Relative Performance Evaluation and Corporate Innovation: Tournament Incentive or Risk-Taking?

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Abstract

We show that firms adopting relative performance (RPE) evaluation exhibit more fruitful innovation output for the U.S. listed firms from 1998 to 2019. We find that the adoption of RPE promotes corporate innovation. The positive association mainly manifests in firms with more promotion-based incentives and more risk incentives in CEO compensation. The RPE affects innovation through inter cooperation efficiency and risk-taking ability. In addition, we document that RPE improves innovation efficiency and is more effective than other compensation arrangements. Besides, our findings suggest that that firms adopting RPE are associated with better operating performance.

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Keywords: corporate innovation; goal conflict; relative performance evaluation; risk preference

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1 Introduction

Holmström (1979) proposes a competitive compensation scheme (relative performance evaluation), where the agent's compensation is determined by the relative performance to solve the moral hazards. However, the adoption of relative performance evaluation (RPE) seems less widespread than the evident advantages suggested in previous literature (Jensen and Meckling, 1976; Antle and Smith, 1986; Baiman and Lewis, 1989; Aggarwal and Samwick, 1999; Douglas, 2006). Moreover, a recent study criticizes the inadequate effect of incentive contracts to promote managers to pursue shareholder value (Morse, Nanda, and Seru, 2011) and emphasize that the costs of using information about peer performance in contracting are negligible. Considering the possible trade-offs between increasing incentive efficiency and indispensable costs, it is worthwhile to investigate the overall effect of RPE on firm performance, which is directly associated with the volume of CEO's compensation.

Regarded as an investment in a sense, innovation combines goal conflict between shareholders and managers, risk, and jobs in which performance evaluation is difficult (Eisenhardt, 1989). The emergence of RPE provides a solution for performance evaluation when the individual output is unobservable (Holmström, 1979; Holmstrom, 1982), influencing the goal conflicts and risk preference of managers. Further, it is axiomatic that the level of corporate innovation in RPE-firms may distinguish from non-RPE firms since the role of CEOs are more important in determining some corporate decisions than others (Bertrand and Schoar, 2003; Coles and Li, 2020).

In this study, we extend the literature regarding pay-for-target-performance incentive based on an explicit method, and investigate how the adoption of relative evaluation in

CEO compensation contract is associated with more innovation output. Specifically, we follow Carter, Ittner, and Zechman (2009) and construct a dummy variable to identify the use of RPE incentive as CEO compensation component based on available data provided by Institutional Shareholder Services (ISS) Incentive Lab. Our explicit method avoids downward bias when inferring RPE adoption using the implicit approach (Zhou and Swan, 2003). We conjecture that the RPE scheme in CEO compensation constructs is associated with corporate innovation because of motivation to acquire future competitive advantage and improved risk-taking ability when insulated from random shocks. Tournament-like competition among focal firm and its target improves the incentive efficiency and riskiness (Do, Zhang, and Zuo, 2021). Corporate innovation is characterized as a risky investment that increases competitive advantage (Urbancova, 2013; Herrera, 2015), accompanied by failures (Van der Panne, Van Beers, and Kleinknecht, 2003).

We construct a panel dataset including corporate innovation, RPE indicators, and several firm characteristics for a sample of U.S.-listed firms from 1998 to 2020. The recently available compensation information obtained from Institutional Shareholder Services' Incentive Lab helps identify whether CEOs' compensation under the RPE scheme. We construct a dummy variable of relative performance evaluation use to identify the role of this specific compensation structure on managerial investment behaviors and the innovation output. Compared to the implicit approach based on regression estimation, which is inevitably disturbed by the strong presumption, the explicit identification captures the actual RPE adoption more precisely. The results show that when compensated for relative performance, CEOs invest more in innovation and the innovation output is improved. We also examine the effect of RPE on innovation strategy and patent quality to get a more comprehensive reflection of the impact of RPE on the promotion of innovation, apart form innovation output. The association is more pronounced in firms with more promotion-based incentives and more risk-taking incentives, indicating that the association between relative performance evaluation and corporate innovation is sensible to internal cooperation and managerial risk preference, which is closely related to possible channels.

Moreover, we examine the impact of the RPE scheme on corporate innovation efficiency and compare the efficiency of incentives that award for success in different terms. The results show that RPE use increases innovation efficiency and the association remains positive when CEO is awarded long-term incentives. As for non-equity incentives, the result shows that short-term incentive decreases innovation efficiency. We also compare another compensation arrangement(i.e., pay-for-performance) apart from RPE and find that RPE is more effective on promoting innovation. In contrast, the effect of the pay-for-performance scheme on innovation is not statistically significant. To investigate which incentive motivates innovation more efficiently, we compare the impact of awards that compensate for success in different periods. The results show that long-term incentive works well in improving innovation. At the same time, the negative effect of non-equity incentive on innovation indicates that short-term failure in innovation investment is penalized, which inhibits the patent outcome. Finally, we test whether the motivation for innovation under the RPE scheme is to enhance performance metric and firm value by focusing on the interaction term of RPE and innovation when the explained variable is possible performance metric. The results show that innovation activities under the RPE scheme improve operating performance, while there is no obvious increase in shareholder wealth.

We also explore the potential mechanisms in the relationship between RPE adoption and corporate innovation and find that improved internal information quality and a higher level of CEO risk-taking facilitate innovation output. Moreover, we adopt mediation analysis to compare the role of encouraging innovation outcomes and the results show that being more adventurous (i.e., being more risk-taking and having greater tolerance for failure) accounts for the significnat mediating effect. To address the possible endogeneity problem, we adopt propensity score matching and sample selection model and conclude that our results are not biased by endogenous issues. Our primary findings are robust to a series of robustness checks, including alternative variable definitions, model specifications, and sampling criteria.

Our study contributes to three strands of the literature. First, we provide an insight into the influence of RPE on the principle-agent scheme in a firm. As a tool of corporate governance, RPE is widely considered to solve moral hazards and motivate managers to increase shareholder wealth (Jensen and Meckling, 1976; Holmström, 1979; Antle and Smith, 1986). However, incentive contracts have been widely criticized for providing inadequate incentives to promote shareholder value recently (Morse, Nanda, and Seru, 2011). Apart from the impact of RPE on the goals of agents and shareholders, Do, Zhang, and Zuo (2021) documents that the adoption of relative performance evaluation increase the risk-taking ability of the agents, which may induce unnecessary risks for shareholders value. In this study, we shed light on managerial behaviors under the RPE scheme by investigating the differences of goals and risk appetite between agents and shareholders.

Second, our work also contributes to the growing studies on the determinants of corporate innovation process, especially the role of remuneration schemes. Apart form internal firm characteristics including female board representation (Chen, Leung, and Evans, 2018), foreign institutional investors (Luong et al., 2017), corporate venture capital (Chemmanur, Loutskina, and Tian, 2014), headquarter location (Adhikari and Agrawal, 2016), outside factors are also documented associated with corporate innovation, such as external labor market (Nguyen and Zhao, 2021), competitor constraints (Grieser and Liu, 2019). In our research, we focus on the impact of executive compensation contract as a corporate governance mechanism on corporate innovation output and innovation strategy and examine the role of interest alignment due to the performance-based incentive in the RPE scheme.

Finally, our study is closely related to the recent finance literature that examines the link between employee treatment and firm value. Chang et al. (2015) show that non-executive incentive schemes matter for corporate innovation. Manso (2011) investigates the attributes of an optimal incentive scheme that motivates innovation and finds that long-term incentive are more valuable. The findings of Ederer and Manso (2013) also indicate that corporate innovation is sensitive to performance-based financial incentives. Not only financial incentives, Acharya, Baghai, and Subramanian (2014) find that laws that protect employees also incur corporate innovation. We contribute to this strand of literature by using a measure of monetary incentive as a part of employee treatment, and show that performance-based treatment schemes have an effect on corporate innovation.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature and proposes a testable hypothesis. Section 3 discusses the data and methodology, and report summary statistics. Section 4 examines how RPE is associated with corporate innovation, explores the possible mechanisms, performs a series of robustness checks, and provides further discussion. Section 5 finally concludes this study.

2 Related Literature and Hypothesis Development

Considering the significant importance of innovation for firms, literature explore the latent firm and manager characteristics contribute significantly to firms' innovation productivity beyond the several previously documented external factors, such as institutional ownership (Aghion, Van Reenen, and Zingales, 2013), takeover pressure (Atanassov, 2013), and supplier-customer geographic proximity (Chu, Tian, and Wang, 2019). Specifically, managerial features (Tang, Li, and Yang, 2015; Sunder, Sunder, and Zhang, 2017) and the employee job security (Manso, 2011; Chang et al., 2015; Biggerstaff, Blank, and Goldie, 2019) are also closely associated with corporate innovation. Moreover, the structure and the condition of corporate governance also significantly influence the corporate innovation.

Theory basis provide evidence for a positive effect of RPE on corporate innovation, including the incentive effect of tournament-like compensation structure and risk preference with the removal of common shock.

First, managers are motivated to reap high benefits in the future by innovation to win the tournament induced by relative performance evaluation. First discussed in Lazear and Rosen (1981), relative performance evaluation is widely considered as a tournament scheme when participants are compensated via the results of the tournament (Dye, 1992; Hannan, Krishnan, and Newman, 2008; Casas-Arce and Martinez-Jerez, 2009; De Angelis and Grinstein, 2020). CEO compensation increases with the achievement of beating the predefined aspirational peers (Jayaraman et al., 2021). Such compensation incentive is closely related to the result of the tournament between a firm and its peer group. Since between-group competition in the tournament reduces the within-group conflict and positively affect the cooperation levels (Rapoport and Bornstein, 1987; Bornstein and Ben-Yossef, 1994; Erev, Bornstein, and Galili, 1993; Bornstein and Ben-Yossef, 1994; Tan and Bolle, 2007), we expect an improved internal information environment, which is proved by (Moyano-Fuentes and Martínez-Jurado, 2016). Thus, we expect more innovation since the internal information environment acts as a driver of innovation (Huang, Lao, and McPhee, 2020). Besides, managers insulated from competitive pressure seek to avoid difficult activities (Giroud and Mueller, 2010). By contrast, under the compensation tournament scheme, managers may engage in difficult activities for empire building, and literature finds better performance under a tournament incentive than individual performance evaluation (Hannan, Krishnan, and Newman, 2008). In a word, we expect a positive effect of the RPE scheme on corporate innovation.

Second, the risk-sharing effect of relative performance evaluation also introduces more innovation. RPE scheme removes industry-wide risk factors that are beyond the CEO's control (Antle and Smith, 1986; Jensen and Murphy, 1990), altering the CEO risk-taking behaviors (Fumas, 1992; Do, Zhang, and Zuo, 2021). As Holmstrom (1989) argued, innovative activities involve exploring of untested and unknown approaches that have a high probability of failure with contingencies that are impossible to foresee. Since passing and operating the innovative projects is a signal of the risk-taking capacity of management (Hirshleifer, Low, and Teoh, 2012), we expect a positive impact of RPE on innovation.

However, there are also controversial voices, which provide the probability of the inefficiency or even a negative effect of tournament scheme induced by tournament incentive structure on innovation.

First, the relationship in the tournament between the focal firm and its peers depends on the type of strategic competition. In imperfectly competitive settings, firms compete either as strategic substitutes or strategic complements (Bulow, Geanakoplos, and Klemperer, 1985). Aggarwal and Samwick (1999) document that the nature of product market competition affects the use of RPE in CEO pay due to different managerial behaviors. Specifically, if a firm's product market outputs are strategic complements with rivals, RPE incentivizes managers to take aggressive price strategies that lower shareholder returns. In contrast, if the firm's output is a strategic substitute with that of its competitors, then managers have weaker incentives to maximize the firm value but stronger incentives to increase all other firms' value (i.e., collusion). Similar results can also be found in recent studies (Vrettos, 2013). Therefore, the effect of RPE on managerial incentive and behaviors may be insignificant because the negative and positive effects offset each other when using the aggregate peer group including substitute- and complement-peer-group as a reference.

Second, the risk-sharing effect of RPE has a negative on the tournament optimality. According to Lazear and Rosen (1981), the tournament outperforms the other linear piece-rate based on output and compensation based on comparison against a fixed standard when agents are risk-averse. However, if agents are risk-neutral, all three incentive schemes work optimally. Under the scheme of relative performance evaluation, the risk-sharing effect induced by removing common risks possibly disturbs the tournament incentive. Thus, the effect of relative performance evaluation on innovation may be insignificant.

Finally, there is a possibility that the CEO pursues a quiet life and is reluctant to the tournament. Specially, managers may prefer a quiet life to empire-building and dislike the costly efforts associated with innovation projects (Bertrand and Mullainathan, 2003; Giroud and Mueller, 2010). Therefore, the adoption of relative performance evaluation may be inefficient to motivate executives to build empire under the quiet-life hypothesis. These considerations suggest that the effect of RPE adoption on corporate innovation is ultimately an empirical question and we propose our hypothesis in the null form:

H_0: *Ceteris paribus, RPE adoption is not associated with corporate innovation.*

3 Data and Methodology

3.1 Data and Sample

We obtain stock prices, shares outstanding, standard industrial classification (SIC) codes from the Center for Research in Security Prices (CRSP), firm-level annual accounting data from Compustat, and CEO compensation and demographics from Excucomp. We also collect detailed contract items and specific compensation components from the Institutional Shareholder Services (ISS). ISS provides over fifteen years of detailed data on the terms of executive compensation plans, including RPE adoption and detailed elements. We obtain detailed U.S. patent information from Mike Woeppel's website[1], which includes information on the patent assignee (the entity, such as the firm, which owns the patent), the number of citations received by the patent, the technology class of the patent, the patent's application and grant year, and the names of the inventors who receive credit for the patent.

We start with the patent dataset available at Mike Woeppel's website. To control for unobserved time-invariant firm effects, which better mitigates the concern of omitted factor bias, and look into the heterogeneous response to deregulation within a given state, we include firm-level data. Specifically, we match the patent dataset with Compustat data following the procedures developed in Hall, Jaffe, and Trajtenberg (2001). We exclude firms

[1]The data could be available at `https://www.mikewoeppel.com/data`.

with negative sales and firms headquartered outside the U.S. We also exclude firms in the utility ((SIC 4900–4999) and finance industry (SIC 6000–6999). Our final sample our sample starts from 1998 to 2019 and consists of 64,798 firm-year observations.

