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Compensation Structure and the Creation of Exploratory Knowledge in Technology Firms

ABSTRACT

Given the importance of exploration in a firm's overall innovation program, scholars have sought to understand organizational factors that give rise to exploration-oriented innovations. We propose theory and empirical evidence that relates firms' use of financial incentives to their exploratory innovation performance. We expect that a larger proportion of long-term incentives in R&D employee compensation should be positively associated with the creation of exploratory innovation in a firm. In addition, we propose that a higher level of horizontal pay dispersion is negatively associated with the creation of exploratory innovation. We examine innovations reflected in the patents of a unique six-year, unbalanced panel dataset of 94 high-technology firms in the U.S. Empirical results confirm that firms with high level of horizontal pay dispersion have less exploratory patent innovations. However, surprisingly, firms that pay their R&D employees a higher proportion of long-term financial incentives in total compensation have lower level of exploratory innovation. This implies the possibility that popular long-term incentive plans in high-technology sectors (e.g., stock option plans) have failed to achieve their intended goals in practice. We discuss factors that might moderate the negative impact of long-term incentives on exploratory innovation.

I. Introduction

The seminal work by March (1991) and other scholars have established the importance of the exploration-exploitation framework in understanding organizational learning and innovations. In the knowledge management domain, exploration-oriented innovation often involves experimentation, distal search, and variation from existing knowledge base. Exploitation-oriented innovation, on the other hand, is often associated with implementation and refinement of existing knowledge, local search, and variation reduction. Both types of innovations are believed to affect organizational performance (Auh and Menguc, 2005) and in general firms need to balance the allocation of resources between exploration and exploitation (Gupta et al., 2006). However, March (1991) also highlighted that exploratory innovation is inherently more vulnerable, as returns from exploration are systematically less certain and more remote in time, and exploration-oriented activities are often more distant from the locus of action in an organization. This observation implies the necessity for organizations to direct more attention to exploratory innovation.

Inspired by March's framework, management scholars over the past two decades have investigated factors that are linked to the generation of exploratory innovations. At an organizational level, for example, studies have examined the role of organizations' absorptive capacity, resource slack, structure, culture and identity, age and size (Lavie et al., 2010 provides a comprehensive review of literature). However, the innovation performance of an organization is intimately tied to the effort of the individual employees since knowledge is borne out of their creative activities. As far as our knowledge is concerned, there has been no attempt on either the theoretical or the empirical front that links an organization's compensation structure, particularly the compensation of employees in organizations' research and development divisions, to the creation of exploration or exploitation-oriented knowledge in the organization.

Existing research has produced strong and consistent evidence that financial incentives ranks among the top drivers of employees' work effort and performance (Locke, et al., 1980; Guzzo, et al., 1985; Stajkovic and Luthans, 1997; Jenkins, et al., 1998; Milkovich and Newman, 2008). Building on these works, we argue that an organization's compensation structure may be informative about employees' level of innovation effort and their allocation of effort in different types of innovations. First, in contemporary organizations, an employee's total compensation consists of various components such as salary, bonus, options, restricted stocks, benefits, etc., each is awarded by the organization to elicit the desired effort. Short-term incentives such as salary and bonus are intended to tie an employee's attention more towards short-term productivity while the long-term incentives such as restricted stocks and options are designed to align employees with a longer perspective of the organization's performance (Galbraith and Merrill, 1991). Thus, the design of an organization's compensation structure with regard to how components are apportioned could affect how employees view risk-and-outcome tradeoffs associated with exploratory and exploitative knowledge generation. Second, to the extent that social comparison is prevalent in organizations (Nickerson and Zenger, 2008), an employee's innovative effort may also be influenced by his or her position relative to others in the pay hierarchy. In this regard, the question remains how pay dispersion—i.e., the distribution of total compensation among employees—could affect the allocation of an employee's innovative effort. In this article, we seek to theorize on the relationship between an organization's compensation structure and its creation of exploratory knowledge. In addition, we empirically test our arguments using a dataset with detailed information on the patent innovations and the compensation structures of a sample of U.S. high-technology firms from 1997 to 2002.

Our research joins the small but growing body of research that documents the relationship between compensation and innovation. Among the remarkably small number of empirical investigations that empirically links the changes in corporate R&D and innovation outcomes, by far most of the attention has been devoted to occupants of high-level positions such as CEO (e.g., Balkin, et al., 2000), head of central research and development (R&D) organization (Lerner and Wulf, 2007), or divisional or strategic business unit (SBU) CEOs (Galbraith and Merrill, 1991; Dechow and Sloan, 1991; Holthausen et al., 1995). The focus on the compensation of high-level corporate officers may be largely driven by the consideration that these officers are responsible for allocating resource across different research projects, hence potentially have a bigger impact on the directions of corporate research and innovation outcomes.

The role of senior executive officers notwithstanding, some trends in the organization of industrial research suggest it no longer sufficient to focus exclusively on the role of top-level executives. First, beginning in the late 1980s, industrial research in the U.S. has become more decentralized. Firms increasingly shunned centralized R&D as in the cases of the legendary Bell Lab in AT&T and the Xerox PARC in favor of a divisional research structure in which decisions on research are not longer limited to the corporate headquarter (Rosenbloom and Spencer, 1996). Indeed, Lerner and Wulf (2007) found that financial incentives to head of corporate R&D department bear no relationship with innovation performance in firms that have divisional R&D organizations. Second, the past three decades also saw firms becoming less hierarchical and more flexible in structure and management. There are reports of firms using lab-like, small project teams as the basic unit of research (e.g., Battelle, 2005, on Google; Liu and Stuart, 2010, on a biotechnology firm) and emphasizing more on the role of middle-ranked managers in the innovation process (e.g., Nonaka, 1988). A third noticeable trend is the diffusion of the discretionary time practice for research employees in companies. In companies such as 3M and Google, engineers are allowed to use a fraction of their time at work to on projects of their own choosing, even if the projects are not directly related to any immediate corporate goals (Battelle, 2005). Together, these trends suggest that middle managers and rank-and-file research employees who are below the executive ranks are gaining more autonomy in today's de-layed and de-centralized organizations and that they are potentially playing a stronger role in the knowledge creation process. Therefore, our paper extends previous research by studying how the compensation structure for employees below the executive rank is related to the patterns of knowledge creation in firms.

