Does CEO Turnover Matter for Corporate Innovation?

Abstract

We exploit exogenous variations in CEO turnover to investigate the influence of incoming CEOs on corporate innovation. Using difference-in-differences (DID) and a battery of robustness tests, our results reveal that CEO turnover matters and triggers economically significant improvements in innovation post-turnover. Our results also show that CEO turnover-innovation nexus is stronger where incoming CEOs hold overseas experience and are overconfident. This suggests that CEOs personal attributes drive innovation performance post-turnover. We contribute to the growing literature and provide empirical evidence of the positive impact of incoming CEOs on pursuing value enhancing investment strategies.

JEL Classification: G34, J63; O32

Keywords: CEO Turnover, Corporate Innovation, Difference-in-Difference

1. Introduction

The chief executive officers (CEOs) are typically viewed as critical to the success and survival of firms and CEO changes represent one of the most important events in firms' life. CEO changes (turnovers) have important long-term implications for firms' corporate policies and outcomes. As such, literature documents a significant impact of CEOs on firm performance (Nourayi and Daroca, 2008; Saidu, 2019; Bandiera *et al.*, 2020); leadership change (Carmeli *et al.*, 2011; Chen *et al.*, 2019) and survival rate (Jenter *et al.*, 2016). Consequently, CEO changes have attracted considerable attention from academics and media. Recent studies also suggest decline in average CEO tenures (Goyal and Low, 2019), increase in involuntary dismissals and high performance-turnover sensitivity (Alexandridis *et al.*, 2019). Although existing research has examined the effectiveness of CEO changes on post-turnover operating and market performance, little is known about the impact of such changes on innovation performance of the firms. Investment in research and development (R&D) and innovative activities is one of the most important investment decisions made by the CEOs because investment in developing new products, processes and technologies often confers the competitive advantages which are vital for future productivity performance (Scherer, 1984; Ettlie, 1998). Given the paucity of evidence related to the impact of CEO turnovers on innovation, we examine whether successor CEOs impact firms' post-turnover innovation.

In this study, we investigate the CEO turnover-innovation link in a large sample of Chinese listed firms. Our choice of Chinese sample is mainly motivated by at least two reasons. First, China is the largest emerging market and second largest economy in the world. A large part of China's rapid economic growth is attributable to the innovative capabilities of Chinese firms. In fact, China has emerged as one of the most innovative nations in the world during the past decade.[1] Second, there are significant institutional differences between Chinese and

[1] China filed 1.2 million patents in 2016 more than the combined total of the US, Japan, The Republic of Korea and the European Patent Office. It was ranked among the 20 most innovative economies in the world for the first

developed markets. The ownership, control and corporate governance mechanisms of Chinese listed firms are radically different compared to the firms from developed markets, which might have important implications for CEO changes. Moreover, weak legal and institutional environment, underdeveloped investor protection legislation, state control and ownership, and importance of political connections (Kato and Long, 2006; He *et al.*, 2014; Cao *et al.*, 2017) might have significantly different implications for causes (and consequences) of CEO changes on Chines firms' policies compared to their Western counterparts.

Prior literature examining the CEO turnover-performance link suggests that turnovers (particularly forced and/or compulsory) are preceded by poor operating and market performance (Warner *et al.*, 1988; Weisbach, 1988; Denis *et al.*, 1997; Fee and Hadlock, 2004; Jenter and Lewellen, 2020). This also suggests that if CEO changes are in response to poor performance, we should observe performance improvements following CEO turnovers, and forced turnovers should results in more significant improvement in post-turnover periods. The empirical evidence on the effects of turnover on post-turnover performance, however, is at best mixed. While some studies document improvements in operating earnings and stock returns (Denis and Denis, 1995; Huson *et al.*, 2004) following turnovers, others studies do not find evidence of performance improvements following CEO changes (Wiersema, 2002; Cao *et al.*, 2017). It is evident from the above discussion that the turnover-performance literature is almost exclusively focused on operating (accounting) and stock return performance around and after CEO changes. Although previous studies examine changes in R&D spending around CEO turnovers (Dechow and Sloan, 1991; Murphy and Zimmerman, 1993), there has been lack of studies examining the effect of CEO turnover on a comprehensive set of innovation (quantity

time in 2018 (WIPO: https://www.wipo.int/pressroom/en/articles/2018/article_0005.html). According to a recently released Global Innovation Index 2020 by WIPO, China ranks 14th among the most innovative nations in the world. The report further adds that "China has established itself as an innovation leader, with high ranks in important metrics including patents, utility models, trademarks, industrial designs, and creative goods exports". (https://www.wipo.int/pressroom/en/articles/2020/article_0017.html).

and quality of patents) related measures particularly in emerging markets such as China. Moreover, although R&D expenses measure the innovative input in firms, realised innovation output measures such as patent counts and citations are better measures of overall innovation performance of firms (Hirshleifer *et al.*, 2012).