3.2 Variable Construction

3.2.1 Measures of Relative Performance Evaluation

Before the SEC requirement in 2006, firms were not required to disclose their compensation peers' identifies to shareholders in their annual report. Therefore, empirical can only identify the adoption of relative performance evaluation by testing the relationship between manager's compensation and the excess excellent performance. Following this line of thought, a two-stage procedure proposed by Antle and Smith (1986) regresses CEO pay on unsystematic and systematic performance in the second stage to distinguish relative performance evaluation adoption. The limitation is obvious: the empirical association is not equivalent to the relative performance evaluation adoption.

We use an explicit approach of relative performance evaluation based on detailed data on the executive compensation plan's terms over fifteen years that are readily available from Institutional Shareholder Services (ISS) recently. Specifically, the dummy variable *RPE* equals one for firms that adopt relative performance evaluation in CEO compensation and zero otherwise, following the method of Carter, Ittner, and Zechman (2009). The explicit approach identifies the use of relative performance evaluation more correctly, providing a possible explanation for the lack of empirical evidence for relative performance evaluation adoption when using implicit approach.

3.2.2 Measures of Corporate Innovation

In our study, the primary variable of interest is corporate innovation, which measures the realization of a firm's long-term research and development investments (Cho et al., 2016). We adopt several patent-related proxies to capture the innovation investment and innovation output. We construct all the innovation variables based on the NBER patent database.

In baseline regression, we mainly use the number of patents and citations to capture the innovation output. According to Brav et al. (2018), patents are the most natural and measurable output from the process of innovation. Therefore, our first proxy of innovation output *LNPATG* is the natural logarithm of one plus the number of patents granted for each firm in each year, following Chu, Tian, and Wang (2019). The second measure of innovation output *LNPATA* is the natural logarithm of one plus the number of patent applications filed during the year (Sunder, Sunder, and Zhang, 2017). These two measures capture the quantity of innovation output. Besides, we construct another innovation output proxy *LNCITE* to measure the quality of the patent, which is defined as the natural logarithm of one plus the number of citations received on the supplier's patents filed (and eventually granted) for each firm in each year, following the method of (Chu, Tian, and Wang, 2019).

Apart from citations, there are other frequently used measures for patent quality, including the patent's originality, and the patent's generality, and the patent's scope (Brav et al., 2018). We also use innovation diversity, exploration, and exploitation to reflect the innovation strategy. The innovation quality and innovation strategy provide a more comprehensive reflection of a company's innovation activities rather than a simple count of patents and citations. Moreover, we also focus on the innovation efficiency and construct the efficiency proxy based on information about patents and inventors. The innovation efficiency takes into consideration the firm's ability to generate patents and patent citations per dollar of research and development (R&D) investment since the patent can be managed by mangers to achieve the expectation of shareholders. The specific construction of the variables will be discussed in the relevant sections.

3.3 Econometric Model

We examine the association between relative performance evaluation and corporate innovation by estimating the following panel regression model:

$$Y_{i,t+1} = \beta RPE_{i,t} + \gamma X_{i,t} + \delta_i + \theta_t + \varepsilon_{i,t+1}, \tag{1}$$

where $Y_{i,t+1}$ denotes the corporate innovation measure *LNPATG*, *LNPATA*, and *LNCITE* of firm i in year t+1. Following Carter, Ittner, and Zechman (2009), our main explanatory variable *RPE*, is a dummy variable that equals one for firms that adopt relative performance evaluation in CEO compensation contracts and zero otherwise. The vector X includes potential observable firm-level and industry-level determinants of a firm's innovation output as control variables. Following Chu, Tian, and Wang (2019), the control variables include firm size, measured by total assets (*LNSIZE*), firm age (*LNAGE*), leverage (*LEV*), profitability measured by return on assets (*ROA*), market to book ratio (*MTB*), capital expenditures (*CAPX*), research and development investments (*R&D*), the growth rate of sales (*SG*), asset tangibility (*TANG*), cash holdings (*CASH*), institutional ownership (*INSTHOLD*), the Herfindahl index based on sales and the squared Herfindahl index (*HHI* and HHI^2). The detailed methods of variable construction are presented in the Appendix Table A1. We also include industry and year fixed effects to control time-invariant industry factors and general business cycles.

3.4 Descriptive Statistics

Panel A of Table 1 reports the descriptive statistics of the main variables. The mean (median) value of several corporate innovation measures *LNPATG*, *LNPATA*, and *LNCITE* are 0.872, 0.911. and 1.1871, respectively. The average (median) of *RPE* is 0.0066 (0.000), suggesting approximately 6.6% of total firm-year observations adopt relative performance evaluation in CEO compensation contracts. The average absolute performance evaluation adoption is 18.9%. In terms of firm-level characteristics, an average firm has total assets of $325.71 billion, leverage of 0.218, return on assets of −7.4%. In addition, firms have an average market-to-book of 3.077. Moreover, firms have an average percentage of foreign income, and intangible assets to total assets are 1.0% and 16.7%, respectively.

Panel B presents the Spearman correlation matrix for the main variables. The relative performance evaluation measure *RPE* has a significant and positive correlation with the natural logarithm of the number of granted patent *LNPATG*. The relative performance evaluation proxy is significantly associated with all the control variables such as *LEV*, *SIZE*, and *ROA*. The correlation among control variables is modest, with correlation coefficients generally below 0.3, suggesting minor multicollinearity problems.

(Insert Table 1 about here)

Figure 1 shows the time-series average of the number and percentage of firms that adopt RPE from 1998–2019. Both the number and the percentage of RPE-firms increase sharply during the period of 2006–2014. This increase starts exactly from the disclosure requirement of SEC in 2006. Recently, the popularity of RPE adoption remains stable at about 12.5%.

(Insert Figure 1 about here)

4 Empirical Results

4.1 RPE and Corporate Innovation

Our primary estimation examines the association between relative performance evaluation and corporate innovation. Table 2 presents the relevant results.

Column (1) reports the result when *LNPATG* is used as the first explanatory variable. We include the *ABS*, a dummy variable used to identify absolute performance evaluation for CEO compensation, to control the influence of another type of compensation contract on corporate tax avoidance. The estimated coefficient of *RPE* is positive (coefficient=0.2161) with a t-statistic of 4.06, which is significant at the 1% level. This value is equivalent to a 4.83% increase in the numbers of applied patents with one standard deviation increase in *RPE*. The significantly positive coefficient suggests that the adoption of relative performance evaluation increases innovation output. The positive coefficient of *ABS* suggests that the adoption of absolute performance evaluation also motivates corporate innovation. Besides, *LNSIZE* has a significantly positive coefficient on innovation, suggesting that large firms are associated with better innovation productivity. The positive coefficient of firm age indicates that older firms are more innovative.

In Column (2), we use the number of applied patents as another innovation measure. The coefficient of the relative performance evaluation proxy is 0.3406 with a t-statistic of 5.82. This value is equivalent to a 7.08% increase in the number of granted patents with one standard deviation increase in *RPE*. The economic magnitude is larger than that in Column (1) when we use the number of applied patents as an innovation measure. Moreover, when we use the citation to capture corporate innovation in Column (3), the significantly positive coefficient of *RPE* is consistent with that in Columns (1) and (2). In conclusion, the results in Table 2 indicate that the adoption of specific compensation practices provokes corporate innovation.

As an essential indicator of the firm's long-term competitiveness, a higher level of innovation is realized in firms that adopt RPE in CEO compensation contracts. The result indicates that the pay-for-target-performance mechanism under the RPE scheme facilitates the CEO's incentive to invest in future competitive advantage. At the same time, innovation activities are documented to require tolerance for failure, which is closely related to managerial risk preference. Therefore, our result also provides evidence that RPE exposes managers to common risk that they cannot control and increase managerial risk-taking (Do, Zhang, and Zuo, 2021). In total, innovation activities are broadly seen as an essential component of competitiveness but also accompanied by risk (Gunday et al., 2011), and both of the characteristics are closely related to managerial decisions under the RPE scheme in theory. In this section, the empirical evidence confirm the rationality of our hypothesis.

(Insert Table 2 about here)

4.2 Innovation Strategy and Patent Quality

Cain and McKeon (2016) find that CEO personal risk-taking is associated with elevated risks in the firms they manage. To provide evidence that our results relate to the desire for competitive advantage rather than mere risk-taking, we examine the characteristics of patents. Specifically, we examine the innovation strategy and patent quality beyond a simple patent count and citation count.

There are several frequently used measures for innovation strategy and we focus on the innovation diversity, exploitation, and exploration following the method of (Brav et al., 2018). Firstly, we construct a proxy, proposed by Sørensen and Stuart (2000) and further extended by Custódio, Ferreira, and Matos (2013), to measure a firm's innovation diversity. This diversity measure equals one minus the Herfindahl index of the number of new patents across different technology classes, measured over the most recent three years:

$$PATDIV_{i,t} = 1 - HHINEW_{i,t} \tag{2}$$

where $HHINEW_{i,t}$ is the Herfindahl index of the number of patents filed by firm i in the past across 2-digit technology classes. A high diversity value indicates higher diversification, or lower concentration of patenting activities, across different technology classes.

Secondly, we focus on the extent to which the new patents are exploratory or exploitative in the RPE scheme and use the measures proposed by Manso (2011) and further developed by Custódio, Ferreira, and Matos (2013). Specifically, a patent is considered exploitative if at least 80% of its citations are based on the existing knowledge of the firm, whereas a patent is exploratory if at least 80% of its citations are based on new knowledge. Existing knowledge includes all the patents that the firm invented and all the patents cited by the firm's patents filed over the past five years. We calculated the aggregated percentage of exploitative/exploratory new patents at the firm-year level to capture whether a firm's innovative strategy relies heavily on existing knowledge (e.g., incremental relative to existing patents) or focuses on exploring new technologies. Both exploitative and exploratory innovation is essential for firms to prosper, or even survive (Tushman and O'Reilly III, 1996). Therefore, we expect firms adopting RPE excel at exploiting existing products and at exploring new opportunities.

As for innovation quality, we adopt the scope variable proposed by Katila and Ahuja (2002), originality proxy and generality proxy proposed by Trajtenberg, Henderson, and Jaffe (1997). First, the scope variable is defined as the ratio for the number of new citations made by patents firm i applied for in year t divided by the total number of citations made by all patents applied for in year t:

$$SCOPE_{i,t} = \frac{NEWCITE_{i,t}}{CITE_{i,t}} \tag{3}$$

where $NEWCITE_{i,t}$ is the number of new citations made by patents firm i applied for in year t, and $CITE_{i,t}$ is the total number of citations made by all patents applications in year t. Note that new citations are ones that have never been made by the firm in the past five years.

Second, the originality proxy is calculated the maximum of originality scores of all patents filed by firm i in year t. The originality score is defined as one minus the Herfindahl index of the technology category distribution of all patents that have been cited by this particular patent:

$$ORI_{i,t} = 1 - CITEDHHI_{i,t} \tag{4}$$

where $CITEDHHI_{i,t}$ is the Herfindahl index of the citations made by the patents applied for in a given year by a firm based on three-digit technology classes. A higher value of Originality indicates that the patents cited in the portfolio of patents applied for in a given year by a firm belong to a wider range of technological fields.

The generality proxy is defined as the maximum of generality scores of all patents filed by firm i in year t. The generality score of a patent is computed as one minus the Herfindahl index of the technology category distribution of all patents that have cited this particular patent.

$$GEN_{i,t} = 1 - CITEHHI_{i,t} \tag{5}$$

where $CITEHHI_{i,t}$ is the Herfindahl index of the technology category distribution of all patents that have cited this particular patent. The index will take high values (high generality) if a patent receives citations from subsequent patents that belong to many different technological fields.

Table 3 presents the related results. In Columns (1)–(3), we examine the effect of relative performance evaluation on innovation strategy. All the coefficients of *RPE* are significantly positive, suggesting that the use of relative performance evaluation increases the innovation's diversity, innovation's exploitation, and innovation's exploration. Compared to the simple count of patents and citations in the baseline regression, the results indicate that apart from diversified innovation, adopting relative performance evaluation is capable of simultaneous knowledge management processes, exploiting current competencies and exploring new domains. The significantly positive coefficients of *RPE* in Columns (4)–(6) shows that the quality of innovation is improved under tournament milieu. Specially, the innovation scope is extended and the innovation is more original and more general, which reflects a bolder innovation policy. In sum, by analyzing the innovation strategy and innovation quality, we conclude that the adoption of RPE is also efficient in improving the innovation policies comprehensively rather than only focusing on the patent quantity.

(Insert Table 3 about here)

4.3 Identification Issues

Previous literature regarding the association between compensation incentive and corporate innovation points out the potential endogenous problem. For example, it may not be random that a firm adopt an RPE scheme in CEO compensation contract, and this may cause a self-selection bias. It is also possible that some omitted variables that affect both the adoption of relative performance evaluation and corporate innovation drive the results. Moreover, there is a reverse causality concern that firms with high innovation potential tend to use performance-based incentives to maintain the level of innovation.

In addition to using lagged values of relative performance evaluation in the baseline regression model, in this section, we further address the potential endogeneity issue in several alternative ways, including propensity score matching and Heckman sample selection.

4.3.1 Propensity Score Matching

To mitigate the potential endogeneity bias arising from reverse causality, we compare firms adopting relative performance evaluation (i.e., treatment firms) to a sample of control firms without performance-based incentive (i.e., control firms) matched on the propensity for a firm to adopt relative performance evaluation. The primary benefit of a matched sample using the propensity scores is that it allows us to attribute any more clearly observed effects to the adoption of relative performance evaluation itself, rather than to the firm characteristics associated with RPE adoption.

To identify the matched control sample, we estimate a Logit model using the full sample. The specification of the Logit model is the same as the baseline model, apart from the exogenous variable *RPE* adoption. We use the Logit model to calculate a propensity score of relative performance evaluation adoption for each firm. For each treatment firm, specifically firms that adopt relative performance evaluation, we select one control firm with the closest propensity score and these firms constitute the matched sample. To ensure that the matching is satisfactory, we assess covariate balance by testing whether the means and medians of the covariates used differ between the treatment firms and matched control firms.