We focus on two aspects of corporate compensation in our analysis. First, based on exploratory knowledge embodied in firms' patent innovations, we analyze whether a higher ratio of long-term incentives in a firm's compensation structure is associated with more exploratory patent knowledge being created. Second, we examine the pay dispersion of a firm's compensation structure. We argue that pay dispersion, particularly horizontal pay dispersion, may increase the intensity of competition among employees and drive employees to put more effort in exploitation-oriented innovations, which are less risky and tied more closely to short-term performances. Our results confirm the idea that high level of pay dispersion discourages the generation of exploration-oriented patent knowledge. We found that a one standard deviation increase in horizontal pay dispersion in a firm lowers exploratory patent count by 16 percent. However, the empirical results do not provide support for the exploration-enhancing effect of long-term incentives in compensation packages. Surprisingly, an increase in the proportion of long-term incentives in total compensation has a significantly negative effect on a firm's exploration-oriented patent count. We discuss possible reasons for such a finding in section V.

The rest of the paper is organized as follows: section II develops the hypotheses about effects of long-term incentives and pay dispersion in compensation on exploratory innovation; section III describes data, variables, and estimation method; section IV presents results; section V discusses the findings and conclude.

II. Hypotheses

Given the fixed amount of resources, organizations are confronted with not only the choice of *how much* to pay (i.e., pay level), but also the choice of *how* to pay (i.e., pay structure). The how-to question has drawn significant amount of scholars' interest. In particular, two aspects of an organization's compensation structure have received most attention in the literature of financial incentives and innovation performance. In some studies, scholars are interested in the types of incentives given to organizational members, senior executive members in particular, that best promote innovation (Dechow and Sloan, 1991; Holthausen et al., 1995; Bloom and Milkovich, 1998; Balkins et al., 2000; Oyer and Schaefer, 2005; Lerner and Wulf, 2007). The focus of interest in most of these studies is the effect of long-term financial incentives such as stock options, restricted stock grants, and other forms of stock ownership programs. A second salient aspect of focus in the inquiries of corporate compensation concerns the effect of pay dispersion on organizational outcomes (e.g., Pfeffer and Langton, 1993; Bloom, 1999; Bloom and Michel, 2002; Shaw et al., 2002; Brown et al., 2003; Siegel and Hambrick, 2005; Carnahan et al., working paper). We follow previous studies and examine how a firm's use of (i) long-term incentives and (ii) pay dispersion is associated with the type of patent innovations generated by the firm's employees.

II.1. Long-term Incentives and Exploratory Innovation

In March's (1991) conceptual framework of exploration and exploitation, one of his main concerns is that organizations face tradeoffs in choosing to focus on one activity versus another. Though it is still a subject of debate, by and large, scholars studying knowledge exploration and exploitation in organizations agree with, and inherently rest their inquiries on this assumption. Exploratory innovations are more experimental and risky, but associated with more long-term opportunities. Exploitative innovations, on the other hand, are more tied to the existing knowhow of the firm and more associated with short-term productivity of the firm.

Though such tradeoffs should exist across levels of organizational hierarchy, the challenge posed to mid-level managers and employees might be even more salient. Researchers on organizational diversification and decentralization have expressed suspicion that decentralization and greater autonomy by themselves will lead middle managers to innovate more (Hoskisson et al., 1993). Rivkin and Siggelkow's (2006) simulation study further demonstrated that given the coordination complexity of exploratory innovation and risk-averse nature of lower-to-middle-level managers, greater reliance on the innovation effort of lower levels of an organization's hierarchy could be detrimental to creation of exploratory innovation in the organization.

Similar allocation dilemma could exist for rank-and-file research employees. Take, for example, researchers in pharmaceutical and biotechnology firms. Researchers in both industries often need to draw from basic science research generated by universities and public research institutions. Such basic scientific knowledge might not be related to the immediate research targets that the corporate researcher is focusing on as part of his or her routine work and might not factor in his or her performance metrics. However, such knowledge prepares the researcher for better absorbing cutting-edge discoveries from the public research domain, thus is more inductive to exploratory innovations. [CITE COCKBURN AND HENDERSON HERE].

Building on prior research, there are two areas where organizations can intervene with regard to managers' and employees' perceptions of the exploration-and-exploitation tradeoff. The organization can devise ways to solve the coordination problem in exploratory innovations and it can use incentives programs to alter managers and employees' risk tendency and decision horizon. We focus on the second area in our discussion below.

Typical compensation packages in contemporary organizations consist of base (fixed) pay (e.g., salary), variable pay (e.g., long-term and short-term incentives), and benefits (e.g., healthcare insurance and sick pay). Short-term incentives include profit sharing or gain sharing plans, and bonuses. They are typically awarded based on realized performance of past year or past few years. Long-term incentives offered by firms include various types of stock options, grants of restricted stocks, or other payment forms that are tied to long-term performance of the firm. In technology-intensive industries, in particular, stock options have been used widely among employees as a tool for attracting, retaining and motivating research talents (Anderson et al., 2000; Yanadori and Marler, 2006). Microsoft, for example, is known as providing a relatively lower base salary and making more use of stock options in compensation packages, hence has created 10,000 Microsoft millionaires (Gerhart and Rynes, 2003).