Theoretical arguments from the literature predict improvements in innovation performance following CEO changes due to divergent incentives of departing and successor CEOs. The quite life hypothesis suggests that lazy incumbent managers would under-invest in innovation due the risks involved in innovation in absence of incentives or threat of replacement. These agency issues are likely to be more severe in firms where managers are close to departing their firms due to retirement or contract expiration (Murphy and Zimmerman, 1993). Dechow and Sloan (1991) find reduction in R&D spending in firms where CEOs are close to departing their firms. Similarly, Boot (1992) argue that managers are reluctant to divest poorly performing investments due to career concerns. These agency issues are likely to be exacerbated in emerging markets like China due to the lack of robust corporate governance mechanisms, market discipline and political entrenchment. The managerial turnover provides an opportunity to incoming CEOs to reset the poor investments decisions of departing managers and the empirical evidence supports this conjecture. For instance, evidence suggests that successor CEOs reverse value destroying decisions by divestures and operational downsizing (Weisbach, 1995; Pan *et al.*, 2016). Similarly, Alexandridis *et al.* (2019) show that forced CEO turnovers are followed by performance improvements and successor CEOs add value through superior mergers and acquisitions, reversing prior poor investments through asset disposals and adopting more efficient investment strategies. The above evidence suggests a positive CEO turnover-innovation link particularly in cases of forced and involuntary CEO dismissals. This also suggests that most CEO changes are indeed highly endogenous events. The turnover-innovation relationship, however, is less obvious in case of non-performance induced

(exogenous events such as death or health issues, retirements, contract expirations etc.) turnovers and is an interesting empirical question.

We test CEO turnover-innovation relationship on a large sample of CEO replacements in Chines listed firms from 2008-2017. We manually collect CEO turnover related data from firms' annual reports, their press releases, and online sources and combine this data with demographic information for CEOs in China Stock Market and Accounting Research (CSMAR) database. Given endogenous nature of CEO turnovers (Sarkar *et al.*, 2019), we exploit variations in CEO changes caused by exogenous reasons for identification: health, retirements and contract expirations. We use a generalised difference-in-difference (DID) estimation approach to test CEO turnover and innovation relationship. In order to further account for differences between firms with and without CEO changes, we use a matched sample approach (in line with Berger *et al.*, 2014). Our primary measures of innovation are the number of patent applications (invention, invention and utility) filed during the year, R&D expenses, and adjusted citations received by the invention patents during the year (Hall *et al.*, 2005). Patent counts and citations are widely used measures for quantity and quality of innovation output.

Our results reveal that exogenous CEO turnovers are positively associated with innovation performance of firms experiencing the CEO changes. We show that successor CEOs increase innovation input (R&D spending), output (patent numbers) and the quality of output (patent citations) in firms exogenously switching CEOs relative to a closely matched sample of control firms which do not experience CEO change. Our results are not only statistically significant but are also economically sizeable. For instance, successor CEOs are associated with an increase of 18.89% in invention patents, 18.29% in invention and utility patents, 10.51% in R&D expenses and 9.30% in citations respectively. In order to further verify that the significant changes in innovation are indeed caused by CEO turnover, we conduct placebo tests. We find that results from our main regressions cannot be replicated using either an earlier pre-

turnover year as an actual turnover year (placebo year) or using a non-turnover control firm as a firm experiencing actual turnover (placebo firm). Overall, these results suggest that it is in fact CEO turnover that triggers improvements in post-turnover innovation.

To further validate the impact of CEO turnover on innovation, we conduct a series of tests. First, we include additional controls for CEO and board related characteristics. Second, we employ Poisson and Tobit models as alternative estimations techniques. Third, we use alternative and a more conservative matching between firms with and without CEO changes. Fourth, we use only health issues and retirements as exogenous reasons for CEO turnovers. We show that our main results remain insensitive to all the above robustness tests.