In Figure 2, we compare the kernel density of propensity scores between the two groups after matching and find no significant difference. The test of covariate balance in Panel A of Table 4 shows that the matching covariates are not significantly different from each other between the treatment and control groups. The result suggests that the matching procedure has minimized the difference in the firm characteristics between the treatment and the control group.

The results based on the matched sample are reported in Panel B Table 4. The corporate innovation proxies are *LNPATG*, *LNPATA*, and *LNCITE*. The coefficients of our main explanatory variable *RPE* are all significantly positive when we measure innovation by the number of patents and citations, suggesting that the results in baseline regression are not biased by systemic firm characteristics. In a word, the main results of this paper remain robust after controlling the differences in the systemic characteristics of firms based on the matched sample.

(Insert Table 4 about here)

4.3.2 Heckman Selection Model

In our study, whether the firms apply relative performance evaluation in CEO compensation comes from the announcement of the detailed compensation contract in the proxy disclosures. However, the disclosure is not compulsory before the requirement of SEC in 2006, indicating that it's not sure whether firms disclose the details of manager's compensation practices to signal well-running operations or they want to disguise the compensation contracts for specific purposes. The firms included in ISS may be inconsistent with total firms, and it is not clear whether our sample correctly reveals the adoption of RPE in all companies comprehensively.

To mitigate this concern, we employ Heckman (1979) two-stage method to solve the endogenous problem caused by sample selection deviation. In the first step, we estimate a probit model with a binary dummy (*RPE*) as the dependent variable, which equals one if a firm adopt relative performance evaluation and zero otherwise. Apart from the control variables, we also include the percentile and the number of firms that adopt RPE in the same industry to estimate the possibility of the specific firm adopting RPE. Heckman estimator requires exogenous variables correlated with a firm's propensity to adopt a relative performance evaluation scheme, but not with corporate innovation. Note that the percentile and the number of firms that adopt RPE in the same industry are likely to be an important factor for a firm when deciding whether to use the RPE scheme, but less likely to be closely correlated with corporate innovation. The inverse Mills ratio (IMR) is generated from the first step and then included in the second step model to control for the potential sample selection bias. The specification of the second step model is the same as the baseline regression model.

The results in Table 5 present the results of the Heckman Selection Model. In Column (1), the estimated coefficients of the percentage of firms that adopt RPE in the same industry is significantly negative, suggesting that external RPE adoption helps estimate the adoption of the specific firm. In Columns (2)–(4), we include the inverse miller ratio to control the influence of unobservable interference variables. The estimated coefficients of *RPE* are all significant when we use three innovation measures as baseline regression, suggesting that our results are not biased by sample selection issues.

(Insert Table 5 about here)

4.4 Cross-Sectional Analysis

In this section, we examine the heterogeneous association between relative performance evaluation and corporate innovation. According to our hypothesis, the influence of RPE on innovation depends on managerial behaviors. Therefore, we test whether our results depend on the factors that may influence managerial decisions.

Firstly, we examine whether intra-firm tournament incentive influence the association between RPE and corporate innovation because competitors are a historically important and increasingly popular mechanism for encouraging innovation (Boudreau, Lacetera, and Lakhani, 2011). Promotion-based compensation incentive for non-executives is documented to increase R&D and improve innovation efficiency as well (Shen and Zhang, 2018). In a firm where non-executives admit the innovation contest under the motivation the tournament incentives, CEO have strong intention to invest in innovation. Therefore, in firms with a less competitive tournament, we suppose the positive effect of RPE on innovation output is more pronounced.

If a manager is compensated using convex payoff schemes, then his or her expected wealth is an increasing function of firm risk (Cain and McKeon, 2016). This wealth effect should lead to a preference for higher levels of risk, such as innovation investment, which is considered full of risks of failing. Studies document that higher sensitivity of CEO compensation portfolio value to stock volatility (Vega) are more likely to have large increases in R&D investments and high-Vega compensation portfolios may induce managers to overinvest in inefficient R&D projects and therefore hurt firm performance (Coles, Daniel, and Naveen, 2006; Shen and Zhang, 2013; Mao and Zhang, 2018). More innovation output and decreased efficiency may induce a detrimental effect of innovation performance. Since the relative performance evaluation scheme considers operating performance when determining managers' compensation, we conjecture that managers have the incentive to improve the innovation efficiency to gain the future competitive advantage, especially when they have relatively more innovation investment. Therefore, we conjecture that the effect of relative performance evaluation on innovation output is more pronounced in high-Vega firms, where CEOs are more likely to invest more innovation expenditure and alleviate the inefficiency of over-investment since their award is closely related with firm performance.

The results are presented in Table 6. Consistent with our conjecture, the positive association between relative performance evaluation and corporate innovation only exists in firms with more promotion-based incentives and a manager who is more risk-taking. Specifically, in Columns (1)–(2), the coefficients of explanatory variable *RPE* are significantly positive only in firms with less promotion-based incentives for VPs. The results indicate that the influence of relative performance evaluation on innovative investment is closely related to internal cooperation conditions. Previous literature shows that the existence of inter-executive pay disparity is influential to managerial behaviors and innovation that requires teamwork and the engagement of all executives (Jia, Tian, and Zhang, 2016). Our result shows that the enhancement of RPE on innovation manifests in firms with a atmosphere where cooperation is more accessible. In Columns (3)–(4), the results show that the influence of relative performance evaluation on corporate innovation is more pronounced in firms with more risk-taking incentives for managers. Since innovation is risky, unpredictable, long-term, and multistage, posing severe challenges to the design of incentive contracts (Holmstrom, 1989), it is axiomatic that more risk incentives encourage risky managerial behaviors, intensifying the effect of RPE on innovation. In conclusion, the cross-sectional analysis provides an insight into the characteristics that are possibly associated to the underlying mechanism.

(Insert Table 6 about here)

4.5 Possible Mechanism

We try to explore the mechanisms of the relationship by focusing on the factors of innovation and examining the influence of managerial risk appetite in the association. We can draw a preliminary conclusion that the effect of improved internal information quality and the improved ability to undertake the risk of rent skim may be possible channels of the relationship between relative performance evaluation and corporate innovation.

First, the tournament induced by the RPE scheme improves information quality through tournament incentives, which is an important driver of innovation. Extensive literature has identified external factors of that alter managers incentives to innovate (Atanassov, 2013; Aghion, Van Reenen, and Zingales, 2013). Moreover, there is evidence that the tournament-like progression in the CEO labor market positively influences corporate innovation strategies (Lonare, Nart, and Kong, 2019; Kong, Lonare, and Nart, 2020; Nguyen and Zhao, 2021). Product market competition between firms positively affects and accounting information quality, which is an essential driver of innovation (Huang, Lao, and McPhee, 2020). Thus, we expect the internal information environment acts as a possible mechanism in the relationship between relative performance evaluation and innovation.

Second, increased risk-taking also acts as a possible mechanism. According to agency theory, RPE filters out common noise from the CEO's performance (Holmström, 1979; Holmstrom, 1982; Jensen and Murphy, 1990; Aggarwal and Samwick, 1999). Empirical evidence also shows that the firm's riskiness is altered by its CEO's incentive to win the tournament (Do, Zhang, and Zuo, 2021). Since innovation is characterized by a high failure rate (Bowers and Khorakian, 2014), we conjecture that the incentive use of the RPE increases managerial risk-taking and introduces more innovation.

This section performs mediation analyses to identify the underlying channels of internal information quality and CEO risk-taking that affects corporate innovation. Specifically, we apply a standard two-step mediation analysis approach formulated as follows:

$$M_{i,t} = \beta RPE_{i,t} + \gamma X_{i,t} + \delta_i + \theta_t + \varepsilon_{i,t} \tag{6}$$

and

$$Y_{i,t+1} = \beta RPE_{i,t} + \alpha M_{i,t} + \gamma X_{i,t} + \delta_i + \theta_t + \varepsilon_{i,t+1}, \tag{7}$$

where $Y_{i,t+1}$ denotes the corporate innovation measure *LNPATG* of firm i in year t+1, and M denotes the mediating variables.

In the first step, the association between RPE adoption and internal information quality or CEO risk-taking is investigated. In the second step, the innovation measure is regressed on relative performance evaluation, mediating variables, absolute performance evaluation proxy, and other firm characteristics. As for the internal information quality proxy, *IIQ* is calculated as the number of days between the end of the fiscal year and the earnings announcement date,divided by 365 and multiplied by negative one (Gallemore and Labro, 2015). A high value of the index indicates that firms have a higher level of internal information quality. Based on John, Litov, and Yeung (2008), we construct the CEO risk-taking proxy *ROARISK*, which is defined as the company earnings volatility. A high value of the index represents a high level of corporate risk-taking. The mediating effect holds if the coefficients of *RPE* and the mediating variables are statistically significant.

Table 7 presents the results of the mediation analyses. Column (1) repeats our baseline results that relative performance evaluation has a positive and significant association with corporate innovation. The coefficient of *RPE* when we use internal information quality proxy as dependent variable is significantly negative at the 1%, with a t-statistic of -3.36, indicating that the adoption of RPE improves internal information quality. In Column (3), the RPE scheme is positively associated with CEO risk-taking index *ROARISK*, and the coefficient of *RPE* is significant at the 1% level (t-statistic = 4.65). The finding indicates that firms that adopt relative performance evaluation are associated with a high degree of risk-taking, which may derive from the decrease of common risk factors and CEOs' reluctance to risk.

In Column (4), we include the two mediating variables in the regression and compare the relative explanatory power of the two possible underlying mechanisms. Consistent with the results when we include possible channels, respectively, the coefficient of *IIQ* is significantly negative and that of *ROARISK* is significantly positive. The result suggests that the mediating effect rarely (12.18%) comes from improved internal quality, whose mediating effect is statistically significant at the 1% level. Most (87.82%) of the mediating effect comes from CEO risk-taking, and the effect is significant at the 1% level. The findings of the mediation analyses demonstrate that the relative performance evaluation affects corporate innovation mainly through the increased degree of CEO risk-taking and improved internal information quality. A higher level of internal information quality ensures innovation efficiency, and the risk-taking ability motivates managers to engage in more innovative investment.

(Insert Table 7 about here)

4.6 Robustness Checks

To examine the robustness of the expected positive association between relative performance evaluation and corporate innovation, we perform several additional tests in this section.

4.6.1 Additional Controls

To test the robustness of our results, we include several factors associated with corporate innovation from the perspective of managers and corporate governance. Considering the fact that individuals such as CEOs set their strategies as a function of their attributes, it is increasingly popular for accounting and finance researchers to explore the manager characteristics that are associated with corporate innovation. Building on recent literature, CEO characteristics that can influence innovation come from CEO personality (such as overconfidence), CEO demographics (such as age and gender), CEO experience (such as tenure), and CEO compensation (You et al., 2020). Thus, we select several CEO-level characteristics that are detrimental to innovation, including the logarithm of the CEO's total compensation (Lerner and Wulf, 2007), the logarithm of CEO age (Sheikh, 2012; Jia, 2017), the logarithm of CEO tenure (Sunder, Sunder, and Zhang, 2017; Jia, 2017), and a dummy variable to identify CEO gender (You et al., 2020; Expósito, Sanchis-Llopis, and Sanchis-Llopis, 2021).

As for another set of additional controls, we control CEO duality (Jia, 2017), board independence (Chen et al., 2016), and the natural logarithm of the compensation of the highest paid executives. Corporate governance and CEO duality are documented act as an essential role in mediating the relationship between innovation and firm performance (Jermias, 2007). According to our analysis in previous sections, an important purpose of innovation is to gain a competitive advantage and improve performance. Thus, it is necessary to control the corporate governance, which is detrimental to the association between innovation and financial performance. Finally, we test whether the association remains positive when we include all the managerial factors and corporate governance factors mentioned above.

The results are presented in Table 8. The significantly positive coefficients of *RPE* in Columns (1) and (2) suggest that our results remain positive when we further control managerial factors and corporate governance, respectively. When we include all the factors regarding managers and corporate governance mechanisms, we find robust results as well.

(Insert Table 8 about here)

4.6.2 Alternative Relative Performance Evaluation Measure

We plan to evaluate the sensitivity of association between relative performance evaluation and corporate innovation to another two alternative selections of RPE measures. Following Antle and Smith (1986), we construct an implicit RPE measure (i.e., *RPER*) by calculating the t-statistic of the percentile of *TSR* in the same industry in the regression with CEO total compensation as the dependent variable. Specifically,

$$LNTDC_{i,t+1} = \alpha + \beta TSR_{i,t} + \gamma CDFTSR_{i,t} + \delta LNSIZE_i + \varepsilon_{i,t+1}, \quad (8)$$

where *LNTDC* is the natural logarithm of the total compensation of the CEO, *TSR* is the total shareholder return, *CDFTSR* is the percentage of total shareholder return in the industry. Rewarding CEOs for taking actions that increase shareholder wealth implies that $\beta > 0$. RPE adoption implies that CEO pay revisions should be negatively related to the industry and market return. *RPER* is a dummy variable defined as whether γ is negatively related to the industry and market return.

Moreover, we use another proxy to capture the incentive effect of relative performance evaluation based on detailed information of performance-based awards provided by ISS. Specifically, we use the total fair value of the plan-based awards for CEOs scaled by total assets. Compared to the binary variable in baseline regression and the estimated proxy from the implicit approach, this absolute measure of relative performance evaluation captures the direct motivation provided by plan-based awards in the RPE scheme.

Table 9 presents the relevant results. In this section, we use *TGETR* to measure corporate tax avoidance. According to Columns (1) and (3), only the coefficients of *PEER* remain significantly positive while the estimated coefficients of *INDEX* are not significant. The result indicates that only RPE contracts that use peer groups as benchmarks increase corporate tax avoidance. The result is consistent with our hypothesis, suggesting that the tournament effect between the corporate and its peers in the CEO compensation contract motivates the CEO to engage in more tax avoidance. The result provides supportive evidence that the influence of RPE on corporate tax avoidance is mainly driven by the RPE adoption of peer group benchmarks.

