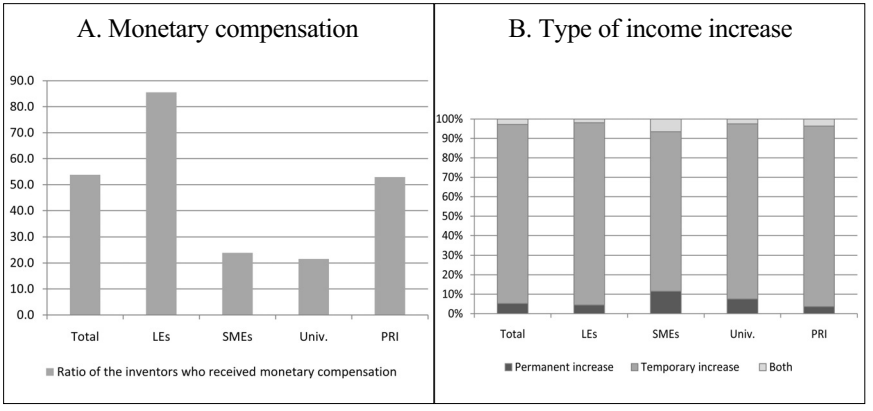
The low level of monetary compensation could be one reason for the poor satisfaction among inventors. In addition, the delay in compensation could also affect their level of satisfaction (Harhoff and Hoisl, 2007). Furthermore, in the case of German inventors, the criteria for calculating the compensation amount could be arbitrarily decided by the employers and could likewise induce dissatisfaction among the inventors. Moreover, if the

compensation was calculated in proportion to sales, radical innovations of which profitability could be initially very low and sharply increase later, were likely to have disadvantages in comparison with incremental innovations or the revision of existing technology (Harhoff and Hoisl, 2007). Moreover, the unfair allocation of compensation among co-inventors could be another reason for low satisfaction with monetary compensation.

<Figure 3A> shows the results for the question about the inventors' experience with monetary compensation from their inventions. Overall, 53.8% of the inventors responded to have experienced monetary compensation. Up to 85.5% of the inventors in large enterprises experienced monetary compensation. Meanwhile, 52.9% of the inventors in public research institutes, 23.9% in SMEs, and 21.6% in universities had such an experience. The low rate of inventors who experienced monetary compensation would be due to the relatively high rate of non-monetary compensation.

Next, the inventors who have been compensated due to their employees' inventions were asked how the monetary compensation affected the increase in their income. Specifically, they were asked whether their income

<Figure 3> Monetary compensation and type of income increase



Note: This question for the increased income type by monetary compensation is targeted for inventors having experiences with monetary compensation for their inventions.

permanently increased through "rising wage by promotion" or "gains from patent royalty," or whether it was temporarily increased through "bonuses," "cash prize," or "royalty or a similar type of income rise." As shown in <Figure 3B>, the ratio of temporary income gain was higher across the types of organizations. Only 8% of the total respondents experienced either a permanent income increase or both permanent or temporary income increase; 6.5% of the inventors in the large enterprises, 21.2% in the SMEs, 5.6% in the universities, and 6% in public research institutes experienced them. A relatively high ratio of inventors in SMEs received permanent income increase or both permanent and temporary income increase.

<Table 2> shows the ratio of monetary compensation to annual income

<Table 2> Ratio of monetary compensation to annual income

		Organizations				
		Total	LEs	SMEs	Universities	PRI
Less than 1%	No. of respondents	(337)	(242)	(20)	(13)	(62)
	Share (%)	58.7	65.1	30.3	36.1	62.0
1%~5%	No. of respondents	(145)	(84)	(24)	(12)	(25)
	Share (%)	25.3	22.6	36.4	33.3	25.0
5%~10%	No. of respondents	(31)	(13)	(8)	(5)	(5)
	Share (%)	5.4	3.5	12.1	13.9	5.0
More than 10%	No. of respondents	(34)	(13)	(13)	(4)	(4)
	Share (%)	5.9	3.5	19.7	11.1	4.0
No response	No. of respondents	(27)	(20)	(1)	(2)	(4)
	Share (%)	4.7	5.4	1.5	5.6	4.0
Average ratio of monetary compensation to annual income (%)		2.02	1.45	4.92	4.34	1.33

