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Unintended consequences of compensation peer groups on corporate innovation[☆]

Yuan-Teng Hsu [a], Chia-Wei Huang [b,*], Kees G. Koedijk [c,d]

[a] Research Center of Finance, Shanghai Business School, Shanghai, China
[b] Department of Finance, College of Commerce, National Chengchi University, 64, Section 2, ZhiNan Rd., Taipei City, Taiwan
[c] School of Economics, Utrecht University, Utrecht, The Netherlands
[d] CEPR, London, United Kingdom

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ABSTRACT

When companies select and use compensation peers to determine chief executive officer (CEO) compensation, they create unintended peer effects on corporate innovation due to the similarities between these companies and their compensation peers in terms of product markets, CEO characteristics, and compensation schemes. After controlling for industry and geography peer groups, the findings confirm that the average innovation activity of compensation peers is a significant and distinct predictor of corporate innovation. Further analysis showed that (1) the peer effect is stronger in firms and compensation peers that pay their CEOs using long-term compensation, in firms with stronger labor market competition and board monitoring, and in peer companies that experience higher innovation competition and are closer to the median peer company in the peer group; (2) the obtained results are likely not attributable to the knowledge spillover mechanism and are more consistent with the peer pressure mechanism; and (3) the Securities and Exchange Commission's 2006 executive compensation disclosure rules may have generated peer effects.

1. Introduction

To enhance compensation transparency, the Securities and Exchange Commission (SEC) adopted new proxy disclosure rules in 2006 that require firms to disclose executive compensation peer companies that will be referenced for determining executive compensation. The main reason why firms engage in this practice, known as executive compensation benchmarking, is to inform the compensation committee of the range of practices used by peer firms to compete for executive talent (Bizjak et al., 2008; Bizjak et al., 2011; Albuquerque et al., 2013).[1]

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* Corresponding author.
E-mail addresses: yuanteng.hsu@gmail.com (Y.-T. Hsu), d94723002@ntu.edu.tw (C.-W. Huang), c.g.koedijk@uu.nl (K.G. Koedijk).
[1] Another reason could be rent extraction by inappropriately increasing CEO compensation (Faulkender and Yang, 2010, 2013).

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A firm and its compensation peers are likely to share similar product market characteristics, chief executive officer (CEO) talent/skill/characteristics, and compensation schemes. Thus, the CEOs of compensation peers may be considered potential competitors of a firm's CEO in the labor market (Holmström and Kaplan, 2003; Bizjak et al., 2008; Albuquerque et al., 2013; Francis et al., 2016; Choi et al., 2022). Consequently, compensation peer companies may exert "unintended" effects on a firm's innovation practice.

The innovation investments of a compensation peer group may affect corporate innovation decisions in three ways: First, as intergroup competition affects a manager's attitude toward risk, a CEO facing a group of competitive peers must exert more effort to maintain or create a competitive advantage to increase their chance of either keeping their present job or winning the job market tournament (Fama, 1980; Lazear and Rosen, 1981; Holmström, 1999; Francis et al., 2016). Thus, intragroup competition may be expected to intensify, as a firm's CEO and the CEOs of compensation peers are likely to share similar product market characteristics and compete for the same pool of human capital (Holmström and Kaplan, 2003; Bizjak et al., 2008; Albuquerque et al., 2013; Choi et al., 2022).

Second, Manso (2011) explicitly modeled the innovation process and identified long-term compensation as the optimal strategy for incentivizing innovation. Moreover, Baranchuk et al. (2014), Gopalan et al. (2014), and Welker (2015) showed empirically that longer-term contracts incentivize managers to choose innovation projects. As compensation peers are typically used as a reference both for determining CEO total compensation and for designing the structure of the compensation package (Ertimur et al., 2013; Larcker et al., 2019), the degree of similarity between the compensation schemes of a firm's CEO and its compensation peers' CEOs may be the main mechanism by which investments in innovation of a compensation peer group affect corporate innovation.

Finally, the social regret effect, in which a poor outcome from a failed innovation investment does not hurt as much if others have chosen the same investment (Gardner and Steinberg, 2005; Cooper and Rege, 2011; Bougheas et al., 2013), is expected to be particularly pronounced in studies on compensation peers because they are assumed to be the reference companies by which the CEOs are evaluated. Thus, CEOs are strongly incentivized to follow their peers' decisions (Scharfstein and Stein, 1990; Bikhchandani et al., 1998).

In summary, given that innovation is inherently risky with a high potential to boost profitability, managers are expected to weigh the related costs and benefits arising from investments in innovation and to follow the innovative decisions made by their compensation peers. CEOs may use this strategy to enhance their personal reputations in preparation for future job tournaments and to lower their potential downside risks. Thus, in this study, investments in innovation by compensation peers are hypothesized to spur corporate innovation, representing a peer effect on this variable.

Baseline regression tests have demonstrated that a firm's innovation is positively associated with the average innovation of compensation peer companies. Innovation is measured by innovation input (i.e., research and development [R&D] expenditures to total assets) and innovation output (i.e., patent counts and citations per patent). Notably, the coefficient for the average innovation of compensation peer companies is highly significant, even after controlling for the innovation of industry and geography peers, suggesting that compensation peers generate significant incremental explanatory power to understand the peer effect on corporate innovation. In addition, even after adding a set of unintended factors, including CEO characteristics, abilities, incentive compensation, and degree of product similarity, into the regressions, the average innovation of compensation peers remained significant, implying that our results are robust to controls for the unintended factors directly affecting corporate innovation.

The findings are not only statistically significant, but also economically important. For instance, after controlling for firm and peer characteristics and firm and year fixed effects, a one standard deviation increase in the average innovation activities of compensation peer companies was associated with increases of 1.03%, 0.234%, and 0.378% in firm R&D expenditures, patent counts, and citations per patent, respectively, implying an increase of around 27.84%, 27.56%, and 53.24% in mean R&D expenditure, mean patent count, and mean citations per patent, respectively. These findings are consistent with the hypothesis that peer effects spur corporate innovation.

While the baseline results support a positive association between the average innovation of compensation peer companies and firm innovation, they may be subject to the reflection problem akin to simultaneity bias (Manski, 1993) and omitted variable bias. The reflection problem refers to a specific form of endogeneity arising from the attempt to infer whether average innovation activities in a compensation peer group influence innovation in the disclosing firm. Omitted variable bias refers to correlated effects that relate innovation within a peer group to unintended factors such as product market characteristics, CEO talent/skill/characteristics, and compensation schemes common to that group.

To address these endogeneity concerns, we adopted several strategies controlling for unintended factors and firm and year fixed effects.[2] The first strategy used a two-stage least squares (2SLS) approach with instrumental variables (IV) to alleviate the endogeneity concerns (e.g., Angrist and Keueger, 1991; Evans et al., 1992; Rivkin, 2001; Angrist and Pischke, 2008). The instruments are whether peer companies violate debt covenants and peer companies' idiosyncratic risk. Breaching a debt covenant shifts control rights to lenders, giving them the right to recall loans, impose penalties, and/or renegotiate loan terms. The lender may use this change in control rights to push borrowers to invest less in innovation projects because the payoff structure of creditors disfavors innovative firms with uncertain or volatile returns (Stiglitz, 1985). Moreover, the hold-up problem associated with bank financing frequently leads powerful banks to stifle innovation by extracting informational rents (Hellwig, 1991; Rajan, 1992), while creditors tend to mitigate the managerial agency problem that managers may overinvest in innovation to enjoy private benefits from such activities (Scharfstein and Stein, 2000). Thus, debt covenant violations are expected to lead firms to reduce investments in innovation.

[2] The group fixed effect strategy may be used to effectively separate the endogenous effect from the correlated effect (Lee, 2007; Lin, 2010).

Following Leary and Roberts (2014), Adhikari and Agrawal (2018), and Grennan (2019), compensation peers' idiosyncratic risk was used in this study as the second instrument to investigate innovation peer effects. Panousi and Papanikolaou (2012) demonstrated the relevance of idiosyncratic risk for innovation policy. Because investment decisions are made by managers on behalf of shareholders, risk-averse managers holding undiversified stakes in the firm may cut back on investment when uncertainty about the firm's future prospects increases, even when this uncertainty is firm-specific. Consequently, we expect a negative relationship between idiosyncratic risk and innovation activities in compensation peers.

The 2SLS results show that the average innovation of compensation peer companies is negatively related to the indicator of whether peers violate debt covenants and to peer companies' idiosyncratic risk; these results confirm the peer effect on corporate innovation.

The second strategy involved a propensity score matching (PSM) methodology to match firms with more peer company innovation to firms with less peer company innovation in the same year, using various firm characteristics and unintended factors as control variables in the baseline regressions. This methodology was intended to confirm that firms were, with the exception of their peers' innovation, not different in terms of observable characteristics. Consistent with the baseline results, we find that firms with more peer innovation are more innovative than the matching firms with less peer innovation.

The third and final strategy used a placebo test that randomly assigned a placebo peer company to each of the selected peer companies and then calculated the average innovation for the placebo peer companies. A placebo peer is defined as a company from the same industry that was not included in the disclosing firm's peer group. We found the disclosing firms' innovation to be insignificantly related to placebo peers' innovation, suggesting that compensation peer companies are relevant to corporate innovation.

In the cross-sectional tests, we found that peer effects have a stronger effect on corporate innovation in disclosing firms and their compensation peers that adopt long-term compensation strategies for their CEOs and face stronger labor market competition and more board monitoring. As found in prior studies, paying CEOs using long pay durations may encourage these CEOs to invest more in innovation projects (Manso, 2011; Baranchuk et al., 2014; Gopalan et al., 2014; Welker, 2015). Thus, similarities in long pay duration may intensify peer effects on innovation. Labor market competition and board monitoring represent termination threats for CEOs (Fama, 1980; Bebchuk and Fried, 2003; Cadman et al., 2021) and thus provide incentives to managers to follow the innovation decisions of compensation peers because they maintain or create a competitive advantage in the labor market.

In addition, the peer effect is more pronounced between a firm and its peer companies when they are close in terms of the technological field and when a peer company and the median company in the compensation group are closer in position. This is because peer effects may intensify with increasing intergroup competition (Mas and Moretti, 2009; Bloom et al., 2013; Bena and Li, 2014; Cornelissen et al., 2017).

In exploring the channels that transmit innovation peer effects, this study found no evidence that these effects are driven by financial intermediaries' propagation, as such effects are absent from peer companies, as defined by common analyst coverage or common institutional investors. Similarly, no significant differences were found between the two subsamples of compensation peers who shared and did not share analysts or institutional owners with the disclosing firm. Therefore, peer effects on innovation, rather than being attributable to the knowledge spillover mechanism, are more consistent with the peer pressure mechanism.

To answer the question of whether reforms in disclosure regulations enhance the peer effect, we employed a difference-in-differences (DiD) approach in a seven-year window around the reform period (2003–2009). The treatment group consisted of firms that disclosed their compensation peer group after the reform, but did not disclose this information before the reform. The control group consisted of firms that did not disclose their compensation peer groups either before or after the reform. Firms that voluntarily disclosed their compensation peer groups before the reform were also excluded. To mitigate endogeneity concerns, we adopted nearest-neighbor PSM without replacement. We found that differences in the change in the average value of the innovation variables between treatment firms and their PSM control firms were significantly positive, suggesting that the executive compensation disclosure rules promulgated by the SEC in 2006 may have generated peer effects that led firms to undertake more innovation projects.

This study contributes to literature in several ways. First, it helps to elucidate changes in corporate compensation-peer-group-disclosure behavior attributable to the SEC's 2006 executive compensation disclosure rules. Recent research on the impact of these rules has focused mainly on CEO pay, information content in financial reports, and peer citations (Albuquerque et al., 2013; Bizjak et al., 2011; Faulkender and Yang, 2010; Ferri et al., 2018; Wang et al., 2020; Peng and Yin, 2021; Choi et al., 2022). However, new rules may have generated other unintended consequences. Our findings suggest that although innovation is not considered when selecting compensation peers, the factors considered (i.e., similar product market characteristics, CEO talent/skill/characteristics, and compensation schemes) are known to influence innovation in firms.