(Insert Table 9 about here)

4.6.3 Model Specifications and Estimation Technique

In this section, we test whether our main results are robust to alternative model specifications and estimation techniques. In baseline regression, we adopt the ordinary least squares (OLS) estimation. The OLS regression model assumes that a normally distributed continuous variable underlies each ordinal variable when performing hypothesis testing. When the distribution of the dependent variable is censored and truncated, ordinary least squares in this setting give biased and inconsistent estimates of the coefficients (Greene, 1981). The assumption of the dependent variable in our sample is not satisfied because the number of firm innovation is positive or zero. Since the observations of innovation output outside zero are censored and constrained, we use the Tobit model to examine the relationship between the use of relative performance evaluation and corporate innovation.

Tobit regression is proposed by Tobin (1958) that has been increasingly adopted to correct the information in the truncated error terms (McDonald and Moffitt, 1980). Tobit model assumes that the dependent variable has a number of its values clustered at a limiting value, usually zero, which is precisely the case of innovation. The Tobit technique uses all observations, both those at the limit and those above it, to estimate a regression line. It is to be preferred, in general, over alternative techniques that estimate a line only with the observations above the limit (McDonald and Moffitt, 1980). In this section, we estimate the Tobit regression following the method of innovation-related studies (Lin et al., 2011; Chen, Leung, and Evans, 2018; He and Hirshleifer, 2019; Liu, Sun, and Zeng, 2020). We expect a significantly positive association between RPE adoption and innovation when using Tobit model as an alternative estimation method.

The relevant results are presented in Table 10. The dependent variables are the same as the baseline regression, including the number of granted patents, applied patents, and the number of citations. The coefficients of the independent variable are positive at the 1% level, indicating that the impact of RPE adoption in CEO compensation contracts on corporate innovation is insensitive to the estimation method. Moreover, the economic magnitude is slightly smaller than the baseline when we use the OLS model, which tends to overestimate the impact of RPE on corporate innovation.

(Insert Table 10 about here)

4.6.4 Sampling Criteria

Previous literature also provides many kinds of sample selection as a robustness check. Following Chang et al. (2015), we exclude firm-year observations with zero patent applications. Besides, we exclude firms engaging in mergers and acquisitions (identified using the SDC M&A database) in the previous two years following the method of Chen, Leung, and Evans (2018). According to (Chang et al., 2015), we exclude industries with below-median average citations per patent. Finally, we exclude the firms in the telecommunication (SIC code 4810-–4813) and energy (SIC code 1200–1399, 2900-–2999) industries following Sunder, Sunder, and Zhang (2017).

Table 11 reports the relevant results. In our baseline regression, we use 3-digit SIC as industry classification when controlling industry fixed effects. As for robustness check, we use

2-digit SIC and Fama-French 48 industry classifications in Columns (1) and (2), respectively. In Column (3), we control the firm fixed effect instead of the industry fixed effect to check whether omitted firm factors cause more tax avoidance. Column (4) further controls CEO characteristics, including the total compensation, age, tenure, gender, and the sensitivity of the CEO's option portfolio value to stock price. The positive association between RPE and tax avoidance remains quantitatively similar when the regression models are altered. We contend that our findings are robust after accounting for industry-level characteristics, firm effects, and CEO characteristics that may affect tax avoidance.

(Insert Table 11 about here)

4.7 Further Discussion

4.7.1 Innovation Efficiency

To identify the mechanism through which CEOs contribute to innovation output in the presence of relative performance evaluation, we examine whether they achieve higher levels of patenting activity from higher innovation efficiency and further explore which kind of award is more efficient in improving innovation efficiency.

First, we examine whether CEOs achieve better innovation outcomes by improving innovation productivity. The incentive effect of RPE and the talent retention purpose can both provide an explanation for the improved efficiency. On the one hand, the RPE scheme creates tournament competition between firms, which reduces the firm inside conflict and positively affect the cooperation levels (Rapoport and Bornstein, 1987; Bornstein and Ben-Yossef, 1994; Erev, Bornstein, and Galili, 1993; Bornstein and Ben-Yossef, 1994). Not only a more cooperative atmosphere between different departments across the firm, the relationship between agents and principles is also aligned by the RPE scheme according to agency theory (Jensen and Meckling, 1976; Holmström, 1979; Holmstrom, 1982; Jensen and Murphy, 1990). In other words, executives are motivated to invest a future competitive advantage by engaging in a effective corporate innovation. If intrinsic motivation provided by RPE scheme encourages CEOs to engage in innovation activities to win tournaments, we expect that they tend to improve the innovation efficiency by investing innovation investment with more productive output. Moreover, since the outcome of an agent's action choice, specifically, innovation output, can only be observed with a considerable lag, it seems that long-term reward is more useful to facilitate long-term innovation success (Holthausen, Larcker, and Sloan, 1995; Manso, 2011). Thus, we hypothesize that the adoption of relative performance evaluation scheme encourages the executives to improve innovation efficiency to gain future competitive advantage in the tournament, and the relationship is more pronounced if managers have more long-term incentives in their compensation.

On the other hand, the aim of talent retention can also provide an explanation for improved innovation efficiency. De Angelis and Grinstein (2020) support theories predicting that RPE is used to pay CEOs for their talent relative to peers. Managers use the innovation output to prove their ability since innovation activities require the talent or qualification to identify opportunities and make decisions to invest (Lewin, Massini, and Peeters, 2009). the existence of executive stock option, which is more common in long-term incentive plan, increases the firm's growth opportunities (Smith Jr and Watts, 1992).

We adopt the granted patents per employed inventor to capture the innovation efficiency following Chen et al. (2016). Using the Harvard Business School Patent and Inventor database, we identify an inventor as employed by a particular firm at time period t if they file at least one patent for this firm during $t-3$ to t and files at least one patent during t to $t+3$. As for long-term and short-term incentives, we use proxies of compensation mix derived from Balsam et al. (2016). Following the ideas of Holthausen, Larcker, and Sloan (1995), we construct the currency amount of long-term incentive plan (LITP) scaled by total compensation of the CEO to capture the long-term incentives. Similarly, we use the currency amount of the non-equity incentive plan scaled by the total compensation of the CEO to measure the short-term incentives.

The relevant results are presented in Table 12. In Column (1), we investigate the influence of RPE adoption on innovation efficiency using the dummy variable. The estimated coefficient is significantly positive at the 1% level, indicating the using relative performance evaluation motivates managers to improve innovation efficiency. In Columns (2) and (3), the coefficient of short-term incentives is significantly negative but positive when the explanatory variable is long-term incentives. The results are consistent with our conjecture, suggesting that the effect of short-term incentives on aligning interests between managers and shareholders is not as efficient or even exacerbating agency conflicts, thus hurting innovation productivity. The role of long-term incentive in promoting innovation efficiency indicates that long-term incentives are more suitable to improve innovation efficiency, whose outcome is relative lagged. Moreover, the results also proves that managers prove their talent by improving innovation productivity in the RPE scheme.

(Insert Table 12 about here)

4.7.2 Compensation Scheme and Innovation Incentive

In this section, we examine the effect of different managerial incentives on corporate innovation. Specifically, we compare pay-for-performance sensitivity, relative performance evaluation (i.e., pay-for-target-performance sensitivity), and two specific incentives in the RPE scheme, namely, long-term incentive and short-term incentive. Compared to the RPE scheme, pay-for-performance sensitivity simply use the individual performance when determining the CEO compensation and ignore the effect of possible rivals. However, the contest is a historically important mechanism for encouraging innovation (Boudreau, Lacetera, and Lakhani, 2011). Therefore, we expect that the effect of the RPE scheme on innovation output is more pronounced than pay-for-performance sensitivity. As for the two different incentives that reward managers in different periods, we expect a more pronounced association between long-term incentive and innovation than short-term incentives because long-term incentives is more suitable for long-term success since the outcome of innovation investment is lagged (Holthausen, Larcker, and Sloan, 1995; Manso, 2011). Previous studies also show more long-term incentives (such as stock options and restricted stock) are associated with more innovation output (Lerner and Wulf, 2007).

We use *CEOATAX* to measure the existence of pay-for-performance sensitivity following (Gaertner, 2014). The proxy of relative performance evaluation is the dummy variable used in baseline regression, following Carter, Ittner, and Zechman (2009). In terms of incentives for different success achieved in different terms, we use a long-term incentive plan for long-term incentive and s non-equity incentive plan for short-term incentive.

The related results are presented in Table 13. In Columns (1)–(2), we compare the effect of relative performance evaluation and the simple pay for performance compensation structure. The coefficient of *RPE* is significantly positive, while that of the pay for performance proxy *CEOATAX* is insignificant, indicating that the impact of relative performance evaluation on innovation is not driven by tying CEO compensation to corporate performance, but more complicated channels. In Column (3), when we include the proxies of these two compensation schemes at the same time, the result is similar to that when we include proxies separately. The empirical evidence excludes the possibility that the standard pay-for-performance acts as the core driver of innovation in the association between RPE and corporate innovation since many kinds of compensation is documented as detrimental to corporate innovation (Coles, Daniel, and Naveen, 2006; Manso, 2011; Baranchuk, Kieschnick, and Moussawi, 2014), especially pay-for-performance sensitivity (Sheikh, 2012). Accordingly, we demonstrate that the tournament that is unique to RPE is probably the dominating factor that encourage innovation, rather than associating CEO compensation to pre-defined performance metrics.

Columns (4)–(6) present the results about the relative effect of different components in RPE incentives on encouraging innovation. In Column (4) and Column (5), we examine the effect of short-term and long-term incentive on the number of granted patents, respectively. The estimated coefficient of short-term incentive measure *NONEQINCT* is -0.3629, which is significant at the 1% level (t-statics= -2.25). By contrast, the coefficient of long-term incentive proxy *LTINCT* is significantly positive at the 1% level, with a t-statics of 4.73. The results remain similar when we include the two kinds of incentives in the regression simultaneously. The results are consistent with the conclusion in previous literature that a long-term compensation plan is an essential ingredient to motivate innovation (Manso, 2011).

(Insert Table 13 about here)

4.7.3 RPE, Corporate Innovation, and Firm Performance

In a relative performance evaluation scheme, the grant of the performance-based award is directly determined by the achievement of the pre-defined performance goal. Therefore, the influence of investment decisions made by the executive on the performance metric should be taken into consideration if the executive is aimed at gaining excess bonus from the RPE scheme. Innovation is no exception since R&D expenditures are widely understood as an investment activity (Hall, Jaffe, and Trajtenberg, 2005), which improves future performance and reduces the variability of future earnings (Pandit, Wasley, and Zach, 2011). The empirical evidence also shows that participants compensated under a tournament incentive scheme perform better, compared to participants compensated under an individual incentive scheme (Hannan, Krishnan, and Newman, 2008; Kale, Reis, and Venkateswaran, 2009; Coles, Li, and Wang, 2018). Therefore, we expect that innovation in firms incorporating relative performance evaluation as a part of corporate governance tool improves firm performance.

We also try to examine the influence of innovation in RPE-firms on the amount of firm value. In the principle-agent structure of firm, managers can manage resources to their own advantage because they are delegated with decision rights from shareholders. Whether managers adopt policies conducive to shareholder wealth and how to motivate managers to act in shareholders' interest are commonly investigated. Closely associated with managerial behaviors, the link between job satisfaction and firm value is of great interest to academics and practitioners (Edmans, 2012). As an essential part of employee treat associated with job satisfaction, adopting performance-based incentive in the RPE scheme is closely related to the value-increasing activities of the firms. The agency theory predicts that performance-based incentive plans helps align the interests of shareholders and managers and motivate managers to conduct value-increasing activities (Jensen and Meckling, 1976; Jensen and Murphy, 1990).

However, Manso (2011) documents that incentive schemes that motivate innovation are structured differently from standard pay-for-performance schemes used to induce effort or to avoid tunneling. Specifically, long-term compensation plans and timely feedback on performance are essential ingredients to motivate innovation (Manso, 2011). In short, the optimal incentive structure that motivates innovation is different from the optimal incentive structure that aligns the interests of shareholders and managers. Therefore, it is possible that incentives that motivate corporate innovation in RPE schemes are useless in increasing firm value. Moreover, even though the executive compensation contracts are written by shareholders whose objective is to maximize the value of their shares (Aggarwal and Samwick, 1999), whether managers engage in innovation investment is directly derived from their own goal.

We test the influence of corporate innovation on firm performance and shareholder value in RPE-firm with the following equation:

$$Z_{i,t+1} = \alpha RPE_{i,t} + \beta Y_{i,t} + \epsilon RPE_{i,t} * Y_{i,t} + \gamma X_{i,t} + \delta_i + \theta_t + \varepsilon_{i,t+1}, \tag{9}$$

where $Z_{i,t+1}$ denotes the operating performance proxy *CF*, calculated as income before extraordinary items minus total accruals divided by average total assets (Hirshleifer, Hsu, and Li, 2013), and firm value proxy *TOBINQ*, defined as the Tobin's Q of the focal firm (Desai and Dharmapala, 2006). $Y_{i,t}$ denotes the corporate innovation output.

Table 14 presents the relevant results. The coefficients of the interaction term are all positive and significant at the 10% level in Columns (1)–(3), implying that corporate innovation in the RPE compensation structure improves operating performance. Even though the compensation arrangement can be agency conflicts itself. Our result indicates that RPE alleviates agency conflicts as a whole. In other words, the effect of incentive contracts on exacerbating agency conflicts is less pronounced than the alleviating effect. This result also supports our findings in Section 4.6 that dismissal probability is a channel through which tax avoidance by firms that adopt RPE aligns the interests between CEOs and shareholders. Besides, the results in Columns (3) and (4) suggest that tax avoidance helps improve firm value in the presence of RPE. The results indicate that the tax avoidance in relative performance evaluation scheme is mainly driven by the strong incentive for managers to work for the shareholders' best interests.