Our results so far clearly indicate a positive and significant effect of successor CEOs on innovation. We now turn our attention to the mechanisms which drive these results. A vast body of literature documents that CEOs' personal "style" and characteristics significantly effect corporate policies and innovation (Bertrand and Schoar, 2003; Malmendier and Tate, 2005, 2008; Galasso and Simcoe, 2011; Hirshleifer *et al.*, 2012; Sunder *et al.*, 2017). Based on this literature, we exploit variations in personal characteristics of departing and successor CEOs and examine the impact of these characteristics on post-turnover innovation. We, specifically, use CEO personal attributes including gender, age, education, overseas experience, stock holdings and overconfidence (Barker III and Mueller, 2002; Galasso and Simcoe, 2011; Lin *et al.*, 2011; Sunder *et al.*, 2017; Islam and Zein, 2020). Our univariate analysis reveals that there are significant differences between departing and successor CEOs in terms of their personal characteristics. For instance, incoming CEOs are younger, have more overseas experience, hold higher shares in their firms and are more overconfident compared to their departing counterparts. Our DID analysis framework using the CEO personal attributes also confirms that the association between successor CEOs and innovation is stronger when the successor CEOs are younger, highly educated, hold more overseas experience and are more

overconfident. Overall, these results suggest that personal attributes of successor CEOs drive the innovation performance in post-turnover periods.

To the best of our knowledge, ours is the first study to examine the effects of CEO turnover on corporate innovation, particularly in an emerging market. CEOs sit at the apex of firms' decision making and shape corporate policies, it is important to study the impact of CEO changes on innovation. Our study contributes to the literature in following ways: First, we contribute to the growing literature on the effects of CEO turnover on corporate policies (Denis and Denis, 1995; Wiersema, 2002; Huson *et al.*, 2004; Cao *et al.*, 2017; Sarkar *et al.*, 2019). Our results regarding the positive effect of CEO turnover on post-turnover innovation complement the existing literature showing improvements in investment performance after CEO changes (Murphy and Zimmerman, 1993; Huson *et al.*, 2004; Bereskin and Hsu, 2014). Our results are also related to the strand of literature showing that incoming CEOs increase value by adopting more efficient investment strategies (Weisbach, 1995; Aivazian *et al.*, 2011; Pan *et al.*, 2016; Alexandridis *et al.*, 2019). Second, our paper complements the literature focusing on human-capital based explanation of innovation and examines the effects of personal characteristics on firm's decisions and innovation (Malmendier and Tate, 2005, 2008; Cronqvist *et al.*, 2012; Hirshleifer *et al.*, 2012; Graham *et al.*, 2013; Sunder *et al.*, 2017). We uncover that some personal attributes of incoming CEOs are significantly important for innovation and these results are related to studies showing that heterogeneity in CEO personal dimensions enhances innovation (Barker III and Mueller, 2002; Galasso and Simcoe, 2011; Custódio *et al.*, 2019; Islam and Zein, 2020). Finally, our paper also contributes to the growing literature on CEO turnovers in China (Conyon and He, 2014; He *et al.*, 2014; Cao *et al.*, 2017) and innovation in Chinese firms (Jiang and Yuan, 2018).

The remainder of this paper is organized as follow. Section 2 introduces the research design including sample, variables and empirical modelling. Section 3 presents the empirical results, while additional tests for robustness checks have been provided in Section 4. Section 5 provide evidences on the further analysis. Finally, Section 6 concludes this paper.

2. Research Design

2.1 Sample

Our original sample covers all firms listed on both the Shanghai and Shenzhen Stock Exchanges (SHSE, SZSE) between 2008 and 2017.[2] We use two databases to collect variables used in this study. First, we use China Stock Market & Accounting Research (CSMAR) to obtain financial data, CEO related information and corporate governance variables. We also use company websites and other sources to complete missing information related to CEO turnover and other CEO characteristics. Particularly, we cross reference the reasons for CEO turnover from disclosure on companies' websites and other publicly available information. We exclude all CEO changes where the tenure of the new CEO is less than one year since it is unlikely for any temporary CEO to affect company's innovation in such a limited time period. In addition, we also exclude firms that experience multiple CEO turnovers. Second, we use China National Intellectual Property Administration (CNIPA) to collect information on sample firms' innovations related variables (patent applications and citations). We use sample firm names to collect innovation related variables from CNIPA. We then merge the data from both sources excluding financial firms and firms with missing variables consistent with Yuan and Wen (2018). Our full sample consists of 18,610 firm-year observations for both type of firms: firms with CEO turnover across all turnover reasons and firms without CEO turnovers. For purpose of our analysis, we only keep CEO turnovers where a CEO is replaced due to contract expiration, health and retirement reasons (our exogenous turnover events are detailed in section