Second, it contributes to the growing literature on the determinants of corporate innovation. Several recent studies have focused on using either observable firm-level characteristics or, to a lesser extent, observable managerial characteristics to explain variation in innovation productivity (Hirshleifer et al., 2012; Fang et al., 2014; He and Tian, 2013, 2018, 2020; Hao and Li, 2016; Chang et al., 2019; Ferris et al., 2019; Islam and Zein, 2020). Our research contributes to this literature by providing evidence that most variations in innovation productivity are attributable to peer effects.[3]

Finally, this study contributes to our understanding of the mechanisms underlying peer effects. The primary source of the observed peer effects is likely to be competitive pressure from intergroup competition and knowledge spillover (e.g. Hart, 1983; Mas and Moretti, 2009; Cornelissen et al., 2017). Whereas prior studies have focused primarily on knowledge spillover (e.g. Bloom et al., 2013;

[3] Leary and Roberts (2014) reported that they found no evidence in support of the relationship between corporate R&D investment and industry peer company equity shocks, which was their measure of peer effect. A possible reason is that confounding industry effects render the use of industry rivals unsuccessful in capturing peer effects.

Lychagin et al., 2016; Lucking et al., 2019; Matray, 2021), we show that peer effects in innovation are attributable more to the intergroup competition mechanism than to the knowledge spillover mechanism when the peer group is defined as a compensation peer group.

The remainder of this paper is organized as follows. Section 2 describes the study's sample and methodology. Section 3 presents the empirical results. Section 4 provides further analysis. Section 5 discusses how the disclosure regulation reform affects peer effects. Section 6 presents a set of robustness checks. Finally, the conclusions are presented.

2. Data, variable measurement, and descriptive statistics

2.1. Data

The detailed data on CEO compensation peer companies used in this study were collected from Institutional Shareholder Services Inc.'s Incentive Lab and included details of compensation contracts and peer companies for named executive officers from firms' proxy statements (DEF 14A) for 2006–2013.[4] The year 2006 was the first year covered in the sample because it was the year the SEC required firms to disclose the peer companies used for benchmarking executive pay in the Compensation Disclosure and Analysis section regarding proxy statement filings (beginning with fiscal years ending on or after December 15, 2006). The Incentive Lab database includes the 750 largest (in terms of market capitalization) public firms in the United States for each year. The sample used in this study excludes financial firms (SIC codes 6000–6999). Patent and citation information was obtained from the 2016 edition of the EPO Worldwide Patent Statistical Database (PATSTAT), with supplemental data from Kogan et al. (2017) providing United States Patent and Trademark Office patent database coverage up to 2010.[5,6] Stock returns and financial accounting data were obtained from the Center for Research in Security Prices (CRSP) and Compustat databases, respectively. Institutional ownership information was collected from the Thomson Financial 13f institutional database. Information on CEO compensation was obtained from the Execu-Comp database. The final sample consisted of 5730 disclosing firm-year observations for 956 unique firms and 96,302 firm-year-peer observations for 2518 unique peer companies.

2.2. Variable measurement

We measured resource input into innovation by scaling R&D by book assets (e.g., Ciftci and Cready, 2011; Hirshleifer et al., 2012). Firm-years with missing R&D expenditures were assigned a value of zero, which is a common practice in the literature.[7] The output-oriented measures of innovation were based on patent counts and patent citations, which is a practice widely accepted in the literature for capturing innovation output (e.g., Aghion et al., 2013; Acharya et al., 2014; Hao and Li, 2016; Luong et al., 2017; Rong and Xiao, 2017; Chang et al., 2019).

We used the patenting activity of individual firms to measure their level of innovation[8] and constructed two measures of a firm's innovation output. The first was the number of patent applications filed in a year that were eventually granted. To better capture the actual time of innovation, we used the patent application year instead of the patent grant year as the count year (Griliches et al., 1986; Hall et al., 2001). However, this measure may imperfectly capture innovation quality and importance because patents vary sensitively with their technological and economic significance (Hirshleifer et al., 2012). To further capture the success of innovation output, we constructed a second measure of corporate innovation productivity by counting the number of non-self-citations received by each patent in subsequent years.[9]

The literature indicates two truncation problems in measuring patent activity. The first truncation problem arises because patents appear in the database only after they are granted. The literature indicates an average lag of two years between a patent application and its grant (with the standard deviation of this lag being one year), and that approximately 95% of patents are granted within five years of the application date (Hall et al., 2001). To address this time truncation bias, we ended the period of patent variables in 2014 (i.e., excluding data for 2015 and 2016) and incorporated year fixed effects in our regression analyses (Hirshleifer et al., 2012).[10] Next, we adjusted each patent by the application–grant lag distribution (Hall et al., 2001, 2005). The second truncation bias was attributable to the finite length of the sample. As the citations received by a patent from other patents typically increase over time, patents in the later years of the sample have fewer citations than those in the earlier years. We corrected for this bias by multiplying the raw citation counts for each patent with the weighting index used by Hall et al. (2001, 2005). The weighting index represents the observed citation

[4] In the Incentive Lab database, about 10% of the compensation peers are also used to evaluate relative performance (RPE). Approximately 70% of the RPE peers are used for compensation benchmarking.

[5] The 2016 edition of PATSTAT covers patents granted before the end of 2016.

[6] The data are available at https://iu.app.box.com/v/patents. We thank Leonid Kogan, Dimitris Papanikolaou, Amit Seru, and Noah Stoffman for making these data available.

[7] The results remain unchanged when we deleted firm-years with missing R&D.

[8] While R&D expenditures count only one particular observable input and fail to capture the quality of innovation, patenting activity has been considered a better proxy, as it not only measures innovation output but also captures the effectiveness of innovation inputs (both observable and unobservable; Lerner et al., 2011; Fang et al., 2014; Seru, 2014).

[9] The results are similar when the citation measure includes self-citations.

[10] Bena and Li (2014) also used PATSTAT and removed the last two years to address the truncation concern.

counts by the fraction of predicted lifetime citations actually observed during the lag interval.[11]

The literature shows that the distribution of patent grants is highly right-skewed, with roughly 75% of the observations at zero. To consider the right-skewed distributions of patent counts and citations per patent, we used the natural logarithm of one plus the weight-adjusted patent counts (*PAT*) and the natural logarithm of one plus the citation lag-adjusted citations per patent (*CIT*) as the main measures of innovation output in the analysis.

2.3. Descriptive statistics

Table 1 presents the summary statistics of firm innovation and characteristics and the unintended factors for compensation peers and disclosing firms. To mitigate the influence of extreme observations and eliminate any data coding errors, all variables were winsorized at the 1st and 99th percentiles. The variables were grouped into two distinct categories: peer firm averages and firm-specific factors. The former category included variables constructed as the average of the compensation peers. The latter category included variables constructed as a firm's value in a given year. More importantly, the average ratio of R&D expenditures to total assets was 0.037, which was close to the 0.041 earned by compensation peers. This result suggests that firms and their compensation peers exhibit a similar tendency to invest in R&D. Furthermore, firms appeared to choose compensation peers that are similar in size, operating performance, growth opportunities (proxied by Tobin's Q), sales growth, financial leverage, risk (proxied by stock volatility), stock returns, and institutional ownership, which is consistent with the findings of Faulkender and Yang (2010), Bizjak et al. (2011), and Albuquerque et al. (2013). Moreover, the result also suggests that firms are likely to select compensation peers with similar unintended factors. In terms of the structure of compensation peer groups, the average peer group comprised around 17 firms. Among the selected peers, an average of 35% shared the same Hoberg and Phillips's (2016) three-digit text-based network industry classification (TNIC) as that of the disclosing firm.

3. Empirical results

3.1. Ordinary least squares (OLS) specification

3.1.1. Peer effects in R&D expenditures

We hypothesized that in the presence of the peer effect, firm innovation will be influenced by the innovation investments of their compensation peers. Therefore, we first estimated the model as follows:

$$RDEX_{it} = \alpha + \beta Peer\_RDEX_{it-1} + \boldsymbol{\gamma}' \mathbf{Z}_{it-1} + \varphi_i + \omega_t + \varepsilon_{it}, \quad (1)$$

where $RDEX_{it}$ is R&D expenditures divided by the total assets of firm i in year t; *Peer_RDEX* is the average peer companies' R&D expenditures divided by total assets; and $\boldsymbol{Z}$ is a vector of control variables that includes three variable parts. The first part includes observable firm-specific characteristics. Following Bargeron et al. (2010), Babenko et al. (2011), and Faccio et al. (2011), these characteristics are firm size (*Size*), return on assets (*ROA*), Tobin's Q (*Q*), sales growth rate (*Sales_Growth*), book value of leverage (*Leverage*), stock volatility (*Stock_Volatility*) and return (*Stock_Return*), institutional ownership (*INSTOWN*), and the Herfindahl-Hirschman index (*HHI*).[12] The second part includes two alternative peer group variables: industry and geography peer groups. *Industry_Innovation* is the mean innovation variable of companies that were in the disclosing firm's three-digit TNIC from Hoberg and Phillips (2016), while *Geography_Innovation* is the mean innovation variable of companies whose headquarters are located in the same metropolitan statistical area (MSA) as the disclosing firm.[13] The third and final part includes unintended factors, including CEO outside directorships (*OD*), CEO with PhD degrees (*PhD*), CEO ability proxied by Demerjian et al.'s (2012) Managerial Ability Score (*MAS*) and Custódio et al.'s (2019) General Ability Index (*GAI*), overconfident CEO (*OC*), male CEO (*Male*), CEO age (*Age*), Hoberg and Phillips's (2016) product similarity measure (*SIM*), and CEO pay sensitivity to stock performance (*Delta*) and stock volatility (*Vega*).[14] All variables were winsorized at the 1st and 99th percentiles. φ_i and ω_t are the firm and year fixed effects, respectively. For ease of interpretation, all independent variables were standardized to have a mean of zero and a standard deviation of one. *t*-statistics with standard errors were corrected for heteroskedasticity and firm clustering.

Table 2 presents the results of Eq. (1) using two specifications. The base specification includes peer firm averages, firm-specific characteristics, and two alternative peer groups, while unintended factors are included in the second specification. The results of

[11] We also corrected for the truncation bias in patent citations by scaling the raw citation counts by the average citation counts of all patents applied for in the same technology class and in the same year. The results remained unchanged.

[12] We collected the institutional ownership data from the Thomson-Reuters Institutional Holdings (13F) database and computed HHI as the TNIC HHI in Hoberg and Phillips (2016) using the TNIC horizontal industry network.

[13] Both industry and geography innovation variables are statistically insignificant across models when companies that had been selected as compensation peers are excluded from the alternative peer groups.

[14] We calculated the outside directorships of CEOs using the BoardEx database. We thank Coles et al. (2006) for making CEO pay sensitivity—*Delta* and *Vega*—data available to us.

Table 1
Summary statistics.

	N	Mean	Median	STD
Peer Firm Averages				
Peer_RDEX	5730	0.041	0.017	0.055
Peer_PAT	5730	1.130	0.914	0.999
Peer_CIT	5730	1.064	0.727	1.090
Peer_Size	5730	8.398	8.306	1.309
Peer_ROA	5730	0.049	0.060	0.058
Peer_Q	5730	1.988	1.858	0.671
Peer_Sales_Growth	5730	0.833	0.503	1.580
Peer_Leverage	5730	0.237	0.230	0.110
Peer_Stock_Volatility	5730	0.385	0.350	0.156
Peer_Stock_Return	5730	0.126	0.126	0.308
Peer_INSTOWN	5730	0.747	0.765	0.113
Peer_HHI	5730	0.261	0.245	0.148
Peer_OD	4008	0.466	0.444	0.249
Peer_PhD	4008	0.040	0.000	0.067
Peer_GAI	4008	0.194	0.182	0.438
Peer_MAS	4008	0.042	0.019	0.117
Peer_OC	4008	0.611	0.469	0.554
Peer_Male	4008	0.962	1.000	0.072
Peer_Age	4008	55.924	56.000	3.019
Peer_SIM	4008	3.619	2.334	3.752
Peer_Delta	4008	474.275	254.061	728.090
Peer_Vega	4008	110.754	80.503	94.184
Firm-Specific Factors				
RDEX	5730	0.037	0.004	0.064
PAT	5730	0.849	0.000	1.502
CIT	5730	0.710	0.000	1.494
Size	5730	8.295	8.223	1.424
ROA	5730	0.047	0.055	0.100
Q	5730	1.990	1.613	1.217
Sales_Growth	5730	0.696	0.421	1.195
Leverage	5730	0.248	0.227	0.196
Stock_Volatility	5730	0.396	0.355	0.195
Stock_Return	5730	0.140	0.096	0.471
INSTOWN	5730	0.746	0.812	0.265
HHI	5730	0.254	0.161	0.240
OD	4008	0.472	0.000	0.709
PhD	4008	0.023	0.000	0.150
GAI	4008	0.123	−0.011	0.932
MAS	4008	0.028	−0.019	0.173
OC	4008	0.673	0.311	1.063
Male	4008	0.967	1.000	0.179
Age	4008	55.560	56.000	6.348
SIM	4008	3.791	1.838	4.810
Delta	4008	276.960	128.360	471.864
Vega	4008	81.581	45.975	104.792
Alternative Peer Group Measures				
Industry_RDEX	5730	0.061	0.014	0.094
Geography_RDEX	5730	0.158	0.074	0.409
Industry_PAT	5730	0.545	0.387	0.531
Geography_PAT	5730	0.220	0.144	0.203
Industry_CIT	5730	0.495	0.275	0.564
Geography_CIT	5730	0.194	0.124	0.220
Compensation Peer Information				
Number of peers	5730	16.807		
Dedicated period	5730	3.270		
Proportion of peers that share the same industry with the firm	5730	0.354		

This table presents the number of observations (*N*), means, medians, and standard deviations (STD) for the compensation peers and firms. “Peer Firm Averages” denote variables constructed as the average of the compensation peers. All variables are lagged one year relative to the firm’s R&D expenditures (*RDEX*). Variables are defined in Appendix A and winsorized at the 1st and 99th percentiles.