(Insert Table 14 about here)

5 Conclusion

Increasing research is focusing on the influence of RPE after the available compensation structure data collected by ISS. Apart from focusing on the fact that the RPE scheme ties the CEO compensation to firm performance, it is increasingly popular to pay close attention to the tournament among the focal firm and its peers when examining the effect of the relative performance evaluation. In terms of the tournament among focal firm and its peers, it is vital for managers to beat the rivals and win the tournament of which the result is directly detrimental to the amount of the compensation. As an essential factor of competitive advantage over the rivals, corporate innovation may be introduced by managers under the relative performance evaluation structure. This study aims to shed light on the association between the adoption of relative performance evaluation and the outcome of corporate innovation.

We find that firms adopting relative performance evaluation in CEO compensation contracts have a higher level of innovation output. Besides, the innovation policy tends to be more diversified, exploitative, and exploratory simultaneously. The innovation quality is improved simultaneously, which is reflected in the patent scope, originality, and generality. The result indicates that RPE induces tournament, which is detrimental to managerial decisions. The mediation analysis shows RPE improves the internal information quality and increases the CEO's risk-taking, which are both consequential to innovation outcome. A heterogeneous effect of RPE adoption exists, such that firms with lower internal promotion-based incentives and more risk-taking incentives tend to exhibit a great association between RPE adoption and corporate innovation. Furthermore, RPE helps increase innovation efficiency and the driving force in the RPE scheme is long-term incentives. We also compare RPE with standard pay for performance incentive and find that the effect of pay for performance on innovation is insignificant. Finally, we document that the innovation in firms that adopts RPE improves operating performance but is inefficient to increase firm value. Our findings remain robust to endogeneity issues, alternative variable definitions, alternative model specifications, and alternative sampling criteria.

Our findings provide suggestions for corporate insiders who want to hire managers to improve innovation. Besides, our results call on investors to pay attention to the role of executive compensation incentives in innovation, which is a vital part of corporate governance. Our findings also provide policy implications for regulatory agencies to address managers' appetite for innovation policies.

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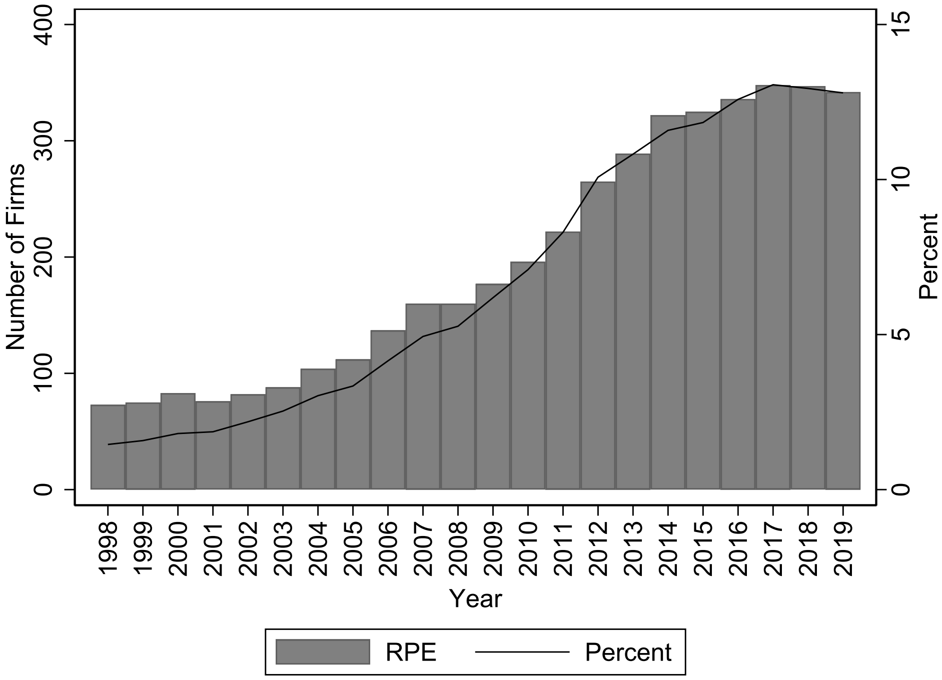

Figure 1: Time-Series Pattern of RPE

The figure shows the time-series average of the number and percentage of firms that adopt RPE from 1998–2019.

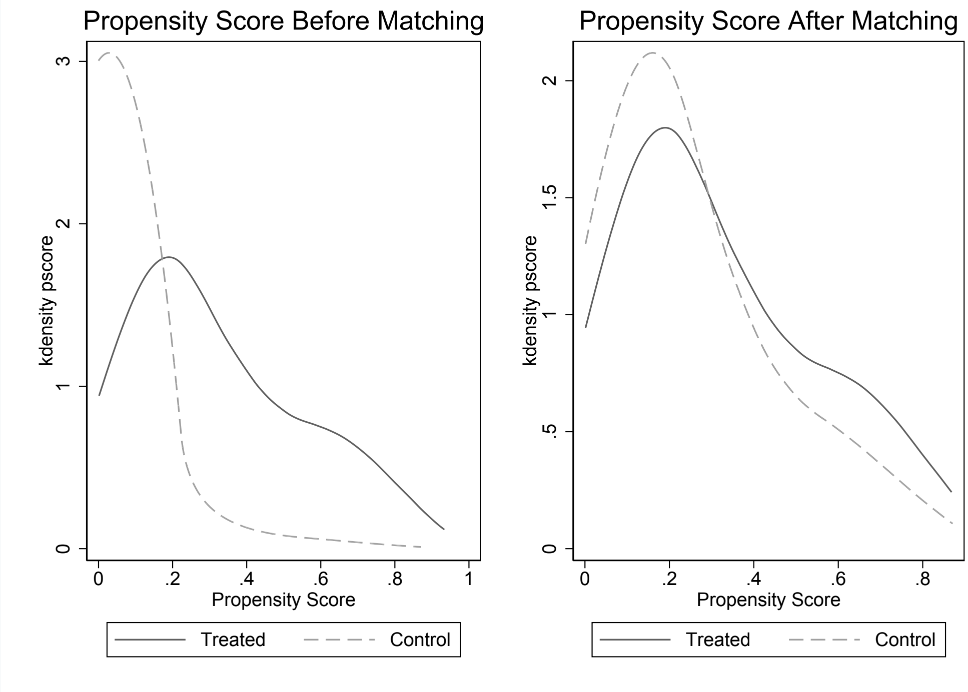

Figure 2: Kernel Density of Propensity Score Before and After Matching

Table 1: Descriptive Statistics

This table presents the descriptive statistics and Spearman correlation matrix for a sample of U.S.-listed firms from 1998 to 2019. The detailed variable definitions are presented in Table A1.

Panel A. Summary Statistics

	Mean	S.D.	Q5	Q25	Median	Q75	Q95	N
LNPATG	0.872	1.293	0.000	0.000	0.000	1.386	3.761	64,798
LNPATA	0.911	1.224	0.000	0.000	0.693	1.099	3.689	64,798
LNCITE	1.871	2.346	0.000	0.000	0.693	3.526	6.589	64,798
RPE	0.066	0.249	0.000	0.000	0.000	0.000	1.000	64,798
ABS	0.189	0.392	0.000	0.000	0.000	0.000	1.000	64,798
LNSIZE	5.786	2.056	2.509	4.266	5.734	7.247	9.327	64,798
LNAGE	2.379	1.046	0.693	1.609	2.485	3.178	3.850	64,798
LEV	0.218	0.223	0.000	0.011	0.170	0.344	0.644	64,798
ROA	-0.074	0.326	-0.682	-0.077	0.026	0.072	0.161	64,798
MTB	3.077	5.559	0.096	1.122	2.008	3.663	10.829	64,798
CAPX	0.050	0.058	0.004	0.015	0.031	0.060	0.166	64,798
RD	0.068	0.136	0.000	0.000	0.008	0.079	0.326	64,798
SG	0.083	0.370	-0.443	-0.041	0.067	0.196	0.646	64,798
TANG	0.236	0.221	0.018	0.070	0.160	0.330	0.746	64,798
CASH	0.214	0.232	0.005	0.035	0.123	0.320	0.729	64,798
INSTHOLD	0.427	0.367	0.000	0.005	0.405	0.776	0.982	64,798
HHI	0.091	0.079	0.039	0.045	0.057	0.107	0.268	64,798
HHISQ	0.015	0.033	0.002	0.002	0.003	0.012	0.072	64,798

Panel B. Spearman Correlation Matrix

	LNPATG	RPE	LNSIZE	LNAGE	LEV	ROA	MTB	CAPX	RD	TANG	CASH	INSTHOLD	HHI
LNPATG	1.00												
RPE	0.27***	1.00											
LNSIZE	0.36***	0.38***	1.00										
LNAGE	0.30***	0.22***	0.31***	1.00									
LEV	-0.03***	0.09***	0.25***	0.05***	1.00								
ROA	0.07***	0.10***	0.43***	0.25***	-0.03***	1.00							
MTB	0.05***	0.01***	-0.02***	-0.08***	-0.10***	-0.04***	1.00						
CAPX	-0.11***	0.01***	0.05***	-0.07***	0.11***	0.02***	-0.01**	1.00					
RD	0.13***	-0.08***	-0.36***	-0.19***	-0.14***	-0.64***	0.12***	-0.12***	1.00				
TANG	-0.13***	0.08***	0.19***	0.09***	0.30***	0.12***	-0.09***	0.64***	-0.26***	1.00			
CASH	0.08***	-0.11***	-0.34***	-0.28***	-0.37***	-0.34***	0.17***	-0.21***	0.56***	-0.42***	1.00		
INSTHOLD	0.22***	0.18***	0.53***	0.19***	0.02***	0.29***	0.04***	-0.04***	-0.15***	-0.01***	-0.09***	1.00	
HHI	-0.09***	0.04***	0.15***	0.08***	0.09***	0.11***	-0.05***	0.09***	-0.21***	0.22***	-0.21***	0.04***	1.00

Table 2: Relative Performance Evaluation and Corporate Innovation

This table presents the association between the adoption of relative performance evaluation and corporate innovation for a sample of U.S. listed firms from 1998 to 2019. The dependent variables include *LNPATG*, *LNPATA*, and *LNCITE*. The main explanatory variable *RPE* is a dummy variable that equals one for firms that adopt relative performance evaluation for CEO compensation and zero otherwise. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTHOLD* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust *t*-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1) LNPATG	(2) LNPATA	(3) LNCITE
RPE	0.3837***	0.2365***	0.6273***
	(6.09)	(3.94)	(6.58)
ABS	0.2589***	0.2533***	0.4188***
	(6.64)	(6.67)	(6.20)
LNSIZE	0.2853***	0.2839***	0.4487***
	(22.96)	(22.61)	(24.52)
LNAGE	0.2069***	0.1758***	0.5633***
	(16.49)	(14.69)	(26.08)
LEV	-0.1276**	-0.2343***	-0.1733**
	(-2.54)	(-5.04)	(-1.97)
ROA	0.0065	0.0003	-0.0729
	(0.24)	(0.01)	(-1.38)
MTB	0.0045***	0.0065***	0.0092***
	(3.62)	(5.36)	(4.27)
CAPX	0.6779***	0.7537***	1.4308***
	(4.44)	(5.04)	(5.05)
RD	1.7030***	1.4986***	2.9220***
	(17.32)	(16.69)	(16.01)
SG	-0.0649***	-0.0107	-0.0205
	(-5.94)	(-1.08)	(-1.02)
TANG	-0.3366***	-0.3137***	-0.7126***
	(-4.00)	(-3.83)	(-4.73)
CASH	0.6023***	0.6006***	1.4027***
	(10.31)	(10.86)	(12.66)
INSTHOLD	-0.1064**	-0.1075***	0.0263
	(-2.51)	(-2.59)	(0.36)
HHI	0.8909*	0.4532	-0.3445
	(1.80)	(1.04)	(-0.47)
HHISQ	-0.6686	0.2001	1.6524
	(-0.66)	(0.22)	(1.04)
Industry FE	Y	Y	Y
Year FE	Y	Y	Y
Observations	64,798	64,798	64,798
Number of Firms	7,857	7,857	7,857
Adjusted R^2	0.33	0.33	0.35

Table 3: Innovation Strategy and Patent Quality

This table presents the how the relative performance evaluation affects corporate innovation strategy and patent quality for a sample of U.S.-listed firms from 1998 to 2019. The dependent variables in Panel A include *PATDIV*, *LNEXPLOIT*, and *LNEXPLOR*. The dependent variables in Panel B include *SCOPE*, *ORI*, and *GEN*. The main explanatory variable *RPE* is a dummy variable that equals one for firms that adopt relative performance evaluation for CEO compensation and zero otherwise. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTHOLD* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust t-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	Innovation Strategy			Patent Quality		
	(1) PATDIV	(2) LNEXPLOIT	(3) LNEXPLOR	(4) SCOPE	(5) ORI	(6) GEN
RPE	0.0504***	0.2640***	0.2497***	0.0217**	0.0558***	0.0366***
	(3.43)	(4.41)	(4.25)	(2.43)	(4.25)	(3.10)
ABS	0.0706***	0.1876***	0.2140***	0.0112	0.0560***	0.0434***
	(6.46)	(5.43)	(5.91)	(1.60)	(5.68)	(5.13)
LNSIZE	0.0713***	0.2167***	0.2651***	0.0284***	0.0612***	0.0586***
	(27.19)	(17.91)	(22.01)	(17.36)	(26.08)	(26.14)
LNAGE	0.0209***	0.1110***	0.0649***	0.0174***	0.0244***	0.0163***
	(6.49)	(10.19)	(5.79)	(7.96)	(8.23)	(6.26)
LEV	-0.0513***	-0.1449***	-0.2334***	-0.0422***	-0.0646***	-0.0607***
	(-3.96)	(-3.52)	(-5.50)	(-4.95)	(-5.50)	(-5.94)
ROA	0.0296***	0.0114	0.0065	0.0272***	0.0215***	0.0157**
	(3.84)	(0.53)	(0.28)	(4.57)	(2.85)	(2.42)
MTB	0.0020***	0.0064***	0.0067***	0.0007***	0.0021***	0.0020***
	(5.82)	(5.88)	(5.80)	(3.11)	(6.53)	(7.07)
CAPX	0.2169***	0.7372***	0.7090***	0.0352	0.1772***	0.1270***
	(5.29)	(5.97)	(5.22)	(1.19)	(4.68)	(3.68)
RD	0.4322***	0.9466***	1.1001***	0.2191***	0.3965***	0.3373***
	(15.43)	(11.92)	(13.50)	(11.82)	(15.83)	(15.56)
SG	0.0017	-0.0127	-0.0093	0.0035	0.0055	0.0027
	(0.49)	(-1.63)	(-1.01)	(1.11)	(1.64)	(0.90)
TANG	-0.0664***	-0.2053***	-0.2257***	-0.0155	-0.0520***	-0.0208
	(-3.20)	(-3.04)	(-3.15)	(-1.14)	(-2.69)	(-1.27)
CASH	0.1841***	0.3766***	0.4770***	0.0691***	0.1770***	0.1528***
	(11.18)	(7.77)	(9.32)	(6.07)	(11.69)	(11.72)
INSTHOLD	0.0097	-0.1340***	-0.1167***	0.0120*	0.0123	0.0054
	(0.88)	(-3.60)	(-2.98)	(1.65)	(1.22)	(0.59)
HHI	0.0325	1.4004***	0.1169	-0.2085**	0.0018	-0.1691
	(0.24)	(3.45)	(0.28)	(-2.08)	(0.01)	(-1.62)
HHISQ	0.2418	-1.8347**	0.6541	0.4558**	0.2090	0.6404***
	(0.87)	(-2.24)	(0.78)	(2.29)	(0.84)	(2.92)
Controls	Y	Y	Y	Y	Y	Y
Industry FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	64,798	64,798	64,798	64,798	64,798	64,798
Number of Firms	7,857	7,857	7,857	7,857	7,857	7,857
Adjusted R^2	0.24	0.26	0.28	0.06	0.20	0.19