Stock-based long-term incentives plans in theory help increase managers' tolerance of innovation-related risks and also increase the span of their decision horizon. Most agencytheory-inspired research has established that managers are more risk averse than principals. Unlike stockholders who can diversify their risks associated with a particular firm by investing in a portfolio with multiple stocks, a manager's wealth is more closely tied to his or her employer firm and hence bears more risks of any exploratory innovations undertaken by his or her employer (Hill and Snell, 1988; Hoskisson et al., 2002). Hence, in theory, a more equity-rich compensation package ties the managers' incentives more closely to that of the principal stockholders, and reduces their risk-hedging tendency on issues such as innovation.[1] In addition, in the common setup of stock options and restricted stock grant plans, incentives are linked incentives to future objectives as opposed to past performance (as in the case of bonus or profit-sharing plans), and the collection of incentives is usually deferred (Tehranian et al., 1987). Such measures effectively orient managers' decisions more toward long-term performance of the firm (Rappaport, 1983).

Empirical research based on the compensation structure of senior executives and divisional (or strategic business unit) managers offers largely supportive evidence on the relationship between long-term incentives and overall innovation performance in an organization. Galbraith and Merrill (1991) surveyed strategic business unit (SBU) managers of 79 high-technology firms and reported that SBU managers with compensation packages more reliant on long-term component are likely to invest in risky R&D.[2] Holthausen et al. (1995) also

[1] Some scholars argue for the popularity of incentive-based pay programs among firms in high-growth sectors, though from a somewhat different perspective (Balkin and Gomez-Mejia, 1987; Rajagopalan, 1997; Bloom and Milkovich, 1998; Makri et al., 2006). These studies were based on the assumption that in high-growth sectors such as technology-intensive industries, an outcome-based compensation scheme (larger proportion of both long-term and short-term incentives) is more appropriate given the high level of risks existing in such industries that make monitoring difficult and thus behavior-based compensation scheme less effective. We agree with this argument, though in our paper we focus more explicitly on long-term incentives.

[2] A caveat of their study design is that R&D investment is based on self-report seven-point Likert scale, rather than objective data.

studied divisional CEOs using proprietary data and found modestly positive relationship between the proportion of long-term incentives in divisional CEO compensation and the division's innovation performance (based on sales-weighted patent count). Lerner and Wulf's (2007) study of compensation of R&D executives of 140 firms spanning over a decade also supported the argument that higher proportion of long-term incentives such as stock options and restricted stocks in the pay to leaders of central corporate R&D is linked to better corporate innovation performance (as reflected in patent count and citations). [3]

Drawing on existing theories on the effect of long-term incentives and the empirical evidence supporting the positive relationship of long-term incentives on overall corporate innovation, we expect:

Hypothesis 1: A firm with a higher average proportion of long-term incentives in employee compensation packages has more exploratory innovations.

II.2. Pay Dispersion and Exploratory Innovation

Pay dispersion is defined as the distributional characteristics of a firm's compensation of its employees. Given the resource constraint, pay dispersion is a key decision that each firm will encounter when structuring its compensation (Bloom, 1999). Previous scholars have paid attention to both vertical dispersion (i.e., differences in pay across levels of an organizational hierarchy) and horizontal pay dispersion (i.e., differences in pay within a given job rank). In this study, we focus on horizontal pay dispersion given stronger relevance of this form of pay dispersion to innovative activities of employees.

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[3] However, in Balkin et al.'s (2000) examination of CEO pay, the authors found less consistent evidence that long-term compensation is related to innovation performance (as reflected in patent count and R&D spending) in high-technology firms. In contrast, they found that CEO short-term compensation is positively related to patent count and R&D spending. Their findings differ from previous research summarized in text, and the difference could result from the level of focus—that their study focused on CEO compensation rather than divisional manaers.

To begin with, horizontal pay dispersion is likely to exert strong impact on employee behavior. The theoretical underpinning for allowing horizontal pay dispersion is that employees' ability, motivation and effort are unevenly distributed in organizations. Thus, compensation should ideally reflect such an unequal distribution. A popular method of differentiation is tying compensation to performance (Wright, McMahan, and McWilliams, 1994). Thus, pay dispersion emerges when firms make attempt to evaluate individual employee performance and reward high-performing employees more than low-performing employees based on their evaluations.

Some management and economic theories point to the beneficial effects of large pay dispersion. For example, expectancy theory (Vroom, 1964) argues that linking pay with performance helps motivate employee to improve performance. With larger pay dispersion, employees might be motivated by the higher upward potential in reward and exert more effort in work. Tournament theory (Lazear and Rosen, 1981) similarly proposes that high dispersion in compensation hierarchy creates high-powered incentives for employees to make more effort in order to achieve a high-level pay. The theory was originally proposed to explain large differentials in vertical compensation structure. However, in principle, large horizontal pay dispersion within the same rank implies a greater-valued prize within the rank, and thus could also elicit employees' effort to achieve better performance.

There are also retention benefits associated with pay dispersion. Compared to lower-pay-dispersion firms, high-pay-dispersion firms often tie reward more closely to performance. Zenger (1992), for example, observed that firms often use a merit-based pay system in which employees with extreme performance at either the top or bottom end are reward or penalized disproportionally from their marginal product contribution. This system may not necessarily help motivate effort, as employees in the middle pack do not see themselves likely getting the large reward if they are not in the top category. However, this system does help the retention of top-performers, or attract top-performers from other firms. The system also helps promote voluntary turnover of employees at the bottom of the performance hierarchy. Together, existing research suggest that a high level of pay dispersion could help improve organizational performance either through eliciting better employee effort or through retention of top-performing employees.

We believe the above discussion on the beneficial effects of pay dispersion applies to employees' innovation effort in firms' research departments. However, existing research offers no prediction on what type of innovation a system of high pay dispersion will encourage. We expect a negative impact of pay dispersion on exploratory innovation for three reasons. First, since most high-pay-dispersion system is based heavily on performance evaluations, and performance evaluation in most firms are likely to be based on outcomes achieved during a short period of time (e.g., past year or even past quarter), employees are more likely to reap top rewards if their innovations are tied to short-term organizational goals. Since exploratory research is inherently more risky, such a pay-for-current-performance system could effectively deter company researchers from seeking high-risk but high-originality projects.