Table 2
Peer effects in R&D expenditures.

	RDEX	*RDEX*
	(1)	(2)
Peer Firm Averages		
Peer_RDEX	0.161***	0.154***
	(4.94)	(4.33)
Peer_Size	0.060***	0.045*
	(3.65)	(1.90)
Peer_ROA	−0.011	−0.006
	(−1.28)	(−0.68)
Peer_Q	0.034***	0.008
	(2.71)	(0.62)
Peer_Sales_Growth	−0.009	−0.011
	(−1.16)	(−1.13)
Peer_Leverage	0.038***	0.028**
	(3.07)	(2.15)
Peer_Stock_Volatility	0.018	0.002
	(1.64)	(0.15)
Peer_Stock_Return	−0.007	0.004
	(−1.32)	(0.55)
Peer_INSTOWN	0.007	0.005
	(1.02)	(0.61)
Peer_HHI	−0.005	−0.005
	(−0.95)	(−0.68)
Peer_OD		−0.007
		(−0.97)
Peer_PhD		−0.011
		(−1.15)
Peer_GAI		0.002
		(0.28)
Peer_MAS		0.008
		(0.88)
Peer_OC		−0.001
		(−0.12)
Peer_Male		−0.006
		(−0.79)
Peer_Age		0.001
		(0.15)
Peer_SIM		0.053
		(1.55)
Peer_Delta		0.014**
		(1.97)
Peer_Vega		−0.008
		(−0.72)
	(1)	(2)
Firm-Specific Factors		
Size	−0.255***	−0.263***
	(−7.53)	(−5.90)
ROA	−0.028***	−0.017*
	(−2.92)	(−1.80)
Q	0.002	0.018
	(0.20)	(1.26)
Sales_Growth	0.024***	0.041***
	(2.62)	(3.44)
Leverage	−0.059***	−0.085***
	(−3.96)	(−4.01)
Stock_Volatility	−0.012	0.009
	(−1.56)	(1.01)
Stock_Return	−0.002	−0.006
	(−0.30)	(−0.93)
INSTOWN	0.001	0.003
	(0.01)	(0.21)
HHI	−0.014***	−0.012**
	(−2.63)	(−2.30)
Industry_RDEX	0.098***	0.113***
	(3.11)	(3.01)
Geography_RDEX	0.003*	0.003
	(1.94)	(0.85)
OD		0.002
		(0.31)

(*continued on next page*)

Table 2 (*continued*)

	RDEX	*RDEX*
PhD		0.011*
		(1.79)
GAI		0.015
		(1.51)
MAS		0.001
		(0.12)
OC		0.012**
		(2.29)
Male		0.010**
		(2.08)
Age		−0.015*
		(−1.85)
SIM		0.026
		(0.95)
Delta		0.004
		(0.33)
Vega		0.002
		(0.25)
Firm Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
N	5730	4008
Adj. R^2	0.971	0.972

This table presents the results of the regressions of R&D expenditures on the compensation peers' R&D expenditures. The dependent variable is the ratio of R&D to total assets. "Peer Firm Averages" denote variables constructed as the average of the compensation peers. All independent variables are lagged by one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

both models reveal that the coefficients of the average peer firm R&D expenditure are positive and highly statistically significant at the 1% level. The positive sign suggests that R&D investments by compensation peers strengthened the firm's tendency to invest in R&D.[15] In terms of economic magnitude, in Model (1), a one standard deviation increase in *Peer_RDEX* is associated with a 0.161 standard deviation change in *RDEX* (a relative increase of 27.84% compared to the mean *RDEX* of 3.7%). Notably, in terms of peer effect variables, although the average R&D expenditures of industry peers were found to be significantly related to firm R&D investments, the coefficients of *Peer_RDEX* were highly significant. These results suggest that the peer effect of compensation peer groups is a distinct and influential variable in determining corporate R&D expenditures and generates significant incremental explanatory power in understanding the peer effect on corporate innovation.

The effects of peer firm characteristics, other than R&D expenditures, on corporate R&D expenditures were shown to be economically small, while peer firm size and leverage showed the most robust relationship. The coefficients of the two variables were far less than the magnitude of *Peer_RDEX*, implying that the primary channel by which peer firms may influence corporate R&D expenditures is via their R&D expenditures. In terms of the unintended factors, CEOs with PhD degrees, overconfident CEOs, male CEOs, and young CEOs were found to invest relatively more in R&D, which is consistent with the findings of Hirshleifer et al. (2012), Sunder et al. (2017), He and Hirshleifer (2022), and Zhang (2022).

In summary, as shown in Table 2, peer effects significantly influence corporate R&D expenditures. Thus, when making R&D expenditure decisions, firms reference and respond to the actions of their compensation peers.

3.1.2. Peer effects on patenting

This section examines the peer effects on the fruits of innovation output, as proxied by the number of patents a firm applies for (and is eventually granted) in a given year and by the number of citations per patent. The model is expressed as follows:

$$Output_{it} = \alpha + \beta Peer\_Output_{it-1} + \boldsymbol{\gamma}' \boldsymbol{S}_{it-1} + \varphi_i + \omega_t + \varepsilon_{it}, \quad (2)$$

where *Output* is either the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year (*PAT*) or the number of citations per patent in a given year (*CIT*) of firm ***i*** in year ***t***. *Peer_Output* is the average peer company's innovation output. ***S*** is a set that includes control variables (as defined in Eq. (1)), the average innovation output of industry and geography peer groups, and *Peer_RDEX*, and is used to control for the impact of innovation input on output.

[15] To understand the direction of the peer effect on corporate innovation, we created two dummy variables to measure positive and negative changes in the average innovation activity of compensation peers. We re-estimated Equations (1) and (2) by replacing the peer innovation variable with these two variables. The (untabulated) results show that the peer effect on corporate innovation was driven primarily by disclosing firms following their peer companies' increase in innovation.

Table 3
Peer effects in patent counts and citations.

	Ln(1 + PAT)	*Ln(1 + PAT)*	*Ln(1 + CIT)*	*Ln(1 + CIT)*
	(1)	(2)	(3)	(4)
Peer Firm Averages				
Peer_PAT	0.138***	0.134***		
	(3.20)	(2.71)		
Peer_CIT			0.242***	0.247***
			(10.69)	(9.17)
Peer_RDEX	0.009	0.034	0.028	0.074
	(0.32)	(1.00)	(0.66)	(1.40)
Peer_Size	0.025	0.015	−0.020	−0.049
	(1.44)	(0.65)	(−0.60)	(−1.10)
Peer_ROA	−0.005	0.005	−0.012	−0.013
	(−0.71)	(0.64)	(−0.89)	(−0.97)
Peer_Q	0.020*	0.024*	0.021	0.039*
	(1.90)	(1.94)	(1.13)	(1.75)
Peer_Sales_Growth	−0.007	−0.003	−0.026*	−0.007
	(−1.04)	(−0.47)	(−1.84)	(−0.49)
Peer_Leverage	0.002	−0.002	0.029*	0.040*
	(0.18)	(−0.21)	(1.78)	(1.92)
Peer_Stock_Volatility	−0.024**	−0.012	−0.018	−0.013
	(−2.06)	(−0.82)	(−0.84)	(−0.51)
Peer_Stock_Return	0.004	0.010	0.020*	0.029**
	(0.64)	(1.23)	(1.77)	(2.03)
Peer_INSTOWN	0.008	0.010	0.014	0.049***
	(1.01)	(1.05)	(1.06)	(3.01)
Peer_HHI	−0.026***	−0.015	−0.054***	−0.044**
	(−2.69)	(−1.32)	(−3.18)	(−2.07)
Peer_OD		0.004		0.007
		(0.41)		(0.44)
Peer_PhD		0.001		0.017
		(0.06)		(0.96)
Peer_GAI		0.011		0.009
		(0.84)		(0.39)
Peer_MAS		0.010		0.024
		(1.08)		(1.50)
Peer_OC		0.001		0.001
		(1.33)		(0.11)
Peer_Male		0.002		0.013
		(0.29)		(0.88)
Peer_Age		−0.002		−0.007
		(−0.27)		(−0.50)
Peer_SIM		0.011		0.028
		(0.52)		(0.78)
Peer_Delta		0.006		0.018
		(0.60)		(1.03)
Peer_Vega		0.007		0.012
		(0.43)		(0.48)
	(1)	(2)	(3)	(4)
Firm-Specific Factors				
RDEX	0.001	0.002	0.081***	0.037
	(0.08)	(0.13)	(2.66)	(1.12)
Size	0.028	0.026	−0.049	−0.053
	(1.09)	(0.78)	(−1.04)	(−0.93)
ROA	0.004	−0.014*	−0.017	−0.015
	(0.61)	(−1.94)	(−1.39)	(−1.21)
Q	−0.001	0.011	−0.009	0.006
	(−0.12)	(0.90)	(−0.46)	(0.24)
Sales_Growth	−0.010	−0.015	−0.001	−0.030
	(−0.94)	(−1.23)	(−0.06)	(−1.52)
Leverage	0.012	−0.003	−0.004	−0.002
	(1.05)	(−0.26)	(−0.19)	(−0.09)
Stock_Volatility	0.005	−0.002	0.001	0.003
	(0.58)	(−0.16)	(0.06)	(0.14)
Stock_Return	−0.003	−0.008	−0.001	−0.013
	(−0.60)	(−1.20)	(−0.10)	(−1.11)
INSTOWN	−0.005	−0.016	0.015	0.001
	(−0.49)	(−1.33)	(0.92)	(0.02)
HHI	0.009	0.001	0.013	−0.012
	(1.27)	(0.08)	(0.91)	(−0.68)

(*continued on next page*)

Table 3 (*continued*)

	Ln(1 + PAT)	*Ln(1 + PAT)*	*Ln(1 + CIT)*	*Ln(1 + CIT)*
	(1)	(2)	(3)	(4)
Industry_PAT	0.077**	0.075**		
	(2.16)	(2.09)		
Geography_PAT	0.072*	0.073		
	(1.80)	(1.19)		
Industry_CIT			0.144***	0.123***
			(5.94)	(4.18)
Geography_CIT			0.106***	0.065**
			(3.73)	(2.16)
OD		0.009		−0.002
		(1.09)		(−0.12)
PhD		0.013		−0.003
		(1.37)		(−0.21)
GAI		0.026***		0.067***
		(2.76)		(4.06)
MAS		0.015*		0.008
		(1.66)		(0.52)
OC		0.020**		0.028**
		(2.02)		(2.15)
Male		−0.010		−0.021
		(−1.19)		(−1.43)
Age		−0.030**		−0.039*
		(−2.27)		(−1.88)
SIM		−0.001		0.003
		(−0.01)		(0.12)
Delta		0.005		0.007
		(0.24)		(0.20)
Vega		0.038**		0.071***
		(2.14)		(2.74)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
N	5730	4008	5730	4008
Adj. R^2	0.949	0.958	0.837	0.861

This table presents the results of the regressions of patent counts and citations on compensation peer R&D expenditures. The dependent variable is the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year (*PAT*) or the number of citations per patent in a given year (*CIT*). "Peer Firm Averages" denote variables constructed as the average of the compensation peers. All independent variables are lagged by one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

Table 3 presents the results of how peer effects affect firms' innovation output. Models (1) and (2) report the regression results for patent count. The coefficient estimates of *Peer_PAT* are positive and significant at the 1% level. The results show that compensation peers with more patents drove disclosing firms to apply for more patents in the subsequent years. To determine whether the peer effect led disclosing firms to achieve greater innovation by obtaining higher-impact patents, we replaced the dependent variable with the natural logarithm of one plus citations per patent in Models (3) and (4). The resulting coefficient estimates for *Peer_CIT* were positive and highly significant at the 1% level. Taken together, the evidence indicates that peers' innovation activities motivated disclosing firms to produce a greater number of patent grants and citations per patent.