Table 4: Propensity Score Matching

This table presents the association between relative performance evaluation and corporate innovation for a matched sample of U.S. listed firms from 1998 to 2019. We define firms adopting RPE as the treatment group and rest of the firms as the control group. The matched sample is constructed by employing the one-to-two nearest neighborhood matching technique using the same set of control variables as the matching covariates. The dependent variables include *LNPATG*, *LNPATA*, and *LNCITE*. The main explanatory variable *RPE* is a dummy variable that equals one for firms adopting RPE and zero otherwise. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTHOLD* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust *t*-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Covariate Balance

	Sample	Control	Treatment	Diff	T-stats
LNSIZE	Full	5.47	8.78	-3.31	-168.66
	Matched	8.42	8.77	-0.35	-1.56
LNAGE	Full	2.15	3.24	-1.08	-74.22
	Matched	3.10	3.25	-0.15	-0.91
LEV	Full	0.21	0.29	-0.08	-28.59
	Matched	0.29	0.29	-0.00	-0.02
ROA	Full	-0.11	0.05	-0.16	-78.85
	Matched	0.05	0.05	-0.00	-0.16
MTB	Full	3.22	3.59	-0.38	-4.24
	Matched	3.54	3.61	-0.07	-0.07
CAPX	Full	0.05	0.05	-0.00	-3.17
	Matched	0.05	0.05	-0.00	-0.10
RD	Full	0.08	0.03	0.05	50.10
	Matched	0.03	0.03	-0.00	-0.12
SG	Full	0.09	0.04	0.04	11.52
	Matched	0.05	0.05	0.01	0.16
TANG	Full	0.22	0.30	-0.08	-20.58
	Matched	0.29	0.30	-0.01	-0.18
CASH	Full	0.24	0.12	0.12	53.67
	Matched	0.12	0.12	-0.00	-0.03
INSTHOLD	Full	0.39	0.67	-0.28	-52.97
	Matched	0.68	0.67	0.01	0.12
HHI	Full	0.09	0.11	-0.01	-11.18
	Matched	0.10	0.11	-0.00	-0.09
HHISQ	Full	0.01	0.02	-0.00	-6.36
	Matched	0.02	0.02	-0.00	-0.08

Panel B: Matched Sample			
	(1)	(2)	(3)
	LNPATG	LNPATA	LNCITE
RPE	0.126**	0.073*	0.312***
	(2.16)	(1.75)	(3.68)
ABS	0.066	0.066	0.180**
	(1.18)	(1.60)	(2.06)
LNSIZE	0.606***	0.391***	0.770***
	(19.51)	(19.04)	(16.70)
LNAGE	0.349***	0.249***	0.912***
	(8.66)	(8.10)	(14.38)
LEV	-0.232	-0.177	-0.380
	(-1.38)	(-1.42)	(-1.49)
ROA	1.544***	0.962***	2.148***
	(6.05)	(5.07)	(5.56)
MTB	0.007**	0.004*	0.010*
	(2.02)	(1.68)	(1.84)
CAPX	0.967	0.185	0.706
	(1.52)	(0.40)	(0.67)
RD	8.107***	5.400***	11.183***
	(9.62)	(8.47)	(9.43)
SG	-0.449***	-0.136***	-0.528***
	(-6.37)	(-2.81)	(-5.00)
TANG	-0.558*	0.071	-1.158**
	(-1.81)	(0.33)	(-2.54)
CASH	0.945***	0.562***	1.483***
	(3.48)	(2.78)	(3.81)
INSTHOLD	-0.103	0.014	-0.036
	(-1.10)	(0.22)	(-0.24)
HHI	-0.464	-0.559	-1.789
	(-0.43)	(-0.70)	(-1.14)
HHISQ	3.855	4.215**	6.673
	(1.43)	(2.05)	(1.63)
Industry FE	Y	Y	Y
Year FE	Y	Y	Y
Observations	9,526	9,515	9,526
Number of Firms	1,695	1,684	1,695
Adjusted R^2	0.40	0.31	0.43

Table 5: Heckman Selection Model

This table presents the association between the adoption of relative performance evaluation and corporate innovation for a sample of U.S.-listed firms from 1998 to 2019. The dependent variables include *LNPATG*, *LNPATA*, and *LNCITE*. The main explanatory variable *RPE* is a dummy variable that equals one for firms that adopt relative performance evaluation for CEO compensation and zero otherwise. *RPEIND* is the percentage of firms adopting RPE in the 2-digit SIC industry in a given year. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTOWN* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). *IMR* denotes inverse Mills ratio. All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust t-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1) RPE	(2) LNPATG	(3) LNPATA	(4) LNCITE
RPEIND	0.0106***			
	(4.07)			
RPE		0.2631***	0.1310**	0.4702***
		(4.21)	(2.20)	(5.00)
ABS	0.7753***	1.2792***	1.1452***	1.7474***
	(14.35)	(10.39)	(9.72)	(9.74)
LNSIZE	0.3976***	0.8659***	0.7916***	1.2048***
	(19.18)	(11.67)	(10.97)	(11.29)
LNAGE	0.1930***	0.4800***	0.4146***	0.9190***
	(6.46)	(12.76)	(11.31)	(16.94)
LEV	-0.2070	-0.4047***	-0.4766***	-0.5343***
	(-1.56)	(-6.37)	(-7.97)	(-5.06)
ROA	0.4585***	0.7583***	0.6576***	0.9062***
	(2.65)	(8.81)	(8.00)	(6.81)
MTB	-0.0023	0.0007	0.0032***	0.0044**
	(-0.74)	(0.59)	(2.67)	(2.01)
CAPX	-0.6685	-0.2585	-0.0649	0.2114
	(-1.20)	(-1.40)	(-0.36)	(0.64)
RD	1.8645***	4.5021***	3.9459***	6.5672***
	(5.53)	(12.80)	(11.67)	(12.39)
SG	-0.2524***	-0.4502***	-0.3476***	-0.5223***
	(-4.70)	(-9.72)	(-7.79)	(-7.54)
TANG	0.8627***	0.9570***	0.8173***	0.9720***
	(5.32)	(5.54)	(4.90)	(3.56)
CASH	-0.1382	0.3612***	0.3898***	1.0887***
	(-0.76)	(5.74)	(6.57)	(9.30)
INSTHOLD	0.1348*	0.1228***	0.0929**	0.3247***
	(1.72)	(2.76)	(2.16)	(4.06)
HHI	1.4525	3.2969***	2.5567***	2.7889***
	(1.51)	(5.89)	(5.00)	(3.28)
HHISQ	-5.4713**	-9.3148***	-7.3593***	-9.6074***
	(-2.37)	(-6.72)	(-5.64)	(-4.47)
IMR		1.6350***	1.4294***	2.1292***
		(8.55)	(7.75)	(7.57)
Industry FE	N	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	64,798	64,798	64,798	64,798
Number of Firms	7,857	7,857	7,857	7,857
Adjusted R^2		0.34	0.34	0.36

Table 6: Cross-Sectional Analysis

This table presents the association between relative performance evaluation and corporate innovation for a sample of U.S.-listed firms from 1998 to 2019. The sample is divided into two parts based on the median level of tournament incentive and CEO option delta. The dependent variable is *LNPATG*. The main explanatory variable *RPE* is a dummy variable that equals one for firms that adopt relative performance evaluation for CEO compensation and zero otherwise. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTHOLD* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust t-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	Tournament Incentive		CEO Option Vega	
	(1) Low	(2) High	(3) Low	(4) High
RPE	0.2795***	0.1010	0.1338	0.1871***
	(3.53)	(1.58)	(1.43)	(3.00)
ABS	0.1339**	0.0136	0.1470**	0.0452
	(2.57)	(0.28)	(2.53)	(0.91)
LNSIZE	0.3218***	0.5629***	0.3278***	0.5628***
	(11.51)	(18.60)	(10.39)	(18.99)
LNAGE	0.1459***	0.2991***	0.1731***	0.2579***
	(6.55)	(8.93)	(6.84)	(7.87)
LEV	0.0009	-0.3760***	0.0001	-0.4241***
	(0.01)	(-2.63)	(0.00)	(-3.10)
ROA	0.2511**	0.8273***	0.2679***	0.9776***
	(2.40)	(4.72)	(2.70)	(4.83)
MTB	0.0014	0.0005	0.0010	0.0024
	(0.39)	(0.19)	(0.28)	(1.04)
CAPX	1.0093***	2.1716***	0.7594**	2.5050***
	(3.21)	(3.30)	(2.15)	(3.80)
RD	4.1435***	8.1067***	4.1991***	7.3154***
	(10.74)	(10.43)	(9.90)	(10.99)
SG	-0.1447***	-0.4939***	-0.1499***	-0.4325***
	(-3.68)	(-7.44)	(-3.36)	(-7.24)
TANG	-0.2934*	-0.9219***	-0.4362**	-0.7845**
	(-1.91)	(-3.00)	(-2.36)	(-2.52)
CASH	0.6308***	0.7109***	0.6873***	0.5872***
	(4.70)	(3.70)	(4.61)	(3.21)
INSTHOLD	-0.0279	-0.0987	-0.1002	-0.0419
	(-0.49)	(-1.28)	(-1.61)	(-0.53)
HHI	-0.4138	0.4223	1.8603*	-0.6957
	(-0.46)	(0.42)	(1.93)	(-0.62)
HHISQ	1.6318	2.0798	-2.5352	3.2907
	(0.96)	(0.89)	(-1.32)	(1.26)
Industry FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	13,424	13,475	13,131	13,349
Number of Firms	2,090	1,779	1,941	1,678
Adjusted R^2	0.23	0.39	0.24	0.39

Table 7: Possible Mechanism

This table presents the mediating effect of tournament incentive and CEO risk-taking in the association between relative performance evaluation and corporate tax avoidance for a sample of U.S.-listed firms from 1998 to 2019. The dependent variable in Columns (1) and (4) is *LNPATG*. The dependent variables in Columns (2) and (3) are *IIQ* and *ROARISK*. *IIQ* is the internal information quality, calculated as the number of days between the end of the fiscal year and the earnings announcement date, divided by 365 and multiplied by negative one. *ROARISK* is CEO risk-taking proxy defined as the company earnings volatility proposed by John, Litov, and Yeung (2008). The main explanatory variable *RPE* is a dummy variable that equals one for firms that adopt relative performance evaluation for CEO compensation and zero otherwise. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *LNSIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *NOL* (a dummy variable that equals one if the loss carryforward is positive and zero otherwise), *FORINC* (foreign income over total assets), *EQINC* (equity in earnings from unconsolidated subsidiaries), *PPE* (property, plant, and equipment over total assets), *SPE* (special items over total assets), *CASH* (cash and marketable securities over total assets), *RD* (R&D expenditure over total assets), and *INTAN* (intangible assets over total assets). All regressions include firm and year fixed effects. We use 3-digit SIC code for industry classification. The robust *t*-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1) LNPATG	(2) IIQ	(3) ROARISK	(4) LNPATG
RPE	0.3845***	-0.0054***	0.0021***	0.3317***
	(6.11)	(-3.36)	(4.65)	(5.31)
IIQ				-0.1541***
				(-3.38)
ROARISK				2.9126***
				(6.96)
ABS	0.2588***	-0.0051***	0.0012***	0.1965***
	(6.64)	(-2.95)	(3.00)	(4.90)
LNSIZE	0.2852***	-0.0163***	-0.0035***	0.3444***
	(22.96)	(-21.91)	(-28.40)	(22.65)
LNAGE	0.2069***	-0.0003	-0.0004**	0.2162***
	(16.48)	(-0.38)	(-2.44)	(15.69)
LEV	-0.1276**	0.0363***	0.0110***	-0.1878***
	(-2.54)	(7.57)	(13.48)	(-3.18)
ROA	0.0065	-0.0483***	-0.0184***	0.1130***
	(0.24)	(-7.11)	(-25.09)	(3.30)
MTB	0.0045***	-0.0004***	0.0002***	0.0034**
	(3.62)	(-4.04)	(7.48)	(2.40)
CAPX	0.6780***	-0.0122	0.0029	1.0311***
	(4.44)	(-0.65)	(0.99)	(5.55)
RD	1.7027***	-0.0920***	0.0122***	1.9783***
	(17.33)	(-6.64)	(6.01)	(16.95)
SG	-0.0649***	-0.0050*	-0.0015***	-0.0785***
	(-5.94)	(-1.94)	(-4.68)	(-5.96)
TANG	-0.3366***	-0.0226***	-0.0124***	-0.4072***
	(-4.00)	(-3.34)	(-10.68)	(-3.92)
CASH	0.6024***	-0.0405***	0.0115***	0.6079***
	(10.31)	(-7.12)	(11.71)	(9.07)
INSTHOLD	-0.1063**	-0.0217***	-0.0060***	-0.1167***
	(-2.51)	(-10.50)	(-12.38)	(-2.65)
HHI	0.8913*	0.0998***	-0.0239***	1.1127**
	(1.80)	(2.91)	(-2.78)	(2.01)
HHISQ	-0.6691	-0.2454***	0.0480***	-0.6851
	(-0.66)	(-3.39)	(2.77)	(-0.58)
Industry FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	64,798	51,954	64,798	51,954
Number of Firms	7,857	6,782	7,857	6,782
Adjusted R^2	0.33	0.08	0.30	0.34
Sig. of total mediating effect				5.15
Pct. of mediating effect: IIQ				12.18
Sig. of mediating effect: IIQ				2.38
Pct. of mediating effect: ROARISK				87.82
Sig. of mediating effect: ROARISK				3.86