Note: The respondent base consists of inventors who received monetary compensation for their inventions. The shares of each column add up to 100%.

for the best patent among the patents that the inventor had applied for. This question was asked of the inventors who responded to have experienced monetary compensation in <Figure 3A>. Following Harhoff and Hoisl (2007) in our survey data, we measured the inventor's compensation as the compensation received for a particular patent divided by the annual income without inventor compensation. Up to 84% of the respondents were compensated with less than 5% of their annual income, indicating that the distribution of invention compensation has a right-skewed distribution. Rather, in most cases, the compensation appeared quite moderate from the inventor's perspective. The ratio of monetary compensation for the surveyed patent to annual income was at an average of 2.02% as presented in <Table 2>. It ranged from 0.1% to 80% of annual income.

The ratio of monetary compensation differed by organization. In the case of large enterprises and public research institutes, 65.1% and 62% of the respondents, respectively, were paid with less than 1% of the annual income. On the other hand, 19.7% of the respondents in SMEs and 11.1% of the respondents in universities answered that they were paid with more than 10% of their annual income. As a result, the average ratio of monetary compensation to annual income differed by organization. Only 1.45% of the annual income was paid on average in large enterprises; 1.33% on average in public research institutes; 4.92% on average in SMEs; and 4.34% on average in universities. We found that the compensation ratio to annual income in larger firms was smaller. However, Harhoff and Hoisl (2007) noted that this would reflect "differences in the organization of R&D – inventor teams in large firms may have more members, thus reducing each inventor's share (p.1157)."

VI. Empirical Analysis

VI.1. Variables

Using data from the inventor survey in Korea described above, we generated a number of variables for our empirical analysis. The variables can be described as follows:

- Patent value (PATVALUE): The variable for monetary value of Korean patents. The respondents were asked to indicate the value interval for their patent. The intervals were less than 100 thousand/100 thousand–1 million/1–5 million/5–10 million/10–50 million/50–100 million/100 million–1 billion/more than 1 billion (unit: Korean Won). This variable is used as a proxy for measuring patent quality, following Gambardella et al. (2008).
- Productivity of inventors (INVPROD): This measure was first proposed by Harhoff and Hoisl (2007). Inventor productivity adjusted for age. Following Harhoff and Hoisl (2007), the total number of Korean patent applications of the inventor is divided by age minus 25. This variable is a proxy for measuring patent quantity.
- Employees' invention compensation plan: Two measures are used in the analysis. First, PATSHARE indicates the ratio of compensation for the patent in question to annual income. Secondly, PATCOMP indicates whether the organizations implemented the employees' invention compensation plan.
- Preferences for employees' invention compensation: Preferences for six different types of compensations are used in the analysis, namely: (1) MON_PRE: preference for monetary compensation, (2) CAR_PRE: Preference for advantages in career such as promotion,

performance, and evaluation, (3) PRES_PRE: Preference for privilege/reputation, (4) ORG_PRE: Preference for improvement in organizational performance, (5) SELF_PRE: Preference for self-satisfaction by technical proof, and (6) ENV_PRE: Preference for improvement in working environment (by employer's compensation).

- Characteristics of inventors: (1) PhDs: this variable indicates the education level of the inventors. It is a dummy variable, indicating that the inventors had doctoral education; (2) AGE: the age of inventors; and (3) MOB_NOT_0: this is a dummy variable, indicating the inventor did not change to another employer.
- Invention process: (1) TARGET: a dummy variable indicating whether the inventions are the outcome of an R&D project or not, (2) INVENTORS: the number of inventors involved in the invention process.
- Control variables: (1) APPYEAR: the year dummy of patent applications, (2) TECHCLASS: five macro-technology classes, (3) FIRMSIZE: dummy variables for firm size classified with more than 250 employees, 100–250 employees, and less than 100 employees.

The summary statistics are presented in the appendix.