Highlighting the economic significance of the peer effect, one standard deviation increase in *Peer_PAT* and *Peer_CIT* were associated with a 0.138 and 0.242 standard deviation change in *Ln(1 + PAT)* and *Ln(1 + CIT)* in Models (1) and (3), respectively. These results imply a 27.56% increase in the mean number of patents and a 53.24% increase in mean citations per patent, suggesting that peer companies' innovation output is a distinct, influential variable among the determinants of firm innovation productivity that provides incremental explanatory power to understand the peer effect on innovation outputs.

3.2. Identification

Although we found a strong positive association between innovation in compensation peers and in the disclosing firm, these results are potentially subject to the reflection problem akin to simultaneity bias (Manski, 1993) and omitted variable bias. The reflection problem refers to a specific form of endogeneity that arises when one attempts to infer whether the average innovation activities in the compensation peer group influences innovation in the disclosing firm. The second concern relates to variables omitted due to correlated effects, whereby innovation within the group relates to unintended factors, such as similar product market characteristics, CEO talent/skill/characteristics, and compensation schemes that are common to the peer group. In both cases, the coefficient estimates from OLS models are biased and inconsistent. To address endogeneity concerns, we employed three different identification strategies with controls for unintended factors and firm and year fixed effects. The first strategy, discussed in Section 3.2.1, employed a 2SLS approach based on two plausibly exogenous IVs—whether peer companies violated debt covenants and peer companies' idiosyncratic risk.[16] The second strategy, which employs the PSM approach by controlling for selection based on observable firm characteristics and unintended factors, is discussed in Section 3.2.2. Finally, a third strategy that executes a placebo test using randomly selected firms in peers' industries that are not compensation peers of the disclosing firm's peer group is discussed in Section 3.2.3.

3.2.1. Instrumental variable approach

In the first strategy, two methods that have been proposed to address endogeneity concerns were considered. These include the IV method (e.g., Angrist and Keueger, 1991; Evans et al., 1992; Rivkin, 2001; Angrist and Pischke, 2008) and the group-fixed effect strategy (e.g., Lee, 2007; Lin, 2010). Specifically, we use IVs that are correlated with the average R&D expenditure of the compensation peers, but are not independently correlated with the disclosing firm's innovation through other channels. We employed a 2SLS approach based on two plausibly exogenous IVs with firm and year fixed effects: whether peer companies violated debt covenants and peer companies' idiosyncratic risk. Regarding the former IV, our examination was motivated by earlier evidence in the literature on the effect of bank interventions on firm innovation. The reduction effect of bank interventions on a firm's innovation may be attributable to three factors. First, a debt contract is not easily handled by innovative firms with uncertain and volatile returns (Stiglitz, 1985) because of the creditor payoff structure (i.e., creditors do not share upside returns when innovation succeeds, but suffer from downside losses when innovation fails). Second, the hold-up problem associated with bank financing encourages powerful banks to stifle innovation by extracting informational rents (Hellwig, 1991; Rajan, 1992). Finally, bank interventions may mitigate the managerial agency problem, in which managers overinvest in innovation to enjoy private benefits (Scharfstein and Stein, 2000).

The variable *Peer_DCV*, an indicator of peers that experience debt covenant violation, was used in this study as an instrument to measure innovation in the disclosing firm.[17] Covenant violations may be used to examine the effect of bank interventions because the governance role of banks is more pronounced after violations of covenants when banks use their control rights to discipline managers and influence firm decisions (e.g., Chava and Roberts, 2008; Nini et al., 2012; Gu et al., 2017; Balsam et al., 2018). Changes in the control rights of peer companies are correlated with their innovation but are unlikely to be related to the innovation productivity of disclosing firms. Therefore, changes in peer innovation driven by debt covenant violation in the peer group is a plausibly exogenous variation that can help identify the direction of causality.[18]

Following Leary and Roberts (2014), Adhikari and Agrawal (2018), and Grennan (2019), we used the idiosyncratic risk of compensation peers as the second instrument for innovation peer effects. Panousi and Papanikolaou (2012) showed the relevance of idiosyncratic risk in the context of innovation policy. Because investment decisions are undertaken by managers on behalf of shareholders, risk-averse managers holding undiversified stakes in their firms may reduce investments when uncertainty about the firm's future prospects increases, even when this uncertainty is specific only to that firm. Therefore, the idiosyncratic risk of compensation peers is correlated with their innovation activities but does not relate directly to the disclosing firm's innovation.

We estimated compensation peers' idiosyncratic risk using the following market model, which was augmented by Leary and Roberts (2014):

$$r_{it} = \alpha_{it} + \beta_{it}(rm_t - rf_t) + \gamma_{it}(\overline{rp}_{it} - rf_t) + \varepsilon_{it}, \tag{3}$$

where r_{it} refers to the total return for firm i over month t, $(rm_t - rf_t)$ is the excess market return, and $(\overline{rp}_{it} - rf_t)$ is the excess return on an equal-weighted compensation peer portfolio. While not a priced risk factor, this last factor is included to remove any variation in returns that is common across companies in the same compensation peer group.

We calculated the results of Eq. (3) for each firm on a rolling annual basis using historical monthly returns. At least 24 months of historical data were required, and up to 60 months of data were used in the estimation. The idiosyncratic volatility of a firm was computed as the standard deviation of the regression residuals from Eq. (3): We compounded monthly idiosyncratic volatility to obtain an annual measure to maintain consistency with the periodicity of accounting data. Next, we calculated an average of this measure, covering all peer companies for each year. Thus, average peer company idiosyncratic volatility (*Peer_IR*) was used as the source of exogenous variation for peer companies' innovation.

Table 4 presents the results obtained using the IV approach and 2SLS regression. For brevity, the results for the control variables are not reported. In Panel A, the first-stage regression results presented at the bottom of the table are obtained using compensation peers' innovation as the dependent variable to check the relevance of the instruments. The instruments *Peer_DCV* and *Peer_IR* were the main variables of interest. The control variables, with the exception of the two alternative peer group variables, were the same as those used in the baseline regression. Firm and year fixed effects were controlled, and standard errors were adjusted for clustering at the firm level.

As noted by Roberts and Whited (2013) and Wooldridge (2015), a valid instrument should satisfy the conditions of relevance and

[16] The discrete nature of covenant violation generates a potentially exogenous source of variation in the bank interventions that may be used to estimate the effect of covenant violations on corporate investment (e.g., Chava and Roberts, 2008; Chava et al., 2017; Gu et al., 2017). Idiosyncratic risk is generally found to be an IV for peer effects (e.g., Adhikari and Agrawal, 2018; Grennan, 2019; Matsumoto et al., 2022).

[17] We thank Greg Nini, David Smith, and Amir Sufi for providing their covenant violations data to us.

[18] To emphasize the impact of debt covenants violation on the composition of the compensation peer group, we observed that approximately 4% of the peer companies violated debt covenants and that the compensation peer groups of approximately 25% of the disclosing firms experienced debt covenant violations. About 51% of the violators were from the compensation peer groups in the following three years.

Table 4
Peer effects in corporate innovation: Two-stage least squares (2SLS) approach.

Panel A: Firm control variables

	RDEX	*Ln(1 + PAT)*	*Ln(1 + CIT)*
	(1)	(2)	(3)
Second stage:			
Peer_RDEX	1.468***	−0.027	−0.032
	(3.55)	(−1.13)	(−0.77)
Peer_PAT		0.245***	
		(2.62)	
Peer_CIT			0.446***
			(2.70)
First stage:			
Peer_DCV	−0.011**	−0.017***	−0.024***
	(−2.50)	(−2.74)	(−2.79)
Peer_IR	−0.012**	−0.023**	−0.051***
	(−2.13)	(−2.19)	(−3.92)
Firm Control Variables	Yes	Yes	Yes
Unintended Factors	No	No	No
Firm Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
N	5730	5730	5730
Cragg-Donald Wald *F*-statistic	19.329	19.723	26.186
p-value for Hansen *J*-statistic	0.617	0.779	0.568
Adj. R^2	0.948	0.934	0.801

Panel B: Firm control variables and unintended factors

	RDEX	*Ln(1 + PAT)*	*Ln(1 + CIT)*
	(1)	(2)	(3)
Second stage:			
Peer_RDEX	1.048***	0.023	0.048
	(3.40)	(0.85)	(1.04)
Peer_PAT		0.269***	
		(2.89)	
Peer_CIT			0.565**
			(2.54)
First stage:			
Peer_DCV	−0.022***	−0.017**	−0.034***
	(−3.76)	(−2.10)	(−3.05)
Peer_IR	−0.010**	−0.013**	−0.046***
	(−2.02)	(−2.02)	(−2.74)
Firm Control Variables	Yes	Yes	Yes
Unintended Factors	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
N	4008	4008	4008
Cragg-Donald Wald *F*-statistic	24.697	19.789	24.738
p-value for Hansen *J*-statistic	0.930	0.885	0.528
Adj. R^2	0.950	0.941	0.821

This table presents the results of the two-stage least squares (2SLS) approach. Panel A includes firm control variables and Panel B includes firm control variables and unintended factors. The dependent variable is indicated at the top of each column. The endogenous variable is the peer firm average of innovation variables. The instruments are the one-year-lagged *Peer_DCV* and *Peer_IR*. *Peer_DCV* is an indicator of peers who experience debt covenant violations. *Peer_IR* is the average peer company idiosyncratic volatility. All independent variables are lagged by one year relative to the dependent variable. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

exclusion. In this study, with regard to instrument relevance, *Peer_DCV* and *Peer_IR* must partially correlate with compensation peers' innovation after all other exogenous variables included in the regression have been netted out. In the first-stage estimates, the coefficients on *Peer_DCV* and *Peer_IR* were found to be negative and significant at the 5% level or better, suggesting *that Peer_DCV* and *Peer_IR* are strong predictors of compensation peers' innovation. In all the models, the Cragg-Donald *F*-statistics exceeded the critical threshold of 16.38 for rejection at the 5% significance level. Therefore, the null hypothesis that the instruments are weakly correlated with the endogenous variable was rejected.

Regarding instrument exogeneity, the IVs were also found to satisfy the exclusion restriction. For all specifications in the second stage, the overidentification test *p*-values for the Hansen (1982) *J*-statistic were larger than 0.10, suggesting that the null hypothesis (i.e., the instruments are valid and orthogonal to the residuals) cannot be rejected and that their exclusion from the second-stage regressions is appropriate. The results for the second stage of the 2SLS regressions show that, similar to the OLS regressions, compensation peers' innovation significantly and positively predicts innovation in the disclosing firm.[19] The results were replicated when the unintended factors were also included, as shown in Panel B.

Overall, the 2SLS results provide strong evidence that the peer effect of the compensation peer group has a strong causal effect on firm innovation.

3.2.2. The propensity score-matched (PSM) approach

For the second strategy, a matching method was used to examine differences in the innovation variables between disclosing firms with high peer innovation (the top tercile of peer innovation) and with low peer innovation (the bottom tercile of peer innovation). We employed a one-to-one nearest-neighbor matching procedure without replacement.[20] The matching began with a probit regression that used the same set of firm control variables and unintended factors used in the baseline regressions and an indicator variable for a disclosing firm, with high peer innovation as the dependent variable. Then, using the predicted probabilities (propensity scores) from the estimated probit regression, we matched each firm with high peer innovation (treatment firm) to a firm with low peer innovation (control firm) to minimize the absolute value of the difference between propensity scores.

Panel A of Table 5 presents the differences in the innovation variables between the treatment and PSM control firms. Statistically significant differences in innovation were found between the treatment and PSM control firms. To confirm the validity of the matching procedure, univariate comparisons were made of treatment and control firm characteristics and of the mean differences in firm characteristics between treatment and control firms, with the results reported in Table 5, Panel B. None of the differences were shown to be significant, implying that the characteristics of the treatment and control firm groups are similar and, thus, that the matching procedure successfully minimized the differences between the treatment and control groups in terms of these characteristics. Overall, this evidence suggests that the endogeneity of peer innovation is unlikely to drive the primary findings of this study.