Table 8: Additional Controls

This table presents the association between the adoption of relative performance evaluation and corporate innovation for a sample of U.S.-listed firms from 1998 to 2019. The dependent variable is *LNPATG*. The main explanatory variable *RPE* is a dummy variable that equals one for firms that adopt relative performance evaluation for CEO compensation and zero otherwise. Column (1) includes natural logarithm of CEO total compensation, age, tenure, and the female indicator. Column (2) includes CEO duality, board independence, and natural logarithm of the compensation of the highest paid executives. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTHOLD* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust *t*-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1) LNPATG	(2) LNPATG	(3) LNPATG
RPE	0.1743***	0.2448***	0.1292**
	(2.94)	(3.96)	(2.14)
LNTDC	0.0088		-0.0050
	(0.39)		(-0.20)
LNCEOAGE	-0.4169***		-0.4743***
	(-2.84)		(-2.83)
LNTENURE	-0.0241		-0.0391*
	(-1.30)		(-1.82)
FEMALE	0.0054		0.0368
	(0.06)		(0.37)
DUALITY		0.0285	0.0945**
		(1.17)	(2.35)
BDINDEP		0.3564***	0.4725***
		(4.19)	(3.43)
LNTOPSALARY		0.0625***	0.0405***
		(7.68)	(4.55)
ABS	0.0350	0.1550***	0.0198
	(0.81)	(3.67)	(0.43)
LNSIZE	0.4716***	0.2825***	0.4373***
	(17.30)	(18.89)	(13.95)
LNAGE	0.2507***	0.1936***	0.2360***
	(9.89)	(12.69)	(8.52)
LEV	-0.2733***	-0.1209*	-0.2429**
	(-2.60)	(-1.80)	(-2.07)
ROA	0.5417***	0.1351***	0.6836***
	(4.82)	(3.09)	(5.24)
MTB	0.0032	0.0033**	0.0013
	(1.34)	(2.16)	(0.50)
CAPX	1.8277***	0.8516***	1.9718***
	(4.51)	(3.91)	(4.25)
RD	5.6829***	2.0783***	5.9786***
	(12.67)	(14.94)	(11.33)
SG	-0.2780***	-0.0952***	-0.2853***
	(-6.83)	(-6.27)	(-5.96)
TANG	-0.6369***	-0.3472***	-0.5897***
	(-3.24)	(-3.21)	(-2.76)
CASH	0.6443***	0.6355***	0.6259***
	(4.77)	(8.40)	(4.19)
INSTHOLD	-0.0949	-0.1810***	-0.1532**
	(-1.61)	(-3.83)	(-2.43)
HHI	0.3815	0.2211	-0.0221
	(0.52)	(0.41)	(-0.03)
HHISQ	1.0921	1.5621	2.4873
	(0.68)	(1.43)	(1.50)
Industry FE	Y	Y	Y
Year FE	Y	Y	Y
Observations	26,392	43,819	22,049
Number of Firms	2,292	4,769	1,879

Table 9: Alternative Relative Performance Evaluation Measure

This table presents the association between alternative relative performance evaluation measure and corporate tax avoidance measures for a sample of U.S. listed firms from 1998 to 2019. The dependent variables include *LNPATG*, *LNPATA*, and *LNCITE*. The main explanatory variables include *RPER* (a dummy variable that equals one for firms that adopt RPE and zero otherwise. We apply implicit RPE identification method following De Angelis and Grinstein (2020)) and *GRANTSIZE* (natural logarithm of one plus the total fair value of RPE scheme over total assets). Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTOWN* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), *HHISQ* (square of HHI), and *CAPINTY* (natural logarithm of one plus the ratio of property, plant, and equipment over number of employees). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust *t*-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1) LNPATG	(2) LNPATA	(3) LNCITE	(4) LNPATG	(5) LNPATA	(6) LNCITE
RPER	0.2925***	0.2265***	0.5578***			
	(6.15)	(5.29)	(7.18)			
GRANTSIZE				0.0215***	0.0095**	0.0346***
				(4.64)	(2.16)	(5.01)
ABS	0.3223***	0.2920***	0.5218***	0.2808***	0.2780***	0.4546***
	(8.33)	(7.84)	(7.82)	(7.09)	(7.22)	(6.62)
LNSIZE	0.2932***	0.2883***	0.4608***	0.2852***	0.2828***	0.4496***
	(23.13)	(22.66)	(24.80)	(22.84)	(22.46)	(24.52)
LNAGE	0.2118***	0.1783***	0.5705***	0.2072***	0.1760***	0.5626***
	(16.72)	(14.77)	(26.24)	(16.42)	(14.64)	(25.98)
LEV	-0.1327***	-0.2365***	-0.1801**	-0.1261**	-0.2325***	-0.1699*
	(-2.65)	(-5.10)	(-2.05)	(-2.52)	(-5.02)	(-1.93)
ROA	-0.0084	-0.0092	-0.0977*	0.0055	0.0005	-0.0733
	(-0.30)	(-0.36)	(-1.84)	(0.20)	(0.02)	(-1.38)
MTB	0.0043***	0.0064***	0.0090***	0.0045***	0.0065***	0.0093***
	(3.49)	(5.26)	(4.13)	(3.65)	(5.34)	(4.27)
CAPX	0.6248***	0.7195***	1.3414***	0.6702***	0.7529***	1.4365***
	(4.08)	(4.81)	(4.68)	(4.44)	(5.10)	(5.14)
RD	1.7454***	1.5296***	2.9997***	1.7024***	1.4974***	2.9268***
	(17.87)	(17.13)	(16.58)	(17.36)	(16.72)	(16.06)
SG	-0.0665***	-0.0115	-0.0228	-0.0659***	-0.0120	-0.0227
	(-6.08)	(-1.16)	(-1.13)	(-6.04)	(-1.22)	(-1.13)
TANG	-0.3276***	-0.3080***	-0.6977***	-0.3318***	-0.3106***	-0.7065***
	(-3.88)	(-3.76)	(-4.61)	(-3.97)	(-3.84)	(-4.70)
CASH	0.6162***	0.6118***	1.4299***	0.6048***	0.6035***	1.4069***
	(10.56)	(11.09)	(12.94)	(10.37)	(10.94)	(12.70)
INSTHOLD	-0.1247***	-0.1198***	-0.0055	-0.1039**	-0.1042**	0.0244
	(-2.93)	(-2.88)	(-0.08)	(-2.47)	(-2.53)	(0.34)
HHI	0.7960	0.3790	-0.5267	0.8291*	0.3614	-0.4836
	(1.61)	(0.87)	(-0.71)	(1.67)	(0.82)	(-0.65)
HHISQ	-0.6179	0.2474	1.7629	-0.5475	0.3209	1.8973
	(-0.61)	(0.27)	(1.11)	(-0.54)	(0.35)	(1.19)
Industry FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	64,798	64,798	64,798	64,485	64,485	64,485
Number of Firms	7,857	7,857	7,857	7,855	7,855	7,855
Adjusted R^2	0.33	0.33	0.35	0.32	0.32	0.34

Table 10: Alternative Estimation Techniques

This table presents the association between the adoption of relative performance evaluation and corporate innovation for a sample of U.S.-listed firms from 1998 to 2019 using Tobit regression, where the dependent variables are left truncated at zero. The dependent variables include *LNPATG*, *LNPATA*, and *LNCITE*. The main explanatory variable *RPE* is a dummy variable that equals one for firms that adopt relative performance evaluation for CEO compensation and zero otherwise. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTOWN* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust t-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1) LNPATG	(2) LNPATA	(3) LNCITE
RPE	0.3378***	0.2036***	0.6090***
	(4.55)	(3.07)	(5.30)
ABS	0.3114***	0.3069***	0.5173***
	(5.38)	(6.30)	(5.33)
LNSIZE	0.4910***	0.4048***	0.7204***
	(25.91)	(24.44)	(25.53)
LNAGE	0.5391***	0.4034***	1.1597***
	(21.91)	(20.71)	(29.49)
LEV	-0.3452***	-0.4364***	-0.5373***
	(-3.48)	(-5.54)	(-3.26)
ROA	0.1094*	0.0535	-0.0453
	(1.71)	(1.14)	(-0.43)
MTB	0.0066***	0.0085***	0.0136***
	(3.19)	(4.91)	(3.93)
CAPX	0.9706**	1.0870***	2.4823***
	(2.45)	(3.52)	(3.69)
RD	3.5314***	2.6049***	5.3738***
	(19.76)	(18.86)	(18.14)
SG	-0.0900***	-0.0018	-0.0134
	(-4.05)	(-0.11)	(-0.36)
TANG	-0.4996**	-0.4971***	-1.1482***
	(-2.41)	(-3.05)	(-3.31)
CASH	1.3431***	1.0484***	2.6206***
	(12.61)	(12.59)	(14.41)
INSTHOLD	-0.0507	-0.0667	0.1444
	(-0.71)	(-1.14)	(1.21)
HHI	0.3588	0.7143	-0.6338
	(0.40)	(1.01)	(-0.46)
HHISQ	2.4257	0.5916	4.1220
	(1.15)	(0.37)	(1.25)
Industry FE	Y	Y	Y
Year FE	Y	Y	Y
Observations	64,798	64,798	64,798
Number of Firms	7,857	7,857	7,857
Pseudo R^2	0.24	0.23	0.21

Table 11: Alternative Sampling Criteria

This table presents the association between relative performance evaluation and corporate innovation for alternative samples of U.S.-listed firms from 1998 to 2019. Column (1) excludes firm-year observations with zero patent applications. Column (2) excludes firms engaging in mergers and acquisitions (identified using the SDC M&A database) in the previous two years. Column (3) excludes industries with below median average citations per patent. Column (4) excludes the firms in the telecommunication (SIC code 4810–4813) and energy (SIC code 1200-1399, 2900–2999) industries. The dependent variable is *LNPATG*. The main explanatory variable *RPE* is a dummy variable that equals one for firms that adopt accounting-based relative performance evaluation for CEO compensation and zero otherwise. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTOWN* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), *HHISQ* (square of HHI), and *CAPINTY* (natural logarithm of one plus the ratio of property, plant, and equipment over number of employees). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust t-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1)	(2)	(3)	(4)
RPE	0.3171***	0.2638***	0.3647***	0.4672***
	(4.61)	(3.59)	(4.94)	(7.10)
ABS	0.2325***	0.3028***	0.4170***	0.2457***
	(4.97)	(6.82)	(7.72)	(6.09)
LNSIZE	0.4143***	0.2254***	0.3425***	0.2966***
	(25.76)	(19.37)	(20.54)	(22.97)
LNAGE	0.1306***	0.1667***	0.2326***	0.2023***
	(6.55)	(14.42)	(13.37)	(15.55)
LEV	-0.1169	0.0020	-0.1980***	-0.1397***
	(-1.56)	(0.04)	(-2.70)	(-2.69)
ROA	0.0635	0.0056	0.0071	0.0131
	(1.53)	(0.21)	(0.19)	(0.46)
MTB	0.0047***	0.0030***	0.0046**	0.0040***
	(3.00)	(2.64)	(2.56)	(3.17)
CAPX	0.5744*	0.3462**	0.5989**	0.9270***
	(1.92)	(2.54)	(2.49)	(5.18)
RD	2.0139***	1.4402***	2.0813***	1.7473***
	(16.28)	(16.23)	(16.64)	(17.65)
SG	-0.1110***	-0.0415***	-0.0594***	-0.0654***
	(-7.36)	(-3.90)	(-3.62)	(-5.72)
TANG	-0.0280	-0.2641***	-0.4884***	-0.2435***
	(-0.17)	(-3.58)	(-3.83)	(-2.85)
CASH	0.6821***	0.5458***	0.7352***	0.6252***
	(8.69)	(9.74)	(9.50)	(10.70)
INSTHOLD	-0.2244***	0.0791**	-0.1562***	-0.1208***
	(-3.82)	(1.98)	(-2.76)	(-2.73)
HHI	0.7381	1.6079***	0.9562	0.6403
	(0.96)	(2.97)	(1.58)	(1.09)
HHISQ	0.3781	-2.0384*	-0.3009	-0.2112
	(0.21)	(-1.92)	(-0.22)	(-0.18)
Industry FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	37,255	44,736	31,894	61,155
Number of Firms	3,717	6,887	4,802	7,406
Adjusted R^2	0.39	0.27	0.39	0.34