VI.2. Model specification

Our analysis primarily proceeds in two kinds. First, we estimate the impact of both employees' invention compensation plans (i.e., PATCOMP and PATSHARE) on both quantity and quality of patents; we use the following simple equations:

$$\Pr(y_i)=X_i\beta+Z_i\delta+\varepsilon_i \qquad (1)$$

In analyzing how theses compensation plan variables are related to the quality of patent, we employed an ordered probit as in (1). In (1), y_i is the interval variable for the inventor's self-evaluated value of a patent (PATVALUE); X_i includes the inventor/project/firm characteristics and technology class dummies; Z_i is either PATSHARE or PATCOMP, and ε_i is the error term.

$$y_i=X_i\beta+Z_i\delta+\varepsilon_i \qquad (2)$$

In analyzing the relationship between the quantity of patent and theses compensation plan variables, we employ OLS as in (2), where y_i is log of INVPROD. The same variables of X_i and Z_i are used for the analysis.

Next, in analyzing the impact of preferences for the compensation types on both patent quality and quantity, we maintain the same estimation framework, in which y_i and X_i are the same variables as in (1) and (2) above. Six preferences variables for compensation plans are simply used for Z_i.

VI.3. Empirical results

<Table 3> and <Table 4> present the empirical results supporting hypotheses I and II. Above all, the simple implementation of employees' invention compensation plan (PATCOMP) had a positive but statistically insignificant impact on patent value, PATVALUE (<Table 3> column 1). The same result applied to public and private sectors (<Table 3> columns 2 and 3). On the other hand, the ratio of monetary compensation to annual income (PATSHARE) had a positive and statistically significant impact on patent value when the total sample was analyzed (<Table 3> column 4). The statistically significant and positive impacts were also present when the

private and public sectors were analyzed separately (<Table 3> columns 5 and 6).

Next, the impact of the employees' invention compensation (PATCOMP) as a determinant of patent quantity (INVPROD) was analyzed

<Table 3> Impact of employees' invention compensation plan on patent quality

	Dependent variable: PATVALUE Estimation method: Ordered probit					
	(1) Total	(2) Private	(3) Public	(4) Total	(5) Private	(6) Public
PATCOMP	0.078 (0.804)	(0.843) 0.0369	0.11 (0.282)			
PATSHARE				**0.0262*** **(3.860)**	**0.0363*** **(3.593)**	**0.0202*** **(2.668)**
PhDs	0.262*** (2.699)	0.299** (2.434)	0.350** (1.965)	0.212 (1.582)	0.225 (1.331)	0.511** (1.986)
Log (INVENTORS)	-0.0432 (-0.474)	-0.0163 (-0.119)	-0.000722 (-0.00558)	0.0368 (0.238)	0.0988 (0.487)	0.18 (0.756)
Log(AGE)	0.877*** (3.680)	1.140*** (3.723)	0.536 (1.263)	1.170*** (3.535)	1.443*** (3.597)	1.113* (1.687)
MOB_NOT_0	0.0223 (0.205)	0.0545 (0.447)	-0.0957 (-0.358)	0.0251 (0.182)	0.0695 (0.456)	-0.411 (-1.221)
TARGET	0.0681 (0.928)	0.0506 (0.576)	0.104 (0.771)	0.0857 (0.886)	0.0791 (0.735)	0.102 (0.420)
Tech dum.	Yes	Yes	Yes	Yes	Yes	Yes
Firm size dum.	Yes	Yes	Yes	Yes	Yes	Yes
Year dum.	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	972	643	329	537	407	130
L.L.	-1606.53	-1050.1	-541.84	-916.83	-684.17	-217.9
Wald chi2	71.804	64.515	13.791	50.285	46.712	31.842
prob>chi2	0	0	0.314	0	0	0.001

Note: Robust standard errors are used; robust z-statistics in parentheses,
*: significant at 10%, **: significant at 5%, ***: significant at 1%.

in <Table 4>. The mere implementation of the compensation plan had a positive impact on the patent quantity of the inventors across sectors (<Table 4> columns 1, 2, and 3). In contrast, the ratio of monetary compensation to annual income (PATSHARE) had no positive impact on