3.2.3. The placebo test

For the third strategy, placebo tests were conducted using the same model specifications as those in Tables 2 and 3. However, each peer of disclosing firm *i* was replaced with a randomly selected company from the same industry that was not included in disclosing firm *i*'s peer group as a placebo peer. This allowed us to observe whether there were other factors that potentially influenced the relationship between compensation peers' innovation and a disclosing firm's innovation. Significant results would imply that one or more omitted variables would confound the peer effect of compensation peers and that more innovation activities by compensation peers may not be the driver behind increased innovation in the disclosing firm.

Table 6 reports the results of placebo tests. The results indicate that innovation activities by the placebo peers had no significant impact on disclosing firms' innovation across the models, which is consistent with the hypothesis that compensation peers affect innovation in a disclosing firm. Overall, the placebo tests suggest that the results are not influenced by confounding factors that were not considered.

4. Further analysis

In this section, the factors likely to facilitate or mitigate the peer effect on corporate innovation are explored. In particular, we examine how labor market competition, pay duration, corporate governance, closeness of technological fields between a peer and a disclosing firm, and a peer's likelihood of being the benchmarking company in the compensation peer group influence the peer effect on corporate innovation.

4.1. Labor market competition

For CEOs, labor market competition represents a threat of termination (Fama, 1980; Bebchuk and Fried, 2003; Cadman et al., 2021). In this study, we hypothesized that following the innovation decisions of their compensation peers can help CEOs maintain or create a competitive advantage in the labor market. Therefore, labor market competition may intensify CEOs' incentives to follow their compensation peers' innovation decisions because doing so generally increases their chance of keeping their present job or winning in the job market tournament (Fama, 1980; Lazear and Rosen, 1981; Holmström, 1999; Francis et al., 2016).

Following Gillan et al. (2009), Kale et al. (2009), and He et al. (2019), two measures were used in this paper to capture labor market competition. The first, industry homogeneity, was developed by Parrino (1997). This measure uses monthly data from CRSP for 1990 to 2005 to construct an equal-weighted stock return index for each industry. The monthly returns of each firm in the industry were then regressed on the industry index and an equal-weighted market index. The industry homogeneity index is the partial correlation coefficient for the industry index averaged across firms in each industry, with industries having higher homogeneity index values likely to face greater labor market competition. The second measure used in this study was the natural logarithm of one plus the number of rival firms (defined as firms in the same industry with assets valued at 50–200% of the firm's assets). A higher number of rival firms indicates that a firm faces more labor market competition.

[19] Our results remain unaffected when the 2SLS model was estimated using the methods of limited information maximum likelihood (LIML) and generalized method of moments (GMM).

[20] The results are unaffected by matching with replacement.

Table 5
Peer effects in corporate innovation: Propensity score matching (PSM) approach.

	Treatment Firms	Control Firms	Mean Difference
Panel A: Differences in innovation activities			
RDEX	0.096	0.001	0.095***
Ln(1 + PAT)	2.195	0.261	1.934***
Ln(1 + CIT)	2.066	0.207	1.860***

Panel B: Differences in matching variables

	Treatment Firms	Control Firms	Mean Difference
Peer Firm Averages			
Peer_Size	8.346	8.407	−0.061
Peer_ROA	0.058	0.065	−0.007
Peer_Q	1.979	2.026	−0.047
Peer_Sales_Growth	0.633	0.717	−0.084
Peer_Leverage	0.204	0.204	0.000
Peer_Stock_Volatility	0.376	0.381	−0.005
Peer_Stock_Return	0.061	0.091	−0.030
Peer_INSTOWN	0.781	0.764	0.017
Peer_HHI	0.266	0.256	0.010
Peer_OD	0.534	0.476	0.058
Peer_PhD	0.040	0.035	0.005
Peer_GAI	0.215	0.240	−0.025
Peer_MAS	0.048	0.048	0.001
Peer_OC	0.481	0.553	−0.072
Peer_Male	0.900	0.880	0.019
Peer_Age	55.378	55.593	−0.215
Peer_SIM	2.585	2.534	0.051
Peer_Delta	438.465	498.198	−59.733
Peer_Vega	98.719	107.739	−9.020

	Treatment Firms	Control Firms	Mean Difference
Firm-Specific Factors			
RDEX	8.200	8.049	0.151
PAT	0.075	0.080	−0.005
CIT	2.143	2.239	−0.096
Size	0.698	0.684	0.014
ROA	0.276	0.247	0.028
Q	0.384	0.387	−0.003
Sales_Growth	0.087	0.120	−0.033
Leverage	0.799	0.789	0.009
Stock_Volatility	0.294	0.292	0.002
Stock_Return	0.053	0.053	0.001
Industry_RDEX	0.102	0.091	0.011
Geography_RDEX	0.565	0.507	0.058
INSTOWN	0.029	0.000	0.029
HHI	−0.063	−0.077	0.014
OD	0.042	0.053	−0.011
PhD	0.720	0.713	0.008
GAI	0.986	0.957	0.029
MAS	55.565	54.638	0.928
OC	2.734	2.953	−0.219
Male	408.269	383.825	24.444
Age	85.428	90.349	−4.920
SIM	8.200	8.049	0.151
Delta	0.075	0.080	−0.005
Vega	2.143	2.239	−0.096

This table presents the mean differences in the innovation variables between firms with high peer innovation (the top tercile of peer innovation) and their propensity score–matched (PSM) firms with low peer innovation (the bottom tercile of peer innovation). The innovation variable is indicated on the left-hand side of each row. We match each firm with high peer innovation to a firm with low peer innovation using one-to-one nearest-neighbor matching without replacement. The matching starts with a probit regression using the same set of control variables as in Eq. (1) and an indicator variable for the firm with high peer innovation as the dependent variable. Subsequently, using the predicted probabilities (propensity scores) from the estimated probit regression, we match each firm with high peer innovation to a firm with low peer innovation that minimizes the absolute value of the difference between propensity scores. The last column, labeled "Mean Difference" presents the difference in means between firms with high peer innovation (treatment firms) and their PSM firms with low peer innovation (control firms). *RDEX* is the ratio of R&D to total assets. *PAT* is the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year. *CIT* is the number of citations per patent in a given year. *RDEX* is winsorized at the 1st and 99th percentiles. ***, **, and * denote the respective significance of the differences between disclosing and non-disclosing firms at the 1%, 5%, and 10% levels.

Table 6
Peer effects in corporate innovation: Placebo tests.

	RDEX		*Ln(1 + PAT)*		*Ln(1 + CIT)*	
	(1)	(2)	(3)	(4)	(5)	(6)
Peer Firm Averages						
Peer_RDEX	−0.001	−0.001	0.004	0.002	0.010	0.002
	(−0.13)	(−0.26)	(1.08)	(0.31)	(1.35)	(0.26)
Peer_PAT			−0.004	−0.005		
			(−1.06)	(−1.11)		
Peer_CIT					−0.006	−0.005
					(−1.20)	(−0.73)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	5730	4008	5730	4008	5730	4008
Adj. R^2	0.937	0.949	0.922	0.927	0.813	0.825

This table presents the results of the placebo regressions of corporate innovation on the average of non-selected peers' innovation. We replace each peer of firm *i* with a randomly selected firm from the same industry as the peer but not included in firm *i*'s peer group; these firms are labeled as "non-selected." The dependent variable is the ratio of R&D to total assets (*RDEX*), the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year (*PAT*), or the number of citations per patent in a given year (*CIT*). "Peer Firm Averages" denote variables constructed as the average of the compensation peers. All independent variables are lagged by one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

To test this hypothesis, we estimated Eqs. (1) and (2) separately for the subsamples of firms facing high and low levels of labor market competition. High (low) labor market competition is defined as a firm's labor market competition in the top (bottom) half of its empirical distribution.

Panels A and B in Table 7 report the regression results for labor market competition proxied by the industry homogeneity index and the number of rival firms, respectively. The even- (odd-) numbered columns show the results for the association between the average peer company's innovation and the disclosing firm's innovation for high (low) labor market competition. For brevity, the results for the control variables are not reported. Although the evidence is generally consistent with the baseline results, the coefficients of the average innovation of compensation peer companies were significantly more positive for high-competition markets than for low-competition markets. All the differences in peer innovation coefficients between high and low competition markets were statistically significant at conventional levels, as demonstrated by the *F*-tests. Overall, these results show a stronger peer effect on corporate innovation for firms in high competition markets than in low competition markets.

4.2. CEO pay duration

The similarity in the long pay duration between the firm's CEO and the CEOs of compensation peers was hypothesized to be the main channel through which the innovation investments of a compensation peer group affect innovation in the disclosing firm. To test this hypothesis, we first calculated the CEO pay duration. Following Gopalan et al. (2014) and Welker (2015), pay duration was calculated using the weighted average duration of the four components of pay (i.e., salary, bonus, restricted stock, and stock options). In cases where the stock and option awards have a cliff vesting schedule, we estimated pay duration as follows:

$$Pay\ Duration = \frac{(Salary + Bonus) \times 0 + \sum_{i=1}^{N_1} Res\_Stock_i \times T_i + \sum_{j=1}^{N_2} Option_j \times T_j}{Salary + Bonus + \sum_{i=1}^{N_1} Res\_Stock_i + \sum_{j=1}^{N_2} Option_j} \quad (4)$$

where *i* denotes a restricted stock grant, *j* denotes an option grant, and *Salary* and *Bonus* are the dollar values of the annual salary and bonus, respectively. Pay duration was calculated relative to the year-end; therefore, *Salary* and *Bonus* had a vesting period of zero. Res_Stock_i is the dollar value of restricted stock grant *i* with a corresponding vesting period T_i (in years). During the year, the firm may have other stock grants with different vesting periods (different T_i), and N_1 is the total number of stock grants. Finally, $Option_j$ is the Black-Scholes value of option grant *j* with a corresponding vesting period T_j (in years), while N_2 is interpreted the same as N_1. In cases where the restricted stock grant (option grant) has a graded vesting schedule, the above formula is modified by replacing T_i (T_j) with $(T_i + 1)/2$ ($(T_j + 1)/2$).

Table 7
Labor market competition.

	RDEX		*Ln(1 + PAT)*		*Ln(1 + CIT)*	
	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Industry homogeneity index						
A.1. Firm control variables						
Peer_RDEX	0.085*	0.144***	−0.034	0.045	0.058	0.081
	(1.81)	(3.14)	(−1.51)	(1.18)	(1.58)	(1.60)
Peer_PAT			0.071	0.150**		
			(1.16)	(2.34)		
Peer_CIT					0.101**	0.190***
					(2.57)	(5.23)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2860	2870	2860	2870	2860	2870
Adj. R^2	0.949	0.967	0.960	0.927	0.869	0.770
A.2. Firm control variables and unintended factors						
Peer_RDEX	0.007	0.113**	−0.016	0.035	0.002	0.073
	(0.13)	(2.23)	(−0.62)	(1.03)	(0.06)	(1.15)
Peer_PAT			0.070	0.154***		
			(1.32)	(3.05)		
Peer_CIT					0.108**	0.196***
					(2.10)	(4.67)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2002	2006	2002	2006	2002	2006
Adj. R^2	0.954	0.974	0.967	0.941	0.890	0.811

	RDEX		*Ln(1 + PAT)*		*Ln(1 + CIT)*	
	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)
Panel B: Number of rival firms						
B.1. Firm control variables						
Peer_RDEX	0.056	0.178***	0.014	−0.040	0.041	−0.053
	(1.28)	(3.06)	(0.71)	(−1.38)	(1.58)	(−1.07)
Peer_PAT			0.062	0.147**		
			(0.56)	(2.33)		
Peer_CIT					0.140***	0.230***
					(4.27)	(6.53)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2857	2873	2857	2873	2857	2873
Adj. R^2	0.945	0.950	0.953	0.953	0.850	0.855
B.2. Firm control variables and unintended factors						
Peer_RDEX	0.112*	0.209***	0.020	−0.034	0.050	−0.073
	(1.85)	(3.31)	(0.75)	(−1.04)	(1.06)	(−1.38)
Peer_PAT			0.080	0.142***		
			(1.51)	(2.84)		
Peer_CIT					0.093**	0.186***
					(1.96)	(4.39)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2000	2008	2000	2008	2000	2008
Adj. R^2	0.948	0.954	0.956	0.968	0.861	0.890

This table presents the results of regressions of corporate innovation on average peer innovation conditional on labor market competition. Panels A and B present the results for labor market competition measured by the industry homogeneity index and the number of rival firms, respectively. The "High" ("Low") columns in Panels A and B present the results for a firm operating in an industry whose industry homogeneity index and number of rival firms lie in the top (bottom) half of its empirical distribution. *RDEX* is the ratio of R&D to total assets. *PAT* is the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year. *CIT* is the number of citations per patent in a given year. All independent variables are lagged by one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

Next, Eqs. (1) and (2) were estimated separately for subsamples of the CEO pay duration of the disclosing firm that are close to and far from the average CEO pay duration of their compensation peers, respectively. Close pay duration refers to when both the disclosing firm's CEO pay duration and the average CEO pay duration of peer companies are higher than the industry median.[21] Far pay duration refers to when either the disclosing firm's CEO pay duration or the average CEO pay duration of peer companies is below the industry median. Table 8 presents the results.