Table 12: Relative Performance Evaluation and Innovation Efficiency

This table presents the association between the adoption of relative performance evaluation and innovation efficiency for a sample of U.S. listed firms from 1998 to 2019. The dependent variable is granted patents per employed inventor *PATGINVT*. The main explanatory variables include *PEE*, which is a dummy variable that equals one for firms that adopt peer group as performance benchmark and zero otherwise, and *INDEX*, which is a dummy variable that equals one for firms that adopt index as performance benchmark and zero otherwise. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTHOLD* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust t-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1) PATGINVT	(2) PATGINVT	(3) PATGINVT	(4) PATGINVT
RPE	0.1120***			
	(6.32)			
NONEQINCT		-0.2115***		-0.2218***
		(-4.50)		(-4.71)
LTINCT			0.0925**	0.1033***
			(2.41)	(2.69)
ABS	0.0461***	0.0907***	0.0542***	0.0796***
	(3.94)	(7.08)	(4.49)	(6.08)
LNSIZE	0.0513***	0.0551***	0.0541***	0.0546***
	(20.43)	(22.08)	(21.65)	(21.85)
LNAGE	0.0320***	0.0347***	0.0343***	0.0347***
	(9.13)	(9.89)	(9.76)	(9.89)
LEV	-0.0202	-0.0229	-0.0243	-0.0237
	(-1.26)	(-1.43)	(-1.51)	(-1.48)
ROA	0.0243**	0.0204*	0.0203*	0.0201*
	(2.23)	(1.86)	(1.86)	(1.84)
MTB	0.0006	0.0006	0.0006	0.0006
	(1.22)	(1.29)	(1.14)	(1.19)
CAPX	0.1936***	0.1823***	0.1783***	0.1795***
	(4.02)	(3.77)	(3.69)	(3.71)
RD	0.4774***	0.4803***	0.4790***	0.4782***
	(13.02)	(13.07)	(13.02)	(13.01)
SG	-0.0257***	-0.0261***	-0.0264***	-0.0260***
	(-4.43)	(-4.50)	(-4.55)	(-4.48)
TANG	-0.0767***	-0.0756***	-0.0724***	-0.0734***
	(-3.45)	(-3.41)	(-3.25)	(-3.30)
CASH	0.1746***	0.1738***	0.1730***	0.1730***
	(8.68)	(8.64)	(8.60)	(8.61)
INSTHOLD	0.0118	0.0092	0.0079	0.0086
	(1.00)	(0.79)	(0.67)	(0.73)
HHI	0.3246	0.3292	0.3259	0.3295
	(1.44)	(1.46)	(1.44)	(1.45)
HHISQ	-0.3192	-0.3417	-0.3339	-0.3417
	(-0.76)	(-0.81)	(-0.79)	(-0.80)
Industry FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	64,798	64,798	64,798	64,798
Number of Firms	7,857	7,857	7,857	7,857
Adjusted R^2	0.07	0.06	0.06	0.07

Table 13: Compensation Scheme and Innovation Incentive

This table presents the association between relative performance evaluation, pay-for-performance, and corporate innovation for a sample of U.S.-listed firms from 1998 to 2019. The dependent variables include *LNPATG*, *LNPATA*, and *LNCITE*. The main explanatory variables include *PEE*, which is a dummy variable that equals one for firms that adopt peer group as performance benchmark and zero otherwise, and *INDEX*, which is a dummy variable that equals one for firms that adopt index as performance benchmark and zero otherwise. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTHOLD* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust t-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1) LNPATG	(2) LNPATG	(3) LNPATG	(4) LNPATG	(5) LNPATG	(6) LNPATG
RPE	0.3845***		0.3860***			
	(6.11)		(6.13)			
CEOATAX		-0.0515	-0.0664			
		(-0.61)	(-0.79)			
NONEQINCT				-0.3629**		-0.4226***
				(-2.25)		(-2.61)
LTINCT					0.5746***	0.5952***
					(4.73)	(4.87)
ABS	0.2585***	0.3248***	0.2591***	0.3679***	0.2556***	0.3040***
	(6.63)	(8.37)	(6.64)	(8.73)	(6.18)	(6.95)
LNSIZE	0.2853***	0.2969***	0.2856***	0.2974***	0.2939***	0.2948***
	(22.96)	(23.39)	(22.98)	(23.46)	(23.21)	(23.30)
LNAGE	0.2069***	0.2153***	0.2071***	0.2158***	0.2149***	0.2157***
	(16.49)	(16.98)	(16.50)	(17.04)	(16.98)	(17.06)
LEV	-0.1275**	-0.1402***	-0.1293**	-0.1378***	-0.1437***	-0.1426***
	(-2.54)	(-2.78)	(-2.58)	(-2.73)	(-2.84)	(-2.83)
ROA	0.0065	-0.0066	0.0065	-0.0068	-0.0081	-0.0085
	(0.24)	(-0.24)	(0.24)	(-0.25)	(-0.29)	(-0.31)
MTB	0.0045***	0.0045***	0.0044***	0.0045***	0.0042***	0.0043***
	(3.62)	(3.59)	(3.61)	(3.64)	(3.38)	(3.42)
CAPX	0.6786***	0.6354***	0.6790***	0.6376***	0.6188***	0.6210***
	(4.44)	(4.13)	(4.44)	(4.14)	(4.03)	(4.04)
RD	1.7027***	1.7152***	1.7032***	1.7138***	1.7032***	1.7016***
	(17.33)	(17.36)	(17.33)	(17.36)	(17.35)	(17.35)
SG	-0.0650***	-0.0680***	-0.0652***	-0.0670***	-0.0671***	-0.0663***
	(-5.95)	(-6.18)	(-5.97)	(-6.10)	(-6.12)	(-6.05)
TANG	-0.3367***	-0.3298***	-0.3379***	-0.3309***	-0.3165***	-0.3184***
	(-4.00)	(-3.90)	(-4.01)	(-3.91)	(-3.74)	(-3.76)
CASH	0.6024***	0.5984***	0.6011***	0.5995***	0.5949***	0.5949***
	(10.31)	(10.19)	(10.30)	(10.21)	(10.14)	(10.14)
INSTHOLD	-0.1064**	-0.1169***	-0.1053**	-0.1165***	-0.1215***	-0.1202***
	(-2.51)	(-2.74)	(-2.48)	(-2.74)	(-2.85)	(-2.83)
HHI	0.8928*	0.8991*	0.8953*	0.9029*	0.8976*	0.9043*
	(1.81)	(1.81)	(1.81)	(1.82)	(1.80)	(1.82)
HHISQ	-0.6715	-0.7259	-0.6751	-0.7359	-0.7211	-0.7360
	(-0.66)	(-0.71)	(-0.66)	(-0.72)	(-0.71)	(-0.72)
Industry FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	64,798	64,798	64,798	64,798	64,798	64,798
Number of Firms	7,857	7,857	7,857	7,857	7,857	7,857
Adjusted R^2	0.33	0.32	0.33	0.32	0.33	0.33

Table 14: RPE, Innovation and Firm Performance

This table presents the relation between the adoption of RPE, corporate innovation, and firm performance for a sample of U.S.-listed firms from 1998 to 2019. The dependent variable is cash flow *CF* and Tobin's q *TOBINQ*. The main explanatory variable *RPE* is a dummy variable that equals one for firms that adopt relative performance evaluation for CEO compensation and zero otherwise. *LNPATG*, *LNPATA*, and *LNCITE* are corporate innovation measures. Other control variables include *ABS* (a dummy variable that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise), *SIZE* (natural logarithm of total assets), *AGE* (natural logarithm of number of years since initial public offerings), *LEV* (total debt over total assets), *ROA* (operating income over total assets), *MTB* (market-to-book ratio), *CAPX* (capital expenditure over total assets), *RD* (R&D expenditure over total assets), *SG* (sales growth rate), *TANG* (property, plant, and equipment over total assets), *CASH* (cash and marketable securities over total assets), *INSTHOLD* (percentage of institutional ownership), *HHI* (Herfindahl-Hirschman index based on firm sales for each 2-digit SIC industry), and *HHISQ* (square of HHI). All regressions include the industry and year fixed effects. We use 2-digit SIC code as the industry classification. The robust t-statistics clustered by the firm are reported in parentheses. The detailed variable definitions are presented in Table A1. ***, **, and * denote the significance at the 1%, 5%, and 10% levels, respectively.

	(1) CF	(2) CF	(3) CF	(4) TOBINQ	(5) TOBINQ	(6) TOBINQ
RPE	-0.0064***	-0.0065***	-0.0069***	-0.0088	0.0276	0.0092
	(-3.08)	(-2.79)	(-2.90)	(-0.18)	(0.54)	(0.18)
LNPATG	-0.0002			0.0729***		
	(-0.35)			(5.69)		
RPE*LNPATGRANT	0.0013*			-0.0134		
	(1.95)			(-0.75)		
LNPATA		0.0007			0.1698***	
		(0.84)			(8.94)	
RPE*LNPATAPP		0.0021*			-0.0378	
		(1.66)			(-1.21)	
LNCITE			-0.0004			0.0616***
			(-0.98)			(6.92)
RPE*LNCITATION			0.0011*			-0.0127
			(1.91)			(-0.89)
ABS	-0.0070***	-0.0072***	-0.0070***	0.4244***	0.4133***	0.4232***
	(-5.23)	(-5.35)	(-5.22)	(11.59)	(11.35)	(11.67)
LNSIZE	0.0053***	0.0052***	0.0054***	-0.1087***	-0.1149***	-0.1083***
	(9.72)	(9.89)	(10.43)	(-11.05)	(-11.56)	(-10.77)
LNAGE	0.0033***	0.0031***	0.0034***	-0.0044	-0.0116	-0.0186
	(5.22)	(5.05)	(5.28)	(-0.35)	(-0.94)	(-1.53)
LEV	0.0230***	0.0231***	0.0230***	0.4641***	0.4754***	0.4606***
	(4.78)	(4.80)	(4.78)	(5.18)	(5.31)	(5.16)
ROA	0.8488***	0.8488***	0.8488***	-0.2431***	-0.2491***	-0.2419***
	(125.27)	(125.19)	(125.29)	(-3.37)	(-3.46)	(-3.36)
MTB	0.0000	0.0000	0.0000	0.1190***	0.1188***	0.1190***
	(0.08)	(0.06)	(0.09)	(27.39)	(27.38)	(27.38)
CAPX	0.0482**	0.0479**	0.0485**	3.1886***	3.1686***	3.1718***
	(2.41)	(2.40)	(2.43)	(14.57)	(14.59)	(14.57)
RD	-0.1574***	-0.1586***	-0.1566***	2.2003***	2.1252***	2.1594***
	(-12.09)	(-12.17)	(-12.07)	(11.61)	(11.23)	(11.42)
SG	-0.0028	-0.0028	-0.0028	0.5294***	0.5246***	0.5248***
	(-0.91)	(-0.91)	(-0.91)	(18.55)	(18.48)	(18.46)
TANG	0.0150***	0.0152***	0.0148***	-0.5335***	-0.5236***	-0.5229***
	(2.68)	(2.71)	(2.64)	(-6.76)	(-6.70)	(-6.63)
CASH	0.0203***	0.0199***	0.0207***	1.4829***	1.4468***	1.4490***
	(4.64)	(4.54)	(4.73)	(18.19)	(17.94)	(18.03)
INSTHOLD	0.0079***	0.0078***	0.0079***	0.4510***	0.4366***	0.4330***
	(5.00)	(4.99)	(5.04)	(12.35)	(11.97)	(11.91)
HHI	0.0360	0.0361	0.0359	0.0497	0.1279	0.1361
	(1.01)	(1.01)	(1.00)	(0.10)	(0.25)	(0.27)
HHISQ	-0.0177	-0.0186	-0.0172	0.0804	-0.1052	-0.0630
	(-0.23)	(-0.25)	(-0.23)	(0.08)	(-0.11)	(-0.06)
Industry FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	60,347	60,347	60,347	64,798	64,798	64,798
Number of Firms	7,263	7,263	7,263	7,857	7,857	7,857
Adjusted R^2	0.80	0.80	0.80	0.32	0.32	0.32

Appendix to

Relative Performance Evaluation and Corporate Innovation: Tournament Incentive or Risk-Taking?

Table A1: Variable Definitions

Variable	Definitions
Dependent Variables	
LNPATG	The natural logarithm of one plus the number of patents granted for each firm in each year, following Chu, Tian, and Wang (2019)
LNPATA	The natural logarithm of one plus the number of patent applications filed during the year
LNCITE	The natural logarithm of one plus the number of citations received on the supplier's patents filed (and eventually granted) for each firm in each year
PATDIV	One minus the Herfindahl index of the number of new patents across different technology classes, measured over the most recent three years.
LNEXPLOIT	The natural logarithm of ratio of the percentage of exploitative new patents at the firm-year level
LNEXPLOR	The natural logarithm of ratio of the percentage of exploratory new patents at the firm-year level
SCOPE	The ratio for the number of new citations made by patents applied divided by the total number of citations made by all patents applied
ORI	One minus the Herfindahl index of the technology category distribution of all patents that have been cited by this particular patent
GEN	One minus the Herfindahl index of the technology category distribution of all patents that have cited this particular patent
PATGINVT	Granted patents per employed inventor
Explanatory Variables	
RPE	Dummy that equals one for firms that adopt relative performance evaluation in CEO compensation contracts and zero otherwise
RPER	Dummy variable that equals 1 for firms that adopt relative performance evaluation and 0 otherwise following implicit approaches
GRANTSIZE	The total fair value of the plan-based awards for CEOs scaled by total assets.
NONEQINCT	The currency amount of the non-equity incentive plan scaled by the total compensation of the CEO
LTINCT	The currency amount of long-term incentive plan (LITP) scaled by total compensation of the CEO
CEOATAX	The sensitivity of CEO cash compensation to income tax expense estimated from a firm-level OLS regression, following Gaertner (2014)
ABS	Dummy that equals one for firms that adopt absolute performance evaluation for CEO compensation and zero otherwise
LNSIZE	Natural logarithm of lagged market value of equity
LNAGE	Natural logarithm of number of years since initial public offerings
LEV	Long-term debt over total assets
ROA	Operating income over total assets
MTB	Market-to-book ratio of assets
CAPX	Capital expenditure over total assets
RD	R&D expenditure over total assets
SG	Sales growth rate
TANG	Property, plant, and equipment over total assets
CASH	Cash and marketable securities over total assets
INSTHOLD	Percentage of institutional ownership
HHI	Herfindahl-Hirschmanindex based on firm sales for each 2-digit SIC industry
HHISQ	Square of HHI
Other Variables	
IIQ	The number of days between the end of the fiscal year and the earnings announcement date, divided by 365 and multiplied by negative one
ROARISK	The company earnings volatility. A high value of the index represents a high level of corporate risk-taking.
CF	Income before extraordinary items minus total accruals divided by average total assets
TOBINQ	Tobin's Q