<Table 4> Impact of employees' invention compensation plan on patent quantity

	Dependent variable: log of INVPROD Estimation method: OLS					
	(1) Total	(2) Private	(3) Public	(4) Total	(5) Private	(6) Public
PATCOMP	**0.317*** **(3.595)**	**0.256**** **(1.974)**	**0.323**** **(2.522)**			
PATSHARE				-0.002 (-0.175)	0.0009 (0.091)	-0.00863 (-0.485)
PhDs	0.195** (2.216)	0.192* (1.710)	0.341** (2.234)	0.163 (1.294)	0.193 (1.242)	0.263 (1.082)
Log (INVENTORS)	0.0704 (0.920)	0.148 (1.385)	-0.00694 (-0.0623)	0.0635 (0.490)	0.221 (1.450)	-0.291 (-1.376)
Log(AGE)	-1.613*** (-7.402)	-1.449*** (-5.273)	-1.849*** (-4.839)	-1.749*** (-5.681)	-1.809*** (-5.268)	-1.247* (-1.821)
MOB_NOT_0	0.0671 (0.722)	-0.0209 (-0.208)	0.498** (2.246)	-0.0126 (-0.109)	-0.0971 (-0.820)	0.588 (1.611)
TARGET	-0.0562 (-0.814)	-0.125 (-1.521)	0.105 (0.823)	0.0141 (0.157)	0.0279 (0.287)	-0.0738 (-0.349)
Tech dum.	Yes	Yes	Yes	Yes	Yes	Yes
Firm size dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Constant	4.957*** (5.993)	4.441*** (4.195)	5.696*** (4.020)	5.750*** (5.068)	5.962*** (4.664)	4.005 (1.586)
Observations	981	652	329	540	412	128
R-squared	0.217	0.219	0.179	0.145	0.122	0.211

Note: Robust standard errors are used; robust t-statistics in parentheses,
*: significant at 10%, **: significant at 5%, ***: significant at 1%.

patent quantity (INVPROD). The same results were found when the total sample, public sector sample, and private sector sample were analyzed (<Table 4> columns 4, 5, and 6).

Thus, the empirical results supported the employees' invention compensation plans despite some disputes arising in the real world. Notwithstanding criticisms that a large portion of patents are useless due to the low quality, the empirical results provided some implications that, in a broader sense, require the design of the employees' invention compensation plan to increase the rate of compensation and induce more valuable patents.

However, cautious interpretation of the empirical results is necessary due to endogeneity. In other words, the higher the compensation rate, the higher the patent value. Simultaneously, the higher the patent value, the higher the ratio of monetary compensation to annual income. Considering that we measure PATSHARE as the ratio of compensation received for a particular patent to the annual income, the compensation rate depends mostly on the invention's value. To resolve this problem, instrumental variables should be used, but further research on such method needs to be conducted.

Next, we discuss inventors' preference for various compensation types. <Table 5> shows the analysis of the impact of preference for each type of employees' invention compensation on the quality and quantity of patents. Among the types, the preference for advantages in career (CAR_PRE), self-satisfaction by technical proof, (SELF_PRE), and improvement in working environment by compensation for the employers (ENV_PRE) were found to be the statistically significant determinants of patent quality (PATVALUE) when the total sample was analyzed (<Table 5> column 1). However, their signs are different: CAR_PRE (+), SELF_PRE (+), and ENV_PRE (-). Interestingly, despite the high ratio of the inventors whose answers revealed a high preference for monetary compensation, the preference for monetary compensation did not have statistically significant