In Table 8, the odd- (even-) numbered columns show the results for the close (far) pay duration subsample. For brevity, the results for the control variables are not reported. Consistent with the peer effect being more significant in disclosing firm CEOs with a longer pay duration, similar to their compensation peers, the coefficient on *Peer_RDEX* was 0.195 (*t*-statistic = 2.78) for the close pay duration subsample and 0.101 (*t*-statistic = 1.53) for the far pay duration subsample. The difference in *Peer_RDEX* coefficients between the two subsamples was statistically significant at the 1% level, as demonstrated using an *F*-test. Similar results were obtained when we used the number of patents and citations per patent as measures of innovation activities. The differences remained statistically significant at the 1% level when we added controls for unintended factors. In summary, these results show a stronger peer effect on corporate innovation in disclosing firms when their CEO shares a similar long pay duration with the CEOs of compensation peers.

4.3. Corporate governance

Corporate boards are likely to terminate poorly performing managers (Weisbach, 1988). This threat incentivizes managers to work hard (Stiglitz and Weiss, 1983). Increased monitoring from boards may increase the demand for results, which encourages managers to focus on quantifiable results such as the number of patents (Balsmeier et al., 2017).

Following Linck et al. (2008), Coles et al. (2014), and Balsmeier et al. (2017), two measures were used in this study to capture board governance. The first is the co-opted board, developed by Coles et al. (2014), which is defined as the number of directors appointed after the CEO assumed office (i.e., "co-opted" directors) divided by the board size. A firm with a greater proportion of co-opted directors on its board is likely to be monitored less stringently. The second measure used to capture board governance is CEO duality, which identifies that the chairperson of the board and CEO are the same individual. When the CEO is also the chairperson of the board, firm activities are expected to be monitored less stringently.

To test this hypothesis, we estimated Eqs. (1) and (2) separately for the subsamples of CEOs facing high and low board monitoring. A high (low) co-opted board is defined as a firm's co-opted board at the top (bottom) half of its empirical distribution.

Panels A and B in Table 9 report the regression results for board governance proxied by the co-opted board and CEO duality are, respectively. For brevity, the results for the control variables are not reported. In Panel A, the even- (odd-) numbered columns show the results for the association between the average peer company's innovation and the disclosing firm's innovation for a high (low) co-opted board. The coefficients of the average innovation of compensation peer companies are more positive for low co-opted boards than for high co-opted boards across all innovation measures. The differences in peer innovation coefficients between high and low co-opted boards are statistically significant at conventional levels, as demonstrated by the *F*-tests. In Panel B, the coefficients of average peer companies' innovation are more positive and smaller for firms with CEO duality than for firms without CEO duality. The differences in the coefficients for these two subsamples were statistically significant at the conventional levels, as demonstrated by the *F*-tests. Overall, these results suggest that the peer effect on corporate innovation is stronger for CEOs facing greater board monitoring than for those facing less board monitoring.

4.4. Closeness of technological fields

In line with the literature (e.g., Mas and Moretti, 2009; Cornelissen et al., 2017), the above findings show that the influence of intergroup competition on innovation may be a channel through which peer effects operate. Close rivals in the product market space may engage in similar innovation activities, with their individual R&D efforts potentially leading to the introduction of new products or services and the further intensification of product market competition (Bloom et al., 2013; Bena and Li, 2014). Thus, disclosing firms and peer companies in the same technological field should experience higher innovation competition and a more intense peer effect.

To test this hypothesis, we examined whether the peer effects of the compensation peer group varied depending on the level of technological field closeness between the disclosing firms and their peer companies. This similarity was measured by whether a peer

[21] Gopalan et al. (2014) found significant cross-sectional variation in pay duration across industries attributable to industry-related differences. For ease of comparison between disclosing firms and their peer companies, especially peer companies operating in industries different from the disclosing firms, we used a pay duration measure adjusted for industry effects.

Table 8
CEO pay duration.

	RDEX		*Ln(1 + PAT)*		*Ln(1 + CIT)*	
	Close	Far	Close	Far	Close	Far
	(1)	(2)	(3)	(4)	(5)	(6)
Firm control variables						
Peer_RDEX	0.195***	0.101	−0.015	−0.010	−0.028	0.051
	(2.78)	(1.53)	(−0.45)	(−0.21)	(−0.51)	(0.54)
Peer_PAT			0.157***	0.032		
			(3.22)	(0.07)		
Peer_CIT					0.190***	0.054
					(5.16)	(0.67)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	3203	2527	3203	2527	3203	2527
Adj. R^2	0.959	0.949	0.955	0.950	0.873	0.839
Firm control variables and unintended factors						
Peer_RDEX	0.154***	0.084*	−0.015	−0.041	−0.016	−0.060
	(2.77)	(1.87)	(−0.39)	(−1.47)	(−0.22)	(−1.36)
Peer_PAT			0.154***	0.058		
			(3.49)	(0.37)		
Peer_CIT					0.181***	0.095
					(6.03)	(1.57)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2110	1898	2110	1898	2110	1898
Adj. R^2	0.967	0.952	0.961	0.960	0.892	0.861

This table presents the results of regressions of corporate innovation on average peers' innovation, conditional on the similarity in pay duration between the firm's CEO and the CEOs of compensation peers. The "Close" columns present the results for both the disclosing firm's CEO pay duration and the average peer companies' CEO pay duration above the industry median. The "Far" columns present the results for either the disclosing firm's CEO pay duration or the average of peer companies' CEO pay duration below the industry median. *RDEX* is the ratio of R&D to total assets. *PAT* is the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year. *CIT* is the number of citations per patent in a given year. All independent variables are lagged by one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

company operated in the same industry as the disclosing firm and by innovation proximity. Following Jaffe (1986) and Bena and Li (2014), we assess innovation proximity as the non-centered correlation coefficient of patent counts between two firms. More precisely, we calculated patent counts in the six technology areas used by Hall et al. (2001) for each disclosing firm *i* and then computed the non-centered correlation coefficient between the firm and its peer company *j*:

$$\frac{S_i S_j'}{\sqrt{S_i S_i'}\sqrt{S_j S_j'}} \tag{5}$$

$S_i = (S_{i,1}, \ldots, S_{i,k})$ is a vector of patent counts in *k* technology areas for firm *i*, where *k* indicates the technology class. We define S_j in a similar manner. Average technology proximity was computed by averaging the proximity of firm *i* to all its compensation peer companies. Innovation proximity captures the technological overlap between a disclosing firm and peer company, assuming market competition to increase at higher degrees of innovation proximity.

Panels A and B in Table 10 report the results for technological field closeness proxied by whether a peer company operates in the same industry as the disclosing firm and by innovation proximity, respectively. For brevity, the results for the control variables are not reported. To obtain the results in Panel A, we first computed the average innovation activities for peer companies operating in the same industry and then for peer companies operating in different industries than the disclosing firm. Consistent with our hypothesis, the relationship between peer innovation and disclosing firm innovation for peer companies operating in the same industry as the disclosing firm is substantially greater and more statistically significant than for peer companies operating in other industries. Moreover, the difference in coefficients was statistically significant in all regressions, as demonstrated by the *F*-tests. However, the coefficients of average innovation activities for peer companies operating in different industries as the disclosing firm were positive and statistically significant only for the citation measure. These findings suggest that the peer effect of compensation peer groups is attributable mainly to industry compensation peers.

In Panel B, *PHigh* and *PLow* represent peer companies that share high and low innovation proximity, respectively, with the

Table 9
Corporate governance.

	RDEX	*Ln(1 + PAT)*		*Ln(1 + CIT)*		
	Low	High	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Co-opted board						
A.1. Firm control variables						
Peer_RDEX	0.231***	0.044	−0.043	0.006	−0.072	0.026
	(2.91)	(0.76)	(−1.00)	(0.16)	(−1.17)	(0.36)
Peer_PAT			0.149**	0.057		
			(2.49)	(0.55)		
Peer_CIT					0.220***	0.124***
					(4.92)	(3.10)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2137	2097	2137	2097	2137	2097
Adj. R^2	0.961	0.954	0.953	0.950	0.882	0.863
A.2. Firm control variables and unintended factors						
Peer_RDEX	0.264***	0.059	−0.044	0.029	−0.102	0.090
	(3.20)	(0.80)	(−1.03)	(0.66)	(−1.28)	(1.14)
Peer_PAT			0.148**	0.058		
			(2.06)	(0.68)		
Peer_CIT					0.226***	0.122**
					(5.11)	(2.40)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	1988	1982	1988	1982	1988	1982
Adj. R^2	0.971	0.965	0.963	0.959	0.895	0.887

	RDEX		*Ln(1 + PAT)*		*Ln(1 + CIT)*	
	No	Yes	No	Yes	No	Yes
	(1)	(2)	(3)	(4)	(5)	(6)
Panel B: CEO duality						
B.1. Firm control variables						
Peer_RDEX	0.158***	0.008	−0.001	−0.034	−0.003	−0.059
	(3.41)	(0.08)	(−0.02)	(−0.88)	(−0.06)	(−1.26)
Peer_PAT			0.115***	0.055		
			(2.66)	(0.21)		
Peer_CIT					0.165***	0.084*
					(5.59)	(1.81)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	4067	1083	4067	1083	4067	1083
Adj. R^2	0.959	0.949	0.975	0.953	0.954	0.841
B.2. Firm control variables and unintended factors						
Peer_RDEX	0.131***	0.125	0.018	−0.032	0.053	0.086
	(2.74)	(0.93)	(0.49)	(−0.76)	(0.89)	(1.57)
Peer_PAT			0.139**	0.052		
			(2.08)	(0.10)		
Peer_CIT					0.193***	0.037
					(5.45)	(0.73)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	3144	856	3144	856	3144	856
Adj. R^2	0.961	0.953	0.978	0.959	0.959	0.860

This table presents the results of the regressions of corporate innovation on the average peers' innovation conditional on corporate governance. Panels A and B present the results for corporate governance measured using co-opted board and CEO duality, respectively. In Panel A, the "High" ("Low") columns present the results for a firm with co-opted board lies in the top (bottom) half of its empirical distribution. In Panel B, the "Yes" ("No") columns present the result for a firm with (without) the CEO to serve as board chairperson. *RDEX* is the ratio of R&D to total assets. *PAT* is the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year. *CIT* is the number of citations per patent in a given year. All independent variables are lagged one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively

Table 10
Closeness of technological fields.

	RDEX		*Ln(1 + PAT)*		*Ln(1 + CIT)*	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Industry peers versus non-industry peers						
Peer Firm Averages						
Peer_RDEX_TNIC3	0.103***	0.086**				
	(2.60)	(2.36)				
Peer_RDEX_NTNIC3	0.046	0.038				
	(1.40)	(1.06)				
Peer_PAT_TNIC3			0.125**	0.123**		
			(2.14)	(2.06)		
Peer_PAT_NTNIC3			0.064	0.059		
			(1.48)	(1.46)		
Peer_CIT_TNIC3					0.187***	0.172***
					(4.61)	(3.23)
Peer_CIT_NTNIC3					0.109**	0.105**
					(2.24)	(2.06)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	5730	4008	5730	4008	5730	4008
Adj. R^2	0.952	0.942	0.953	0.960	0.848	0.869
Panel B: Innovation proximity						
Peer Firm Averages						
Peer_RDEX_PHigh	0.119**	0.092*				
	(2.44)	(1.87)				
Peer_RDEX_PLow	0.021	0.064				
	(0.74)	(1.46)				
Peer_PAT_PHigh			0.101**	0.100**		
			(2.24)	(2.23)		
Peer_PAT_PLow			0.044	0.037		
			(0.99)	(0.56)		
Peer_CIT_PHigh					0.176***	0.171**
					(2.66)	(2.26)
Peer_CIT_PLow					0.107**	0.100*
					(2.25)	(1.95)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	5730	4008	5730	4008	5730	4008
Adj. R^2	0.956	0.957	0.959	0.967	0.872	0.898

This table presents the results of the effects of technological field closeness between disclosing firms and peer companies in terms of the association between corporate innovation and average peers' innovation. Panels A and B present the results for the closeness of technological fields, measured by whether a peer company operates in the same industry as the disclosing firm's three-digit text-based TNIC industry classification and innovation proximity, respectively. *TNIC3* (*NTNIC3*) denotes peer companies operating in the same (different) industry as the disclosing firm. *PHigh* (*PLow*) represents peer companies with high (low) innovation proximity to a disclosing firm. High (low) innovation proximity is the innovation proximity between a peer and disclosing firm in the top (bottom) half of its empirical distribution. All independent variables are lagged by one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

disclosing firm. High and low innovation proximities are the proximity in innovation between a peer and the disclosing firm in the top and bottom half of its empirical distribution, respectively. In Models (1) and (2), *Peer_RDEX_PHigh* was significantly associated with disclosing firm innovation, and when compared to *Peer_RDEX_PLow*, the difference in coefficients was found to be statistically significant. As shown in Models (3) to (6), the results remained the same when innovation activities were defined as the number of patents and citations per patent.