Second, research on creativity suggests that high-pressure environment may hinder employee creativity (Amabile, 1998). When firms evaluate employees by matching their current period outcomes closely against a preset standards, they inadvertently created pressure for employees to deliver short-term results, hence could deter employees from pursuing deeper, high-impact research that is more novel to the firm.

Third, exploratory knowledge often results form novel combination of knowledge in different domains. This suggests that inter-disciplinary and inter-departmental knowledge exchange and collaboration will be more likely to lead to exploratory innovation. However, an often-commented disadvantage of high pay dispersion compensation model is its de-motivating effect on employees due to social comparison. In particular, employees may view pay distribution as a zero-sum game, hence hold off from collaborating and helping their colleagues' innovative pursuit (Pfeffer and Langton, 1993). For the above reasons, we expect that:

Hypothesis 2: A firm with a higher level of horizontal pay dispersion has less exploratory innovations.

III. Method

III.1 Data and Sample

Our analysis draws upon an employee-level compensation data collected as a part of an annual compensation survey administered to U.S. high-technology (mainly information technology) firms by a Boston-based consulting firm. This consulting firm aggregates information about each individual employee's compensation from participating firms, and provides them with market pay information for benchmarking. We were granted the access to the data that span a six-year period from 1997 to 2002. We restricted our sample to the R&D departments 94 publicly-traded firms in the dataset, which report over 2.5 million records of compensation information of R&D employees in entire six-year period. The final dataset we analyze is an unbalanced panel structure of 338 firm-year observations.

The firms that respond to the survey are from the following five industries (two-digit North American Industry Identification System [NAICS] codes are reported in parentheses): manufacturers of printer toner cartridges and photographic chemicals (32); manufacturers of electronic computer, semiconductor machinery, radio and television broadcasting, and wireless communications equipment (33); computer software publishers and reproducers, telecommunications networks and wireless data communication carriers (51); computer software and hardware consulting, installation, and other service providers (54); and teleconferencing service providers (56).

Admittedly, ours is not a randomly selected sample and for this reason we caution over-interpretation of our findings. Nevertheless, systematic, large-scale employee-level compensation information is extremely difficult to come by, particularly at the levels (middle and lower tiered managers and rank-and-file employees) that are covered in our data. Indeed, while compensation information of CEOs and a small number of top-ranked executives can be accessed from the ExceComp data, researchers who studied compensation below the senior executive ranks often relied on similar, consulting-based proprietary datasets as in our case (e.g., Lambert et al., 1993; Main et al., 1993; Bloom and Michel, 2002; Siegel and Hambrick, 2005; Wade et al., 2006; Yanadori and Marler, 2006; Lerner and Wulf, 2007).[4] Therefore, we believe that despite the caveat, this is a valuable dataset for exploring our topic.

The other limitation of our data is that compensation information is dated between 1997 and 2002. However, in order to measure patent-based innovations, a time lag is necessary in reliably assessing the patent application and citation patterns. On average, the time lag between the application and the grant of a patent takes about two to three years (Hall, Jaffe, & Trajtenberg, 1999). Full path of forward citations (future patents that cite a focal firm's patent applications) will display only after a number of years past the patent grant.

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[4] Other researchers resort to researcher-administered surveys (e.g., Collins and Smith, 2006) and certain public sector data sources (e.g., baseball players' compensation by Bloom [1999] and hospitals in California by Brown et al. [2003]). However, self-administered surveys often suffer in terms of depth of information since employers are reluctant to disclose detailed compensation information to researchers and publicly available data are often restricted to a narrow set of sectors. A promising new data source for accessing systematic, large-scale firm compensation data is the Longitudinal Employer-Household Dynamics (LEHD) project, which links employer-employee data from state-level unemployment insurance records and other data products from the U.S. census bureau. Though there are still restrictions and hurdles to go through in order to use LEHD, some researchers have managed to analyze it in their work (e.g., Andersson et al., 2009; Carnahan et al., 2010).

The other data sources we tapped into are the U.S. Patent and Trademark Office's (USPTO)'s Patent Full-Text Database, from which we drew our patent count and citation measures. In addition, we collected firm-level information, such as financial performance, size, R&D expenditure, and sales from the Compustat database.

III.2 Variables

We study the effect of compensation structure on both the performance of innovation and the pattern of innovation. Following most recent research on corporate innovations (e.g., Balkin et al., 2000; Lerner and Wulf, 2007), we rely on corporate patents as indicators of innovation. Though there are certainly concerns with patents as indicators of corporate innovation, we believe patents are appropriate choice of innovation measure. This is because our study focuses on a number of technology intensive (particularly, information technology) industries, where patents are crucial tools for a firm to protect its strategic positions in relevant product markets. For example, semi-conductor firms are known to rely on a thicket of patents to protect their products (Hall and Ziedonis, 2001). In addition, the recent patent war among major telecommunication firms also attests the relevance of patents as part of corporate strategy (Raice and Kain, 2010).

To measure a firm's exploratory knowledge, we computed an *exploratory patent count*, which is the number of all patent applications filed by a firm in a given year that are new to the firm's knowledge stock. Following Sorensen and Stuart (2000), new patents are defined as those that neither self cite (i.e., citing the firms' own patents filed prior to the given year), nor repeat cite (i.e., citing patents that the firm has previously cited in their patent applications filed in the past five years). Though not reported in this paper, for robustness tests, we computed a second measure of *citation-based exploratory innovation*. In computing this measure, we take all patents filed by a firm in a year and examine all the citations they made to previous patents. This second exploratory innovation measure is computed as the proportion of new citations in total citations (i.e, it equals the number of new citations divided by the total number of citations made in the year's patents). New citations are defined similarly to new patents as those citations that are not self-cites nor repeat cites using a past five-year window. [5]

Our data offer fine-grained compensation information that allows us to construct measures to assess the blend of types of incentives a firm offers to its employees. To test arguments about the effect of long-term compensation components, we first compute, for every individual employee in a firm, the proportion of long-term incentives in his or her total direct compensation. The long-term incentives include shares of restricted stocks and stock options. In each year's survey, the firms are asked to provide each employee's past three long-term incentive awards. The survey administrator aggregates the awards and computes the Black-Scholes-growth-adjusted values of these awards. The total direct compensation of each employee includes the long-term incentives and short-term incentives such as salary, bonus, or other forms of profit-sharing awards. We take the average of *proportion of long-term incentives in total compensation* across all employees for a firm in a given year and enter this mean measure into the regressions. In addition, we separately compute *proportion of long-term incentives in total compensation of managers* and *proportion of long-term incentives in total compensation of non-managers*, using appropriate subsets of the data.