[2] We chose 2008 as our starting year since the Chinese government adopted a new accounting standard in 2007 that required disclosure of R&D information

2.2.2). This results in 1543 firm-years (treatment group) where CEO turnover is for exogenous reasons. To obtain the corresponding control group, we match treatment firms with the firms of similar characteristics where no CEO turnover occurred in the respective year (control group).

We match treatment firms with control firms using following matching criteria: firm size, performance (ROA), time period and industry sector. The size criterion ensures comparing firms with similar operations in terms of scope and scales and business model (Schaeck *et al.*, 2011). In particular, we match firm *i* (treatment firm) to other firms in the control group whose total assets range between 70%-130% of firm *i*'s total assets in the same year. The industry sector criterion ensures comparing firms from the same industry sector. Our final matching criteria is based on firm performance. We select control firms whose ROA lies between 70% and 130% of the ROA of the treated firm in the same year. Our matching procedure is a *1:n* matching method to ensure that we have at least one control firm for each firm that experiences a CEO turnover event. We do not restrict the number of control firms in the sample to exploit the large sample of Chinese firms. Our final sample consists of 4,770 firm-year observation including 1,543 CEO turnover firm-years for exogenous turnover events. All variables are winsorized at the 1st and 99th percentiles.

2.2 Variable Measurement

2.2.1 Corporate Innovation

We construct innovation variables using data from CNIPA which contains information on patent application date, application identification, grant date and applicant institution. The Chinese patents are classified into three categories: invention patents, utility model patents and design patents. Invention patents are granted for a new solution to a product or technical process. Utility model patents are for a new technical solution or improvement with lower degree of inventiveness relating to certain features of a product such as shape or structural physical features. Design patents are granted for innovations in external features of a product such as

shape, pattern and/or colour which make the product attractive and fit for industrial application. Given the limited technological innovation involved in design patents, we use only invention and utility model patents to construct our innovation measures following Chinese innovation literature (Tan *et al.*, 2015; Fang *et al.*, 2017; Jiang and Yuan, 2018; Chen *et al.*, 2019). We use application year rather than grant year for our patent counts because application year corresponds more closely to the actual time of the innovation (Hall *et al.*, 2005; He and Tian, 2013; Fang *et al.*, 2014; Jiang and Yuan, 2018).

Our firm-level innovation measures are constructed in four ways. First, *Inven*, is the raw count of invention patents filed and eventually granted to a firm in a given year. Second, *Inven+Utility*, is the raw count of invention and utility patents filed and eventually granted to a firm in a given year. We use natural log of one plus patent counts (*Inven*, *Inven+Utility*) to address the skewness concerns in patent count related variables (Fang *et al.*, 2017; Jiang and Yuan, 2018). Third, we use *R&D Expenses*, an important input-based innovation measure to evaluate a firm's innovativeness, measured as the natural log of *R&D expenses* in a year. Fourth, we use the number of forward citations received by a firm's invention patents (*Citation_Adjusted*). In order to account for the truncation bias in citations, we adjust the citations received by each patent by the average citations in the same cohort (year and industry class) following Hall *et al.* (2005). While patent counts measure the raw output of a firm's innovative activities, citations capture the technological and economic importance of patents granted to a firm (Hall *et al.*, 2005).

2.2.2 CEO Turnover

Prior literature suggests that CEO turnovers may not only be endogenously determined by firm performance (Hermalin and Weisbach, 1991) but also by industry and economic performance (Jenter and Kanaan, 2015). This poses a significant challenge in examining any related effect of CEO turnover, for instance, on innovation in our case. An ideal setting to

examine the causal effect of CEO turnover in our case is whether CEO turnover is exogenous to firm level innovation. In order to overcome the above identification challenge, we examine the reasons for CEO turnover in Chinese firms in detail.