<Table 5> Impact of preference for employees' invention compensation on patent

Dependent variable	PATVALUE Ordered Probit			Log of INVPROD OLS		
	(1) Total	(2) Private	(3) Public	(4) Total	(5) Private	(6) Public
MON_PRE	-0.00519	-0.0112	-0.00826	**0.0594***	**0.0945****	-0.0112
	(-0.146)	(-0.242)	(-0.146)	**(1.812)**	**(2.333)**	(-0.206)
CAR_PRE	**0.0880****	**0.0977***	0.0705	-0.0247	-0.0471	0.00195
	(2.246)	**(1.936)**	(1.111)	(-0.658)	(-0.976)	(0.0329)
PRES_PRE	-0.00782	-0.0093	0.00278	0.0346	0.0158	0.0896
	(-0.197)	(-0.186)	(0.042)	(0.880)	(0.322)	(1.342)
ORG_PRE	0.024	0.0605	-0.0757	0.00155	0.00730	-0.0634
	(0.529)	(1.056)	(-0.902)	(0.0356)	(0.137)	(-0.825)
SELF_PRE	**0.0925****	0.0623	**0.169*****	0.0232	0.0163	0.0452
	(2.482)	(1.327)	**(2.674)**	(0.691)	(0.388)	(0.767)
ENV_PRE	**-0.0676***	-0.0657	-0.0393	-0.0289	-0.0239	-0.0146
	(-1.663)	(-1.230)	(-0.602)	(-0.735)	(-0.484)	(-0.229)
PhDs	0.233**	0.286**	0.323*	0.197**	0.195*	0.408***
	(2.548)	(2.453)	(1.894)	(2.342)	(1.806)	(2.769)
Log (INVENTORS)	-0.00277	0.00293	0.0542	0.0288	0.128	-0.0502
	(-0.0325)	(0.022)	(0.459)	(0.378)	(1.144)	(-0.490)
Log(AGE)	0.823***	1.179***	0.195	-1.656***	-1.515***	-1.980***
	(3.683)	(4.138)	(0.480)	(-8.088)	(-5.875)	(-5.470)
MOB_NOT_0	0.0253	0.0781	-0.126	0.0763	-3.30e-05	0.447**
	(0.232)	(0.645)	(-0.471)	(0.835)	(-0.000332)	(2.139)
TARGET	0.0813	0.0847	0.078	-0.0526	-0.119	0.118
	(1.160)	(1.006)	(0.595)	(-0.793)	(-1.511)	(0.936)
Constant				5.089***	4.476***	6.237***
				(6.567)	(4.509)	(4.679)
Tech dummy	Yes	Yes	Yes	Yes	Yes	Yes
Firm size dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	1041	690	351	1049	697	352
R-squared				0.213	0.234	0.164

L.L.	-1692.3	-1104.37	-569.94
Wald chi2	101.429	82.396	27.944
prob>chi2	0	0	0.046

Note: Robust standard errors are used; column (1)-(3): robust z-statistics in parentheses; column (4)-(6): robust t-statistics in parentheses;
*: significant at 10%, **: significant at 5%, ***: significant at 1%.

impacts on patent value across organizations.

Furthermore, the determinants of patent value differed by organization. In the private sector, the preference for advantages in career (CAR_PRE) had a positive and statistically significant impact on patent value (<Table 5> column 2). On the other hand, in the public sector, the preference for self-satisfaction with technical proof (SELF_PRE) had a positive and statistically significant impact on patent value (<Table 5> column 3).

The empirical results on patent quantity (INVPROD) were different from the previous results for patent quality (PATVALUE). Notably, the preference for monetary compensation (MON_PRE) had a positive and statistically significant impact on patent quantity (INVPROD) in the private firms (<Table 5> column 5). This result indicated that the inventors in the private firms, who prefer monetary compensation, tend to apply for more patents than those who expressed a greater preference for other compensation types.

Overall, the results can be summarized and some implications could be inferred. First, the inventors of the private firms, who have greater preference for monetary compensation, produce more patents, whereas those with greater preference for advantages in career produce more valuable patents. In general, technologically advanced or radical inventions are unlikely to make profits shortly due to various reasons. For example, the market for new innovations is not yet formed, and no demand for the technology would exist after the innovation is produced. Furthermore, it

would take a longer time for the products adopting the very innovations to become commercialized. In such cases, the compensation contingent on the profits would not be as high as the compensation that the inventors can receive from the incremental innovations. By applying for the existing knowledge or technology, the incremental innovations can accelerate the process of development and commercialization. Thus, the more incremental innovations, the more compensation the inventors would receive due to the increasing profits from the related products. This would explain why the inventors who prefer monetary compensation produce more patents. However, if the inventors employed in private firms have greater preferences for the advantages in career, they behave differently by producing more valuable innovations with a high probability of a technological hit. Such technological hit would provide them with opportunities to grow as a star researcher. Then, they could raise their own worth, as well as their permanent pay scale. Consequently, those inventors would rather avoid being generally lured nor induced to invent more patents that are less valuable.

On the other hand, the inventors employed in public organizations with a preference for self-satisfaction by technical proof are more likely to conduct research on more advanced and challenging technologies. In turn, this would increase the possibility to produce more creative and valuable inventions. Thus, public research institutes and universities need to allow their inventors the freedom to pursue fundamental science with little direct or immediate commercial applicability (Lerner and Wulf, 2007). Otherwise, they could provide the inventors the power to decide their research topic by allowing the inventors to research on interesting and challenging topics or show their creativity. Likewise, the differences in the preferences for the compensation types would induce different behaviors among inventors. Thus, discussion on the employees' invention compensation needs to

actively address the important role of both non-monetary and monetary compensation.