We measured *horizontal pay dispersion* of the total direct compensation of R&D employees. The survey administrator provided detailed instructions (e.g., specific

[5] For robustness checks, we also constructed alternative measures of *exploratory patent count* or *citation-based exploratory innovation* in which a seven-year window is used for defining repeat patents or repeat citations.

responsibilities, required experience) for the participating firms to categorize jobs in the R&D department into eight levels: three top levels for managers and the lower five levels for non-managers. This is for the purpose of generating survey data on compensation at similar levels that are comparable across firms. Since this consulting firm is an expert on HR and compensation issues and has a history of conducting such compensation surveys and there is no incentive for the participating firms to misreport information, we believe that the data on job levels are well constructed.

To compute the measure of *horizontal pay dispersion*, we followed management scholars (e.g., Siegel and Hambrick, 2005) and labor economists (e.g., Lin, 2005) and used the coefficient of variation of employee total pay. Coefficient of variation, i.e., the standard deviation divided by the mean of total pay, was calculated for each of the eight job levels and then averaged across all job levels. In additional to measuring *horizontal pay dispersion for all employees,* we also separately measure *horizontal pay dispersion for managers* and *horizontal pay dispersion for non-managers*. We restrict the computation to relevant subsamples when constructing these two measures.

Prior research has informed us on the choice of control variables. First, we controlled for *firm size* with the log of the number of employees following Ahuja (2000) and Katila and Chen (2008). Second, we controlled for *R&D intensity* of the firm, which is measured by the ratio of R&D expenditure to firm sales (Hall and Ziedonis, 2001; Keil et al., 2008). Third, we controlled for firms' performance, using *return on assets (ROA)*. Fourth, we controlled for firm innovation capability with its *past five-year patent stock*, i.e., number of the patents that were successfully granted to the firm in the past five years. The five-year window was chosen because knowledge depreciates quickly in high-technology firms. Fifth, we controlled for firms' *financial slack* because it may affect the investment patterns in R&D (Nohria & Gulati, 1996). Financial slack is measured using firms' current ratio (i.e., current assets divided by current liabilities) (Bourgeois, 1981; Wang, He and Mahoney, 2009). Sixth, we controlled for R&D employees' average *pay level*, which is likely to be associated with the quality of R&D employees and thus their innovation outcomes. We measured pay level following Brown et al. (2003): first we standardized the average total pay of each of the job levels across all firms, yielding eight standardized variables; next, we computed the average of the eight standardized scores to obtain the pay level of the R&D employees in the firm. A positive value indicates a pay level higher than that offered by the market, while a negative value indicates a pay level lower than the market. Six, we included *industry dummies* to control for any unobserved industry differences in innovation. Finally, we controlled for unobserved factors associated with the conditions of a specific year by including *year dummies*.

III.3 Models

Our dependent variable is a count and shows considerable dispersion, hence in our core models, we used negative binomial as our estimator. In order to account for heterogeneity across firms, we experimented with both random effect and fixed effect negative binomial models. We ran the Hausman test for determining which model is more appropriate for our data and the test result suggests for fixed effect estimation. In addition, we have robustness tests with a number of alternative estimators, which will be discussed in the next section.

Table 1 presents descriptive statistics of variables in our estimations, and the covariance matrix.

IV. Results

IV.1. Long-term Incentives and Exploratory Innovation

Table 2 reports random effect negative binomial regression results of the effect of long-term incentives on exploration-oriented patent count. In model 1, we estimated the impact of the proportion of long-term incentives in employee total compensation alone. The variable has a strong and negative effect on exploratory patent count. An increase in the average proportion of long-term incentive pay in total compensation by one percent is associated with a decrease of exploratory patents by 4 percent (=exp[0.01*-3.811). In standardized term, one standard deviation increase in proportion of long-term incentives in pay packages (i.e., 0.06, or 6 percent) is associated with a drop of exploratory patent count by 20 percent.

In model 2, we introduced our control variables. Among the controls, average pay level, past five-year patent stock, average employee tenure, firm size, and financial slack all show positive and significant effects on a firm's level of exploratory patents. With the controls, the effect of proportion of long-term incentives in compensation is still negative and significant.

In the next four models, we broke out our estimation by separately regressing the average proportion of long-term incentives in total pay for managers and that for non-manager employees. Our goal is to assess whether long-term incentives generate different patterns of reactions between R&D managers and non-manager R&D employees. The results suggest that the negative effects of long-term incentives hold for both types of employees, though the negative effect appears to be larger in magnitude for non-manager employees.

These results are contrary to our hypothesis. To ensure that the finding is not resulting from peculiarities of our chosen model specification, we ran several robustness checks using two alternative specifications. First, we replaced our dependent variable with *percent of exploratory* *patents* (=count of exploratory patents / count of patents, both numerator and denominator are flow measures for a given year) and replaced our estimator correspondingly with a fractional logit (as the new dependent variable is a fraction). We obtained similar results on the effect of long-term incentives in this specification.