We identify eleven different reasons for CEO turnovers in our sample based on the information from firms' annual reports, press releases, online sources and CSMAR. These reasons include personal, contract expiration, health, retirement, corporate governance restructuring, job transfer, agent related termination, change of controlling right, dismissal, resignation and case involve. Detailed explanation of each reason can be found in Appendix 1.

We only focus on the plausibly exogenous reasons for CEO turnover in this study namely "Contract Expiration[3]", "Health" and "Retirement". These reasons are least likely to be correlated with innovation for the purpose of identification. Our classification is in line with Cao *et al.* (2017) who classify all these three reasons as normal (non-performance related) turnovers. Moreover, Sarkar *et al.* (2019) use retirement age as an exogenous reason for CEO turnover in their sample. We exclude all other reasons treating them as endogenous turnovers.[4].

2.2.3 Control Variables

Following innovation literature, we control for an array of well know firm-level characteristics that may affect a firm's innovation. We include *Firm Size* (natural log of the total asset) following Shefer and Frenkel (2005), who find a positive effect of firm size on innovation. *Firm Age,* proxied by the number of years since a firm started operations, is included to control for differences in the stage of development across firms following Balasubramanian and Lee (2008). Following David and O'Brien (2006), we use *Leverage* ratio measured as total debt to total assets ratio. We include return on assets (*ROA*) measured as net income divided by total assets to control firms' profitability following Howell (2018). We

[3] We check company's official documents to ensure that there is no renewal of contract for the same CEO.
[4] We carefully checked the firms' relevant filings (e.g. annual report) but failed to find any further details on personal reasons.

include *Book-to-Market* ratio to control for growth opportunities following (Lev and Sougiannis, 1999). Finally, we include state ownership (*SOE*) measured as the percentage shares held by the state following Wang and Kafouros (2009). A detailed definition of these control variables is provided in Appendix 2. In robustness tests, we also include a number of board and CEO characteristics as additional controls also defined in Appendix 2.

2.3 Empirical modelling

To test for the effect of CEO turnover on firm innovation, we employ a difference-in-difference (DID) approach. The DID estimator compares a treatment group to a control group before and after the treatment. In our case, the treatment group includes firms that experienced a CEO turnover due to contract expiration, health issues or retirement.[5] For control group, we use a matched sample of non-CEO turnover firms (explained in section 2.1) following Berger *et al.* (2014). Given that CEO turnovers occur throughout our sample period, we examine the effect of CEO turnover on innovation using a generalised DID approach that deals with multiple events (CEO turnovers) across time and multiple firms. The multiple pre-turnover and post-turnover time periods address many threats to the validity of this approach. A similar research approach has been employed recently in several studies (Bertrand and Mullainathan, 2003; Low, 2009; Haselmann *et al.*, 2010; Sarkar *et al.*, 2019; Carbó-Valverde *et al.*, 2020). Our generalised DID specification is as follows:

$$Y_{i,t} = \beta_0 + \beta_i + \beta_t + \beta_1 \times New\ CEO\_Post_{i,t} + \gamma X_{i,t} + \varepsilon_{i,t} \qquad (1)$$

where *i* indexes firms and *t* indexes time. The dependent variable $Y_{i,t}$ is the natural log of one plus invention patents (*Inven*), natural log of one plus invention and utility patents (*Inven+Utility*), natural log of *R&D expenses* and adjusted citations per patent (*Citation_*

[5] We exclude all firms with missing data and where the new CEO's tenure is less than one year. We also exclude firms with multiple CEO turnover events where the two turnover events occur within three years as it would be less likely for short tenure CEO to have a meaningful impact on the innovation.

Adjusted) respectively. Our innovation variables account for the quantity (raw patent counts), quality (citations) and input (R&D expense) of the innovation. $New\ CEO\_Post_{i,t}$, our main variable of interst, is a dummy variable equal to 1 when and after a firm i undergoes a CEO turnover event at year t, and 0 otherwise. This variable serves as the DID operator and our estimate of the CEO turnover effect is β_1. The firm fixed effects β_i take into account the various time-invariant factors across firms that influence the firms' innovation. The year fixed effects β_t control for aggregate fluctuations in innovation over time. In particular, this generalised DID approach essentially compares the change in innovation for a firm before and after the CEO turnover and compares this change with that of a non-CEO turnover firm (control group) over the same period. $X_{i,t}$ is a vector of control variables including *Firm Size, Firm Age, Leverage, ROA, Book to Market Ratio* and *SOE*, and $\varepsilon_{i,t}$ is error term. We allow for clustering of observations at the firm level to account for the presence of serial correlation in the data.