Overall, these results demonstrate that peer innovation activities have a stronger impact on disclosing firms' innovation when there is more innovation competition between a disclosing firm and its peer companies.

4.5. Likelihood of being a benchmarking company

Both academic and practitioner communities have advocated that, when firms use compensation benchmarking, they most often target the pay of their CEOs to the median pay of a selected peer group (e.g., Bizjak et al., 2008; Faulkender and Yang, 2010; Bizjak et al., 2011; Faulkender and Yang, 2013). Therefore, the relative position of a peer company in the peer group matters because the likelihood of a peer being a benchmarking company (i.e., a median company) increases with its closeness to the median. Thus, we expect the degree of proximity to the median company to relate positively to the peer effect strength.

To test this hypothesis, we examined whether the proximity between a peer company and the median company influenced the peer effects of the compensation peer group. *Q23* (*Q14*) is defined as peers with total CEO compensation within (outside) the second and third quartiles of the peer group.

Table 11 presents the results of this analysis. For brevity, the results for the control variables are not reported. The results are consistent with the prediction that the coefficients of *Peer_RDEX_Q23* are significantly more positive than those of *Peer_RDEX_Q14*. All the differences in coefficients between *Peer_RDEX_Q23* and *Peer_RDEX_Q14* were statistically significant at conventional levels, as demonstrated by the *F*-tests. Moreover, the results continued to hold when innovation activities were defined as the number of patents and citations per patent. Overall, these results show that peer effect has a stronger impact on corporate innovation when peers' relative positions are closer to the median peer company.

5. Discussion

5.1. Alternative channel

This study argues that CEOs often strategically imitate their peers to maintain or create a competitive advantage for their firm, which increases their chances of retaining their present job or winning the job market tournament. This mechanism is referred to in the

Table 11
Likelihood of being the benchmarking company.

	RDEX		*Ln(1 + PAT)*		*Ln(1 + CIT)*	
	(1)	(2)	(3)	(4)	(5)	(6)
Peer Firm Averages						
Peer_RDEX_Q23	0.108***	0.107***				
	(3.09)	(2.93)				
Peer_RDEX_Q14	0.056**	0.045**				
	(2.46)	(2.07)				
Peer_PAT_Q23			0.097**	0.088**		
			(2.57)	(2.19)		
Peer_PAT_Q14			0.048*	0.040		
			(1.74)	(1.13)		
Peer_CIT_Q23					0.166***	0.161***
					(7.45)	(5.88)
Peer_CIT_Q14					0.086***	0.079***
					(3.77)	(2.71)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	5730	4008	5730	4008	5730	4008
Adj. R^2	0.942	0.952	0.953	0.960	0.848	0.869

This table presents the results of regressions of the innovation variables on the average innovation for the compensation peer companies with high and low likelihood to be the benchmark. *Q23* (*Q14*) is defined as a compensation peer company with total CEO compensation within (outside) the second and third quartiles of the distribution. The dependent variable is the ratio of R&D to total assets (*RDEX*), the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year (*PAT*), or the number of citations per patent in a given year (*CIT*). "Peer Firm Averages" denote variables constructed as the average of the compensation peers. All independent variables are lagged by one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

economics literature as peer pressure.[22] However, it is also possible that firms learn fundamental information associated with innovation activities conducted by their peers and then, based on this information, engage in innovation activities similar to those of their peers. This mechanism is referred to as knowledge spillover.[23] To explore the knowledge spillover mechanism, we examined whether propagation by financial intermediaries enhances peer effects.

Cao et al. (2019) argued that corporate social responsibility (CSR) peer effects likely depend on propagation by financial intermediaries (common analysts and common institutional investors) because a peer's CSR policy can spill over to its competing firms through propagation by financial intermediaries. Thus, if propagation by financial intermediaries drives peer effects on innovation, we would expect the peer effect of the compensation peer group to be stronger if peer companies are covered by a common financial analyst or held by common institutions.

As shown in Table 12, we investigated the alternative channel by conducting analyses similar to those in the previous tables, comparing the corporate innovation of peers with and without common financial intermediaries. The "common" characteristic is defined as a firm and its peer being covered by the same financial analyst or being held by the same monitoring institutions. *NCommon* includes the remainder of peer companies. Monitoring institutions are defined as those whose holding value in the firm is in the top 10% of its portfolio. This reflects the fact that institutions allocate monitoring resources to a firm based on the relative importance of that firm's stock in their portfolio (Fich et al., 2015).[24]

For brevity, the results for the control variables are not reported. The coefficients of *Peer_RDEX_Common* and *Peer_RDEX_NCommon* were positive and statistically significant. The differences in coefficients between *Peer_RDEX_Common* and *Peer_RDEX_NCommon* were statistically insignificant, as demonstrated by the *F*-test. Moreover, the results remained the same when innovation activities were defined as the number of patents and citations per patent. Overall, these results suggest that the peer effects of the compensation peer group are probably not attributable to the knowledge spillover mechanism but rather to the peer pressure mechanism.

5.2. Selection of compensation peer groups

It is possible that R&D is a determinant in the selection of compensation peers. Under this condition, the observed positive relationship between disclosing firms' and compensation peers' R&D expenditures would be clearly driven by the choice itself.[25] Testing this hypothesis requires having not only the list of companies selected as compensation peer group members, but also the list of potential peer companies that were not selected. The treatment sample for this test includes peers noted by firms in their proxy filings. Following Faulkender and Yang (2010) and Bizjak et al. (2011), the sample of potential peers included all of the disclosing firms and their selected peers in a given year. Thus, for each firm, the pool of potential peers consists of the remaining disclosing firms and the selected peers.

Subsequently, a PSM approach was applied.[26] Following Faulkender and Yang (2010) and Bizjak et al. (2011), we matched selected peers with unselected potential peers using the variables of total CEO compensation, firm characteristics (i.e., sales, market capitalization, and total assets), firm complexity (i.e., the number of business and geographic segments), index membership (i.e., Dow Jones, S&P500, and S&P Mid Cap 400), CEO responsibility (i.e., whether the CEO is also the chair of the board), number of peers, and talent flows (i.e., whether one of the top five executives moved from the firm during 1992–2005). In addition, unintended factors were added as matched variables in the PSM analysis.

For each firm-peer pair, we calculated the probability (propensity score) that a potential peer would be included in the peer group. Next, we regressed the selected peer indicator variable on the set of variables and estimated the probit regression year by year, allowing the sensitivity of the firm and peer characteristics to change over time. The propensity score was calculated using the estimated coefficients and realizations of the corresponding independent variables for each potential peer. Each selected peer was then matched to the unselected potential peer with the closest propensity score without replacement. This matched sample allowed us to calculate the absolute value of the ratio of average peers' innovation to the disclosing firm's innovation minus one. We then calculated the mean differences in the ratio between the selected peers and the PSM unselected peers.

The mean differences between the selected and PSM unselected peers, as shown in Table 13, were found to be negative and statistically insignificant, suggesting that common innovation intensity is not a determinant factor in choosing compensation peers. Overall, this evidence supports that although the factors used to select compensation peers are not intended to impact decision-making behavior related to innovation, the similarities in the product market, CEO characteristics, and compensation schemes between the disclosing firm and compensation peer firms have unintended peer effects on innovation.

5.3. The reform of disclosure regulation

The evidence found in support of a strong tie between compensation peer innovation and predictable variation in corporate innovation adds a stylized fact to corporate finance. It also raises a fundamental question: Did the 2006 reform to disclosure regulations

[22] See, for example, Kandel and Lazear (1992), Edmans et al. (2012), Cornelissen et al. (2017), and Cao et al. (2019).
[23] See, for example, Foucault and Fresard (2014), Kaustia and Rantala (2015), and Dessaint et al. (2019).
[24] The results continued to hold when we changed the threshold of the holding value in the target to the top 5% of the institution's portfolio.
[25] We thank an anonymous referee for raising this issue.
[26] We did not use multivariate probit regression because the problem of multicollinearity may arise when peer R&D expenditures are correlated with other peer characteristics.

Table 12
Alternative channel: Knowledge spillovers.

	RDEX		*Ln(1 + PAT)*		*Ln(1 + CIT)*	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Common financial analyst						
Peer Firm Averages						
Peer_RDEX_Common	0.105***	0.098**				
	(3.00)	(2.57)				
Peer_RDEX_NCommon	0.091***	0.073**				
	(2.91)	(2.08)				
Peer_PAT_Common			0.079**	0.078**		
			(2.33)	(2.15)		
Peer_PAT_NCommon			0.078**	0.071**		
			(2.31)	(1.99)		
Peer_CIT_Common					0.123***	0.111***
					(5.01)	(4.28)
Peer_CIT_NCommon					0.107***	0.097***
					(4.81)	(3.93)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	5730	4008	5730	4008	5730	4008
Adj. R^2	0.951	0.953	0.952	0.960	0.847	0.868
Panel B: Common institutional investor						
Peer Firm Averages						
Peer_RDEX_Common	0.087**	0.082**				
	(2.52)	(2.49)				
Peer_RDEX_NCommon	0.082**	0.075**				
	(2.37)	(2.16)				
Peer_PAT_Common			0.105***	0.100**		
			(3.01)	(2.55)		
Peer_PAT_NCommon			0.090**	0.084**		
			(2.43)	(2.27)		
Peer_CIT_Common					0.089***	0.083***
					(3.21)	(2.91)
Peer_CIT_NCommon					0.075**	0.071**
					(2.41)	(2.30)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	5730	4008	5730	4008	5730	4008
Adj. R^2	0.949	0.954	0.968	0.975	0.892	0.905

This table presents the effects of common financial intermediaries between the disclosing firm and peer companies on the association between corporate innovation and average peer innovation. Panels A and B present the results for common financial intermediaries measured by whether a peer company and the disclosing firm are covered by the same financial analyst and held by the same monitoring institutions, respectively. Following Fich et al. (2015), monitoring institutions are defined as those whose holding value in the firm is in the top 10% of their portfolios. *Common* (*NCommon*) means that a peer company and disclosing firm are covered by the same (different) financial intermediaries. All independent variables are lagged by one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

enhance the peer effect?

To answer this question, a DiD approach was applied covering a seven-year window around the reform (2003–2009).[27] The treatment group consisted of firms that disclosed compensation peer groups after the reform but did not do so before the reform. The control group consisted of firms that did not disclose their compensation peer groups either before or after the reform. Firms that voluntarily disclosed compensation peer groups before the reform were excluded. To mitigate endogeneity concerns, we used nearest-neighbor PSM without replacement.[28] Each treatment firm was matched to a control firm using one-to-one nearest-neighbor matching without replacement, and matching began with a probit regression as follows:

[27] The DiD approach removes any permanent difference between treatment and control firms and any common trend affecting both groups.
[28] The results are qualitatively similar when matched with replacement.

Table 13
Compensation peer selection.