Second, given that it is notoriously difficult to time the effect of compensation on innovation, we follow Lerner and Wulf (2007) and pooled all observations across years and ran population averaged regressions (i.e., for each firm, we computed averages of all measures across the years in our observational window and the regression models contain only one observation for each firm). The rationale for this alternative specification is that by pooling observations across years, we focused mainly on cross-sectional differences across firms and thus our analysis is less sensitive to assumptions about the timing of incentive effects on innovation. The main patterns of our results related to long-term incentives on exploration remain in this specification, though at a lower statistical significance level. [6]

Given these alternative models, we do not believe that the surprising negative effect of long-term incentives on exploration result from specification errors. We believe that this finding points to interesting contradictions between theoretical prescriptions about the role of long-term incentives in compensation structure and the impact long-term incentives has on firms' exploratory innovation in real practices. We will discuss the implications of this finding and report additional tests in the discussion section.

IV.2. Horizontal Pay Dispersion and Exploratory Innovation

[6] The results of these tests are available upon request.

Our second hypothesis proposes that a firms' horizontal pay dispersion is negatively associated with the firm's exploratory innovation generation. We tested this hypothesis in our Table 3. In model 1, we first estimated the effect of a firm's horizontal pay dispersion alone on its exploratory patent count. As hypothesized, increase in pay dispersion is associated with less exploratory patent innovations. This finding is confirmed in model 2, with the full set of controls. Specifically, an increase of one standard deviation in a firm's horizontal pay dispersion is associated with a decrease in the firm's exploratory patent count by 16 percent (=exp[12.898*-0.013]). Again, in models 3-6, we estimated the effect of pay dispersion separately at R&D manager and non-manager R&D employee levels. The negative effect of pay dispersion holds for both R&D managers and non-manager R&D employees. Interestingly, the result suggests that the negative effect is stronger if high-level pay dispersion is structure among R&D managers.

Tables 4 and 5 report fixed effect replications of models in table 2 and 3. The fixed effect results are consistent with random effect results.

IV. Conclusion and Discussion

Our paper investigates the relationship between firms' compensation structure and the pattern of their innovations as reflected in their patented knowledge. Specifically, we focused the average proportion of employees' long-term compensation in total compensation in a firm and the degree of horizontal pay dispersion in a firm and examined how these two aspects of compensation are related to the generation of exploration-oriented patent innovations. Our sample includes millions of employee compensation records of an unbalanced panel of 94 technology firms from 1997 to 2002.

Our estimations yield two major findings. First, we hypothesized that high degree of horizontal pay dispersion creates competitive pressure among employees for focusing on short-term performances, and in turn may hinder the generation of exploratory innovations. Our results provide strong support for this hypothesis. Second, we found that while incentives such as stock options and restricted stocks are generally believed to be long-term incentives that align employee motivation with long-term performance of their employers, the empirical relationship between average proportion of long-tem component in compensation and exploratory innovation performance of a firm turns out to be significantly negative. This surprising observation appears robust across several alternative specifications of the models.

Why do stock options and restricted stocks, which are designed to motivate employee long-term motivations, fail to deliver its promise? We suspect the negative relationship arises from a combination of factors—the popularity of long-term incentives plans such as stock options in certain industries and regions, and opportunism among employees, and high labor mobility. In regions where long-term incentive plans such as stock options are wide-spread, opportunities for benefiting from a firm's stock option grants are abundant. Particularly in regions where stock-grant incentives are popular and labor mobility is frequent, it is not uncommon for employees to change jobs in order to obtain options of stocks that might deliver better values. Without the intention for a long-term affiliation with one's employer, holding stock options of one's employer firm might create incentives for achieving near-term performance more than long-term performance. With strong near-term performance, the employee who holds stock options can profit from the portion of options that are close to the vesting date, and then move to a new employer.

If the above assumption is held, we believe it should more likely occur among employees and middle managers of firms with lack-luster financial performance. To test the idea, we run our core regression models in Table 2 with two additional variables, a measure of the company's *market-to-book ratio* (which measures the potential for the firm's equity to appreciate in the stock market), and the interaction term between the company's *market-to-book* ratio and the *proportion of long-term incentives in total compensation*. If our assumption about employee opportunism is true, it should occur more in firms with large market-to-book ratios (i.e., with less room of equity appreciation in the stock market), which in turn predicts a negative interaction effect. The results are reported in Table 6. The negative interaction effects hold whether of not we included controls (Model 1& 2) and if we test separately for managers (Models 3&4) and non-managers (Models 5&6).

Our study offers two lessons for managers interested in using compensation as a tool for orienting employees to certain type of innovation effort. The first important lesson is that despite the touted advantages with regard to other aspects of corporate performance, high pay dispersion could be detrimental if a firm or a division's goal is developing exploratory innovation. If firms intend to preserve high pay dispersion while also wish to encourage exploratory innovation, at a minimum, they need to reevaluate and redesign their performance evaluation criteria such that long-term innovation-related achievements are given larger amount of reward or that there is less penalty for people taking on risky exploratory innovations. The second lesson is that though stock ownership plans are designed to align employees with the long-term interest of the firm, in reality such plans may not be achieving their goals. Thus, firms may need to re-examine aspects of the design of such plans. These plans should also be understood in light of local labor market conditions, local HR practices, and the firm's equity market performance to ensure that long-term incentive plans are truly encouraging employees to engage in exploration-oriented innovations.