3. Results and Discussion

3.1 Summary Statistics

Panel A of Table 1 presents the annual frequency of exogenous CEO turnovers in our sample of firms. The results show that our sample firms experience increasingly more CEO turnovers over the sample period, with a peak in year 2016. There are 1534 exogenous CEO turnover firm-years in the sample, which translates to a turnover frequency of roughly 32%. In terms of turnover reasons, a large proportion (82%) of turnovers are due to contract expiration. Panel B (Table 1) presents means and standard deviations for all variables used in the study. Column (1) refers to the treatment group which includes firm-years experiencing a CEO turnover due to either of the contract expiration, health issues or retirement, while column (2) presents means and standard deviations of matched control firm-years without any CEO change. A comparison of means for treated and control observations clearly shows that all innovation related variables have higher mean values for treated firms compared to the control ones. For instance, treated firms have, on average, 1.653 more invention patents compared to the control

firms. The R&D spending shows a considerable difference between the treatment and control groups, whereby R&D spending in treated firms surpasses the control firms by 28.104 million. Overall, these results show that successor CEOs enhance innovation input and output in the post-turnover periods. The mean values for control variables do not show any noticeable differences between treatment and control firms because we use a matched sample.

[INSERT TABLE 1 HERE]

3.2 Correlation Matrix

Table 2 presents correlations for variables used in the study. *NEW CEO_Post* is positively correlated with all the innovation proxies at 5% or better significance level. The correlations between all control variables are not high to give rise to multicollinearity issues in our regressions.

[INSERT TABLE 2 HERE]

3.3 DID results

The DID estimation results are presented in Table 3. Columns 1-4 report results without controls, while columns 5-8 present results including all control variables. All models include firm and year fixed effects. It can be seen that the coefficient on *New CEO_Post* is positive and significant (with varying significance levels) across all models. Apart from statistical significance of these results, the economic impact of CEO turnover on firm-level innovation is considerable. For instance, a CEO turnover is associated with an increase of 18.89%[6] in invention patents, 18.29% in invention and utility patents, 10.51% in R&D expenses and 9.30% in adjusted citations respectively. Overall, our results suggest that exogenous CEO turnovers are followed by increased innovation input (R&D), output (patent counts) and impact (citations). In terms of R&D spending, these results are consistent with Murphy and Zimmerman (1993) and Dechow and Sloan (1991). These results also indicate that incoming CEOs are effective in reallocating resources more efficiently from poor-performing projects

[6] $(exp^{(0.173)}$ -1) ×100. The other log transformed variables (*Inven+Utility and R&D*) are interpreted in the similar fashion.

(Weisbach, 1995) to more promising investment opportunities (Bereskin and Hsu, 2014), resulting in improvements in overall firm-level innovation.

The results for control variables are also consistent with prior literature. *Firm Size* is positive and statistically significant in all models suggesting that larger firms produce more patents consistent with Mazouz and Zhao (2019). *Firm Age* is negatively related to innovation in all models showing that younger firms generate more patents compared to mature firms (Coad *et al.*, 2013). Both *Leverage* and *ROA* indicate a positive and statistically significant relationship with innovation, while *Book to Market* negatively affects innovation. These results are largely consistent with the previous studies (David and O'Brien, 2006). The percentage of state ownership is positively (albeit marginally significant) related to R&D spending consistent with Belloc (2014). Overall, the above results show a strong association between CEO turnover and firm-level innovation.

[INSERT TABLE 3 HERE]

Although above results clearly show a significant impact of successor CEO on innovation in the post-turnover periods, there is a concern that the treated and control firms might have been following different trajectories in terms of their innovation performance. In order to assuage these concerns, we present pre-turnover differences in the means and medians of innovation variables across the treated and control groups following Islam and Zein (2020). More specifically, we calculate means and medians for 3,2 and 1 prior years relative to the turnover year (t=0) for both treated and control firms and test the differences between means and medians of the two groups (treated vs control). The results presented in Appendix 3 show no significant differences between treated and control groups across all innovation proxies in each of the three years prior to the turnover year. These results support our main regression results and provide evidence that the innovation changes in post-turnover periods are a product of CEO turnover.