	Selected Peers	PSM Unselected Peers	Mean Difference
$ABS\left(\frac{Peer\_RDEX}{RDEX}-1\right)$	3.740	3.993	−0.254
$ABS\left(\frac{Peer\_PAT}{PAT}-1\right)$	0.839	0.867	−0.028
$ABS\left(\frac{Peer\_CIT}{CIT}-1\right)$	0.845	0.869	−0.024

This table reports mean absolute differences in innovation variables between the selected peers and the propensity score matched (PSM) unselected firms. For each firm-peer pair, we calculate the probability (propensity score) that a potential peer will be included in the peer group. We regressed the selected peer indicator variable on the set of variables. We estimate the probit regression year-by-year, thus allowing the sensitivity of firm and peer characteristics to change over time. The propensity score was calculated using the estimated coefficients and realizations of the corresponding independent variables for each potential peer. Each selected peer is then matched to an unselected potential peer that has the closest propensity score, without replacement. ***, **, and * denote the respective levels of significance of *t*-tests for differences in mean between the two subsamples at the 1%, 5%, and 10% levels.

$$Pr(Disclosure_{it}) = \alpha + \beta_1 LnMktCap_{it} + \beta_2 Stock\ Volatility_{it} + \beta_3 Q_{it} + \beta_4 Leverage_{it} + \beta_5 Big4_{it} + \omega_t + \theta_j + \varepsilon_{it}, \tag{6}$$

where $Disclosure_{it}$ is an indicator variable that takes a value of one for firm *i* disclosing its compensation peer group in year *t* and zero for S&P 900 non-disclosing firms.[29] The explanatory variables were used as suggested by Healy and Palepu (2001) and as defined in Appendix A. ω and θ capture the year and industry fixed effects. ε is an error term.

Next, using the predicted probabilities (propensity scores) from the estimated probit regression, we matched a control firm to each treatment firm in the year 2005, which minimized the absolute value of the difference between the propensity scores. Notably, it was critical to assess how well the PSM procedure created comparable samples between the treatment and PSM control groups. We performed a univariate analysis to ensure that the firms in the two groups were not statistically different from each other prior to matching. In the untabulated results, we verified that the treatment firms and PSM control firms had indistinguishable characteristics for each control variable.

Table 14 presents the differences in the changes in the average value of the innovation variables from 2003 to 2005 to 2007–2009 between the treatment firms and their PSM control firms. All DiD estimators were positive and statistically significant at the 1% level, suggesting that the SEC's 2006 executive compensation disclosure rules generated peer effects that led firms to undertake more innovation projects.

6. Robustness

We conducted a variety of robustness tests, repeating the main analysis using alternative model specifications, alternative measures of innovation, and alternative regression methods and samples.

6.1. Changes in peer group members

Our results show that the innovation activities of the selected peer companies can predict a disclosing firm's innovation. Although these findings are consistent with the peer effect, they are subject to other interpretations. For example, the observed correlation may arise from the similarity between a disclosing firm and its peers. To address this concern, we focused on companies that were added to or dropped from the compensation peer groups of disclosing firms over time. If the peer effect underlies the positive association with innovation activities between a disclosing firm and its peer group, the added or dropped peers should have no significant influence on a disclosing firm's innovation.

To test this hypothesis, we estimated the same model specifications as shown in Tables 2 and 3, using only the added and dropped peer companies. Panels A and B in Table 15 report the results for the dropped and added peers, respectively. Dropped peers include firms dropped from the peer group in year *t* but included in the peer group in year *t – 1*. Added peers include firms not selected in the peer group in year *t*, but included in the peer group in year $t + 1$. The results confirmed the hypothesis that innovation in the disclosing firms was not significantly related to innovation in the dropped or added peers.

6.2. Alternative measures of innovation

To further capture the underlying quality and fundamental nature of innovation output, we defined two alternative innovation proxies: patent generality and patent originality (Trajtenberg et al., 1997; Hall et al., 2001; Chemmanur et al., 2014; Bernstein, 2015).

[29] The results remain unchanged when S&P 1500 firms were used.

Table 14
Difference-in-differences (DiD) analysis using the SEC's 2006 executive compensation disclosure rules.

	Mean Treatment Difference	Mean Control Difference	Mean DiD Estimator	*t*-statistic for DiD Estimator
RDEX	0.0001	−0.0007	0.0008	5.21
Ln(1 + PAT)	0.0071	0.0024	0.0047	2.67
Ln(1 + CIT)	−0.1935	−0.3231	0.1297	3.10

This table reports the DiD tests using S&P 900 firm data from 2003 to 2009. We examine how exogenous changes in disclosure requirements due to the SEC's 2006 executive compensation disclosure rules affect firm innovation. Firms are classified as disclosing (non-disclosing) firms if they disclose (do not disclose) information on compensation peer groups for 2007–2009. We exclude firms that voluntarily disclosed compensation peer groups for 2003–2005. We employed a matching method to examine the differences in innovation measures between disclosing and non-disclosing firms. The matching procedure we employed is one-to-one nearest-neighbor matching without replacement in 2006. The matching starts with a probit regression, using the model specification in Eq. (6), and an indicator variable for a disclosing firm as the dependent variable. Thereafter, using the predicted probabilities (propensity scores) from the estimated probit regression, we match each disclosing firm (treatment firm) to a non-disclosing firm (control firm), which minimizes the absolute value of the difference between propensity scores. We report the mean differences in the innovation measures between the three-year window before and after the SEC's 2006 executive compensation disclosure rule. *RDEX* is the ratio of R&D to total assets. *PAT* is the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year. *CIT* is the number of citations per patent in a given year. *RDEX* is winsorized at the 1st and 99th percentiles.

Table 15
Changes in peer group members.

	RDEX		*Ln(1 + PAT)*		*Ln(1 + CIT)*	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Dropped peers						
Peer Firm Averages						
Peer_RDEX	−0.013	−0.048	0.008	0.016	0.004	−0.051
	(−0.36)	(−1.41)	(0.53)	(0.75)	(0.12)	(−1.18)
Peer_PAT			0.038	−0.001		
			(1.22)	(−0.02)		
Peer_CIT					0.033	0.027
					(1.59)	(0.85)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2141	1149	2141	1149	2141	1149
Adj. R^2	0.901	0.907	0.951	0.961	0.836	0.855
Panel B: Added peers						
Peer Firm Averages						
Peer_RDEX	0.077	0.055	−0.001	0.007	−0.018	−0.022
	(1.47)	(1.24)	(−0.01)	(0.32)	(−0.65)	(−0.62)
Peer_PAT			−0.021	−0.037		
			(−0.87)	(−1.07)		
Peer_CIT					0.007	0.013
					(0.38)	(0.51)
Firm Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Unintended Factors	No	Yes	No	Yes	No	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
N	2352	1374	2352	1374	2352	1374
Adj. R^2	0.907	0.908	0.968	0.973	0.880	0.904

This table presents the results of regressions of corporate innovation on the average innovation of added and dropped peers. Added peers include firms that have not yet been selected to the peer group in year t but are in the peer group in year $t + 1$. Dropped peers include firms that are dropped from the peer group in year t but are in the peer group in year $t - 1$. The dependent variable is the ratio of R&D to total assets (*RDEX*), the natural logarithm of one plus the number of patents filed (and eventually granted) in a given year (*PAT*), or the number of citations per patent in a given year (*CIT*). "Peer Firm Averages" denote variables constructed as the average of the compensation peers. All independent variables are lagged by one year and defined in Appendix A. All independent variables are winsorized at the 1st and 99th percentiles. The reported coefficients are standardized. Heteroskedasticity-robust *t*-statistics with standard errors clustered by firm are reported in parentheses. Statistical significance at the 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

The patent's generality score was calculated as one minus the Herfindahl index of the three-digit technology class distribution of all patents that cite that patent. A high generality score indicates that patents have been subsequently cited by patents in a wide range of technology fields. Similarly, the patent's originality score was calculated as one minus the Herfindahl index of the three-digit technology class distribution of all the patents it cites. A high originality score means that the patent cites previous patents covering a wide range of technology fields. The Herfindahl measures were corrected using the method used in studies by Hall et al. (2001) and Jaffe and Trajtenberg (2002). We then averaged individual patents' generality and originality scores at the firm level. Overall, the results are robust to the alternative measures of innovation. Detailed results are available from the author upon request.

6.3. Sample selection bias

As the use of a peer group for benchmarking CEO pay is voluntary, the tests conducted in this study may be subject to selection bias. We followed Heckman's (1979) two-stage approach to control for self-selection bias. In the first stage, a probit regression was estimated as the model specification in Eq. (6). In the second stage, regressions of firm innovation were estimated by including the inverse Mills ratio, *Lambda*, as an additional control estimated from the first-stage probit regression.

The baseline results remain unchanged when the inverse Mills ratio was added to the regressions, and the coefficients of *Peer_RDEX*, *Peer_PAT*, and *Peer_CIT* were positive and statistically significant at the 5% level or better. The results are not included in this paper but are available from the author upon request.

6.4. Alternative regression methods and samples

We conducted a set of robustness tests for the baseline results. In particular, none of the following had a major effect on the results: (1) running Tobit, Poisson, and negative binomial regressions to address the issue that innovation variables are non-negative and highly censored at zero; (2) using the Fama-MacBeth regression with the Newey-West correction for autocorrelation; (3) excluding firms with no innovation; (4) excluding peers with no disclosure of R&D; (5) replacing CEO pay sensitivity *Delta* and *Vega* with shares and shares underlying options held by the CEO as a percentage of shares outstanding, respectively; and (6) adding more control variables in the regressions. These control variables included the following: natural logarithm of one plus the number of analysts following the firm; the arithmetic mean of 12 monthly numbers of the Amihud (2002) illiquidity measures for the firm; capital expenditures divided by book value of total assets; Kaplan and Zingales's (1997) index; the natural logarithm of the firm's age, property, plant, and equipment divided by book value of total assets; an indicator for the firm that employs the same peer group for both compensation benchmarking and relative performance evaluation; and tolerance for failure, which was measured using the first principal component of Hofstede's (1980, 1991); Hofstade's (2001) uncertainty avoidance index for CEOs, executives, and outside directors (Pan et al., 2017). For brevity, the tabulated results for the robustness tests are not presented in this paper but are available from the author upon request.

7. Conclusion

In this study, we explored whether the innovation activities of compensation peer groups affect corporate innovation. Using R&D expenditures and patent activities as the primary proxy for innovation, we found that innovation activities undertaken by a firm's peer group trigger innovation in that firm, providing evidence of peer effects on innovation decisions.

To address the endogeneity concerns arising from the reflection problem and omitted variable bias, three different identification strategies were employed. These included (1) a 2SLS approach based on two plausibly exogenous IVs that operate as an indicator for peers who experience debt covenant violation and peer companies' idiosyncratic risk; (2) a PSM approach that controlled for selection based on observable CEO and firm characteristics and unintended factors; and (3) a placebo test that examined randomly selected companies in the peers' industries that are not compensation peers of the disclosing firm's peer group. Analyses based on these three strategies confirmed the baseline results. Based on the evidence, the innovation activities of compensation peer groups spur the disclosing firm to increase innovation activities.

In cross-sectional tests, we found that peer effects are stronger in firms and compensation peers that pay their CEOs using long-term compensation, in firms facing strong labor market competition and board monitoring, in peers that share a high degree of technological field closeness with the disclosing firm, and in peers in compensation peer groups that have a high likelihood of serving as the benchmarking company. Furthermore, we examined whether the 2006 reform of disclosure regulations enhanced peer effects, finding that disclosing firms had more innovation inputs and outputs than non-disclosing firms, and that these effects increased after the reform. Overall, this study provides strong evidence that selecting compensation peers has unintended peer effects on corporate innovation decisions, showing that the main mechanism driving this peer effect is peer pressure, rather than knowledge spillover.

Data availability

The authors do not have permission to share data.

Appendix A. Control variable definitions

Variable	Definition
Size	Natural logarithm of book value of total assets (#6)

(*continued on next page*)

(*continued*)

Variable	Definition
ROA	Operating income before depreciation (#13) divided by book value of total assets
Q	Market value of equity (#199 × #25) plus book value of assets minus book value of equity (#60) minus balance sheet deferred taxes (#74, set to 0 if missing), divided by book value of assets
Sales_Growth	Logarithm of sales divided by prior-year sales
Leverage	Book value of debt (#9 + #34) divided by book value of total assets
Stock_Volatility	Standard deviation of stock returns over fiscal year
Stock_Return	Buy-and-hold stock return over fiscal year
INSTOWN	Arithmetic mean of four quarterly institutional holdings
HHI	TNIC-based Herfindahl-Hirschman Index
OD	Number of outside directorships held by CEO
PhD	An indicator equals 1 if a CEO has doctorate degrees, and 0 otherwise.
GAI	Custódio et al.'s (2019) General Ability Index
MAS	Demerjian et al.'s (2012) Managerial Ability Score
OC	Degree of in-the-money of the CEO's vested stock options
Male	An indicator equals 1 if a CEO is male and 0 for female
Age	CEO age
SIM	Hoberg and Phillips's (2016) product similarity measure
Delta	Dollar change in CEO wealth associated with a 1% change in the firm's stock price (in thousands)
Vega	Dollar change in CEO wealth associated with a 0.01 change in the standard deviation of the firm's returns (in thousands)

represents the Compustat variable item number.

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