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Table 1 Descriptive Statistics and Covariance Matrix

		Mean	Std Dev	1	2	3	4	5	6	7
1	Exploratory patent count	69.070	102.851	1						
2	pay level	0.770	0.318	-0.093+	1					
3	past 5-year patent stock/100	15.409	26.246	0.655**	0.010	1				
4	employee age	38.964	3.066	-0.083	-0.325**	-0.048	1			
5	employee tenure	8.761	4.489	0.119*	-0.285**	0.222**	0.638**	1		
6	ROA	0.002	0.316	0.076	-0.147**	0.035	-0.005	0.065	1	
7	R&D intensity	0.125	0.077	-0.191**	0.378**	-0.200**	-0.445**	-0.541**	-0.199**	1
8	firm size	2.897	1.761	0.505**	-0.172**	0.495**	0.281**	0.603**	0.008	-0.585**
9	financial slack	2.259	1.363	-0.248**	0.268**	-0.232**	-0.357**	-0.434**	-0.024	0.437**
10	long-term incentives / total compensation (all employee)	0.052	0.062	-0.134*	0.792**	0.094+	-0.424**	-0.243**	-0.112*	0.354**
11	long-term incentives / total compensation (managers)	0.066	0.075	-0.125*	0.770**	0.088+	-0.431**	-0.250**	-0.091+	0.357**
12	long-term incentives / total compensation (non-managers)	0.045	0.055	-0.128*	0.781**	0.108*	-0.418**	-0.247**	-0.128*	0.345**
13	pay dispersion (all employee)	18.692	12.898	-0.133*	0.779**	0.043	-0.329**	-0.217**	-0.257**	0.358**
14	pay dispersion (managers)	17.292	11.886	-0.132*	0.801**	0.030	-0.297**	-0.218**	-0.264**	0.342**
15	pay dispersion (non-managers)	21.224	15.557	-0.105*	0.678**	0.067	-0.358**	-0.219**	-0.227**	0.338**

N=369, * $p<0.05$, ** $p<0.01$.

Table 1 Descriptive Statistics and Covariance Matrix (Continued)

		Mean	Std Dev	8	9	10	11	12	13	14	15
8	firm size	2.897	1.761	1							
9	financial slack	2.259	1.363	-0.642**	1						
10	long-term incentives / total compensation (all employee)	0.052	0.062	-0.184**	0.352**	1					
11	long-term incentives / total compensation (managers)	0.066	0.075	-0.187**	0.331**	0.977**	1				
12	long-term incentives / total compensation (non-managers)	0.045	0.055	-0.180**	0.358**	0.984**	0.926**	1			
13	pay dispersion (all employee)	18.692	12.898	-0.217**	0.262**	0.756**	0.730**	0.753**	1		
14	pay dispersion (managers)	17.292	11.886	-0.209**	0.257**	0.740**	0.698**	0.751**	0.973**	1	
15	pay dispersion (non-managers)	21.224	15.557	-0.215**	0.241**	0.701**	0.703**	0.678**	0.943**	0.843**	1

N=369, * p<0.05, ** p<0.01.

Table 2 Random Effect Negative Binomial Regressions of Long Term Incentives on Exploratory Innovation

	(1)	(2)	(3)	(4)	(5)	(6)
pay level		0.460		0.433		0.399
		(0.183)*		(0.189)*		(0.180)*
past 5-year patent stock/100		0.011		0.010		0.011
		(0.002)**		(0.002)**		(0.002)**
employee age		-0.008		-0.017		-0.005
		(0.020)		(0.021)		(0.021)
employee tenure		0.049		0.058		0.045
		(0.020)*		(0.021)**		(0.020)*
ROA		0.101		0.116		0.120
		(0.177)		(0.169)		(0.190)
R&D intensity		0.809		0.908		0.779
		(0.817)		(0.821)		(0.822)
firm size		0.467		0.462		0.459
		(0.062)**		(0.063)**		(0.063)**
financial slack		0.130		0.122		0.123
		(0.048)**		(0.049)*		(0.048)*
long-term incentives / total compensation (all employee)	-3.811	-3.990				
	(0.930)**	(0.949)**				
long-term incentives / total compensation (managers)			-2.637	-3.222		
			(0.748)**	(0.820)**		
long-term incentives / total compensation (non-managers)					-4.325	-4.004
					(1.060)**	(1.014)**
industry dummies		Yes		Yes		Yes
year dummies		Yes		Yes		Yes
constant	0.675	-2.542	0.616	-2.215	0.662	-2.620
	(0.107)**	(0.828)**	(0.109)**	(0.852)**	(0.106)**	(0.839)**
log-likelihood	-1729.7	-1545.2	-1678.9	-1499.4	-1729.7	-1546.0
Wald Chi2	16.80	654.42	12.43	620.45	16.64	652.68
number of variables in model	1	18	1	18	1	18

All covariates are lagged by 1 year; standard errors in parentheses; ** p<0.01, * p<0.05, + p<0.1; number of firm-year observations = 369; number of firms = 94.

Table 3 Random Effect Negative Binomial Regressions of Pay Dispersion on Exploratory Innovation

	(1)	(2)	(3)	(4)	(5)	(6)
pay level		0.301		0.312		0.399
		(0.183)		(0.186)+		(0.180)*
past 5-year patent stock/100		0.009		0.009		0.009
		(0.002)**		(0.002)**		(0.002)**
employee age		0.001		0.007		-0.005
		(0.021)		(0.021)		(0.021)
employee tenure		0.045		0.041		0.045
		(0.021)*		(0.021)*		(0.020)*
ROA		-0.013		-0.004		0.120
		(0.167)		(0.167)		(0.190)
R&D intensity		0.455		0.471		0.779
		(0.822)		(0.823)		(0.822)
firm size		0.433		0.435		0.459
		(0.065)**		(0.065)**		(0.063)**
financial slack		0.097		0.096		0.123
		(0.047)*		(0.047)*		(0.048)*
pay dispersion (all employee)	-0.012	-0.013				
	(0.004)*	(0.004)**				
pay dispersion (managers)			-0.012	-0.014		
			(0.005)*	(0.004)**		
pay dispersion (non-managers)					-0.008	-0.008
					(0.003)*	(0.003)*
industry dummies		Yes		Yes		Yes
year dummies		Yes		Yes		Yes
constant	0.646	-2.571	0.641	-2.768	0.567	-1.930
	(0.124)**	(0.843)**	(0.126)**	(0.854)**	(0.118)**	(0.893)**
log-likelihood	-1735.3	-1547.9	-1735.6	-1548.1	-1682.0	-1502.8
Wald Chi2	7.11	632.00	6.38	628.31	5.30	597.56
number of variables in model	1	18	1	18	1.00	18

All covariates are lagged by 1 year; standard errors in parentheses; ** p<0.01, * p<0.05, + p<0.1; number of firm-year observations = 369; number of firms = 94.