Lastly, other control variables would be briefly explained. More educated inventors produce more patents and produce more valuable ones across organizations. This result is partially consistent with Mariani and Romanelli (2007) who found that the inventor's level of education positively affects the patent quantity of the inventors, not the patent value. The age of the inventors has a positive impact on the patent value but not the patent quantity. Inventors' mobility has a positive link with inventors' productivity in public organizations, consistent with Hoisl (2007). However, the positive relationship is not found in the private firms.

VII. Conclusion

The present paper has discussed the role of employees' invention compensation plan in Korea, using a comprehensive data set of inventor survey in Korea. This is the first attempt to empirically explore the role of employees' invention compensation plan in Korea. Our empirical analysis supports the positive role of inventors' innovations across organizations, particularly the positive impact of the high rate of compensation on the patent value. Even so, there is a caveat that the endogeneity problem remains. However, the implemented compensation plan at least has positive impacts on inventors' productivity across the organization types.

Furthermore, this paper also examines how the preferences for compensation types, such as (1) monetary compensation, (2) advantages in careers that are reflected in promotion, performance, and evaluation, (3) privilege/reputation, (4) improvement in organizational performance, (5) self-satisfaction by technical proof, and (6) improvement in the working

environment (through compensation for employers), affect inventors' innovative activities. The findings are as follows. First, the inventors of the private firms, who have a greater preference for monetary compensation, produce more patents, whereas those with greater preference for advantages in career produce more valuable innovations. Second, the inventors employed in public organizations with a preference for self-satisfaction by technical proof, are more likely to conduct research on more advanced and challenging technologies.

These results suggest that employees' invention compensation plan has room for further discussion on the types of non-monetary and monetary compensation, reflecting the inventors' preferences, whose impacts are different by the organizations that employ the inventors.

[Appendix] Summary Statistics

(N=1067)

Variable	Mean	Std. Dev.	Min	Max
PATVALUE	6.19	1.47	1	8
INVPROD	0.82	0.98	0.03	12.86
PATCOMP	0.72	0.45	0	1
PATSHARE	2.02	6.32	0.1	80
MON_PRE	3.73	1.29	1	5
CAR_PRE	3.54	1.20	1	5
PRES_PRE	2.95	1.14	1	5
ORG_PRE	3.13	1.04	1	5
SELF_PRE	3.77	1.07	1	5
ENV_PRE	2.94	1.11	1	5
PhDs	0.36	0.48	0	1
INVENTORS	1.30	0.87	1	8
AGE	43.39	7.92	25	73
TARGET	0.67	0.47	0	1

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특허 품질과 수량의 결정 요인으로서의 직무발명보상제도

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국문초록

본 연구는 2009년도 한국 발명자 조사 자료를 이용하여 한국의 직무발명보상제도가 발명가들의 혁신에 미치는 영향을 실증적으로 분석한 것이다. 분석결과, 직무발명보상제도와 발명자의 특허성과 간 양의 관계가 있는 것으로 분석되었다. 특히, 직무발명보상 비율이 높을수록 특허의 질적인 면을 제고하는 것을 확인하였다. 또한, 본 연구에서는 다양한 직무발명보상 유형에 대한 발명자의 선호도를 조사하여, 금전적 보상 유형 이외에 비금전적 보상 유형에 대해 논의하였다. 분석결과, 금전적 보상에 대한 선호도가 높은 민간 기업 발명자들은 양적인 특허 생산성이 높은 것으로 확인되었다. 반면, 경력상 가점에 대한 선호도가 높은 민간 기업의 발명자들은 가치가 높은 특허를 창출하는 것으로 확인되었다. 또한, 공공기관의 발명자들의 경우, 기술적 입증을 통한 자기 만족에 대한 선호도가 높은 발명자일수록 보다 우수하고 어려운 기술을 연구하는 것으로 분석되었다. 이러한 결과들을 바탕으로 보다 우수하고 고부가가치의 특허 창출을 위해 금전적 보상뿐 아니라 비금전적 유형의 보상제도의 필요성에 대한 정책적 함의들을 논의하였다.

주제어

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