Table 4 Fixed Effect Negative Binomial Regressions of Long Term Incentives on Exploratory Innovation

	(1)	(2)	(3)	(4)	(5)	(6)
pay level		0.374		0.341		0.285
		(0.225)+		(0.225)		(0.224)
past 5-year patent stock/100		0.011		0.011		0.011
		(0.002)**		(0.002)**		(0.002)**
employee age		0.004		-0.003		0.007
		(0.022)		(0.022)		(0.022)
employee tenure		0.036		0.043		0.032
		(0.027)		(0.028)		(0.027)
ROA		0.067		0.107		0.087
		(0.157)		(0.159)		(0.166)
R&D intensity		-0.253		-0.027		-0.376
		(0.884)		(0.899)		(0.889)
firm size		0.290		0.280		0.268
		(0.082)**		(0.084)**		(0.082)**
financial slack		0.239		0.232		0.228
		(0.057)**		(0.058)**		(0.056)**
long-term incentives / total compensation (all employee)	-2.988	-3.729				
	(0849)**	(1.095)**				
long-term incentives / total compensation (managers)			-2.132	-2.941		
			(0.690)**	(0.891)**		
long-term incentives / total compensation (non-managers)					-3.188	-3.517
					(0.961)**	(1.198)**
industry dummies		Yes		Yes		Yes
year dummies		Yes		Yes		Yes
constant	0.469	-2.007	0.441	-1.751	0.448	-2.003
	(0.090)**	(0.900)*	(0.092)**	(0.906)+	(0.089)**	(0.917)*
log-likelihood	-1528.6	-1002.1	-1465.2	-969.6	-1529.4	-1003.3
Wald Chi2	12.38	445.65	9.55	424.97	11.01	437.12
number of variables in model	1	18	1	18	1	18

All covariates are lagged by 1 year; standard errors in parentheses; ** p<0.01, * p<0.05, + p<0.1; number of firm-year observations = 338; number of firms = 73.

Table 5 Fixed Effect Negative Binomial Regressions of Pay Dispersion on Exploratory Innovation

	(1)	(2)	(3)	(4)	(5)	(6)
pay level		0.157		0.184		0.017
		(0.209)		(0.211)		(0.202)
past 5-year patent stock		0.000		0.000		0.000
		(0.000)		(0.000)		(0.00)
employee age		0.010		0.018		-0.005
		(0.022)		(0.022)		(0.023)
employee tenure		0.038		0.033		0.048
		(0.027)		(0.027)*		(0.028)+
ROA		0.020		0.027		0.074
		(0.166)		(0.165)		(0.181)
R&D intensity		-0.808		-0.807		-0.665
		(0.895)		(0.894)		(0.909)
firm size		0.219		0.218		0.202
		(0.085)**		(0.085)*		(0.086)*
financial slack		0.192		0.193		0.183
		(0.055)**		(0.055)**		(0.057)**
pay dispersion (all employee)	-0.009	-0.011				
	(0.004)*	(0.004)**				
pay dispersion (managers)			-0.010	-0.013		
			(0.005)*	(0.005)**		
pay dispersion (non-managers)					-0.006	-0.006
					(0.003)+	(0.003)+
industry dummies		Yes		Yes		Yes
year dummies		Yes		Yes		Yes
constant	0.454	-1.762	0.454	-2.048	0.398	-1.162
	(0.108)**	(0.915)+	(0.111)**	(0.926)*	(0.102)**	(0.960)
log-likelihood	-1532.9	-1003.9	-1533.1	-1003.5	-1468.9	-973.03
Wald Chi2	4.75	428.32	4.37	430.55	3.29	400.61
number of variables in model	1	18	1	18	1.00	18

All covariates are lagged by 1 year; standard errors in parentheses; ** p<0.01, * p<0.05, + p<0.1; number of firm-year observations = 338; number of firms = 73.

Table 6 Random Effect Negative Binomial Regressions of Long Term Incentives on Exploratory Innovation

	(1)	(2)	(3)
pay level	0.423	0.366	0.343
	(0.200)*	(0.204)+	(0.199)+
past 5-year patent stock/100	0.011	0.010	0.011
	(0.002)**	(0.002)**	(0.002)**
employee age	-0.026	-0.028	-0.023
	(0.020)	(0.020)	(0.020)
employee tenure	0.061	0.064	0.058
	(0.021)**	(0.021)**	(0.021)**
ROA	0.163	0.174	0.180
	(0.213)	(0.193)	(0.230)
R&D intensity	0.763	0.905	0.693
	(0.862)	(0.855)	(0.865)
firm size	0.392	0.402	0.383
	(0.065)**	(0.065)**	(0.065)**
financial slack	0.128	0.122	0.121
	(0.049)**	(0.049)*	(0.048)*
Market-to-book value ratio (MBV)	0.147	0.143	0.145
	(0.079)	(0.079)	(0.082)
LTI / total compensation (all employee)	-4.564		
	(1.014)**		
LTI / total compensation (all) ×MBV	-1.724		
	(0.817)*		
LTI / total compensation (managers)		-3.397	
		(0.850)**	
LTI / total compensation (managers) ×MBV		-1.283	
		(0.628)*	
LTI / total compensation (non-managers)			-4.480
			(1.089)**
LTI / total compensation (non-managers) ×MBV			-1.727
			(0.886)+
industry dummies	Yes	Yes	Yes
year dummies	Yes	Yes	Yes
constant	-1.918	-1.825	-1.912
	(0.798)*	(0.821)*	(0.812)*
log-likelihood	-1343.7	-1308.9	-1344.9
Wald Chi2	704.66	699.00	697.64
number of variables in model	20	20	20

All covariates are lagged by 1 year; standard errors in parentheses; ** p<0.01, * p<0.05, + p<0.1; number of firm-year observations = 322; number of firms = 81.