3.4 Placebo Tests

Our results so far show a consistent effect of CEO turnover on firm level innovation. We want to establish that innovation increases in response to actual CEO turnover and not due to confounding factors. In order to further establish that our earlier results are not driven by omitted variables and spurious correlations, we construct placebo and falsification tests using two different approaches.

First, we redefine our CEO turnover year to be exactly one year before the actual turnover year. For instance, if a firm experiences a CEO turnover in year 2012, we designate year 2011 as the actual event year for that particular firm and include it in the treated sample. Essentially, we backdate each CEO turnover event by one year across all the sample years[7]. Second, we apply falsification at the firm-level by randomly choosing a firm from control group (non-CEO turnover firms) and designate it as a treated firm (with a CEO turnover). This constitutes our alternative treatment sample as we assign a false CEO turnover event to these firms according to the actual turnover event year of the original treatment group[8]. For our analysis, we remove the original treatment firms from our sample and use the alternative (falsified) treatment group. We then rematch the sample using the approach discussed in section 2.1 (matching treatment firms with control firms based on firm size, firm performance, year and industry) and perform estimation using equation 1. If the results of our analysis are driven by unobservable common characteristics or spurious correlations, the placebo test results should closely mirror the results from our main analysis (Table 3). An insignificant estimated coefficient on (*NEW CEO_POST*), would suggest that the increase in innovation is indeed caused by the actual CEO turnover.

[7] The CEO turnover events occur in our sample in each year among different firms. Hence, we repeat the procedure every year starting from year 2009 to year 2017.

[8] For instance, a treated company has matched six different companies in the control group. We randomly select one of six company and consider it as the treated company. Then, using the same matching technique to rematch the sample. The whole randomly selection process has been repeated in 5 times, since we notice each treated firm has at least 5 different firms in the control group.

Tables 4 and 5 show the results of the two placebo tests respectively using the matched samples. These results show that *NEW CEO_POST* is not statistically significant in both tables using *Ln (Inven+1)* as our main dependent variable.[9] These results suggest that the changes in innovation do not occur before the actual CEO turnover and also not in control firms which are falsified as treated firms. Overall, the evidence from placebo tests suggest that association between CEO turnover and innovation is not an artefact of confounding factors.

[INSERT TABLE 4&5 HERE]

4. Robustness Tests

In this section we perform several additional tests to check the robustness of our results. First, although we use a comprehensive set of firm characteristics as the control variable in our baseline regression, yet prior literature suggests that both CEO and board characteristics influence corporate innovation (Bertrand and Mullainathan, 2003; Simsek, 2007; Huang and Kisgen, 2013; Balsmeier *et al.*, 2017; Islam and Zein, 2020). Hence, we expand our selection of control variables by also taking CEO and board characteristics into account. CEO characteristics contain gender, age, education, overseas experiences, percentage of stock holding and overconfidence (Barber and Odean, 2001; Hirshleifer *et al.*, 2012). Board characteristics include board size, board independence and whether the CEO is also a Chairman of the board[10]. We rerun equation 1 including these additional controls for CEO and board characteristics, and present results in Table 6. Even after controlling for various CEO and board attributes, the coefficient for *NEW CEO_POST* is positive and statistically significant across all innovation variables, indicating that our results are robust to these additional controls.

[INSERT TABLE 6 HERE]

Second, we test the consistency of our results by using alternative regression model specifications. In the innovation literature, Poisson and Tobit models are often employed to

[9] Our unreported results remain unchanged using *Ln (Inven+Utility+1), Ln (R&D) and Citation_Adjusted* as proxies of innovation. Unreported results are available from authors upon request.
[10] Detailed explanation of each variable can be found in appendix.

address the count-based nature of patent data (Jiang and Yuan, 2018; Mazouz and Zhao, 2019). We re-estimate our DID model (equation 1) using Poisson and Tobit models to ensure that our results are not specific to alternative econometric estimation techniques. The results presented in Table 7 are consistent with our main regression results in Table 3 and show that our findings are robust to alternative estimation techniques.

[INSERT TABLE 7 HERE]

Third, we use a more conservative (alternative) matching criteria to select control firms for our treated firms. We use control firms where the size and ROA of the control firms are between 90% and 110% of the treated firms in line with Berger *et al.* (2014). This strict matching criterion reduces our sample to 3,501 firm-year observations. We re-estimate regression equation (1) and the results are presented in Table 8. Our main results remain robust to this alternative matching strategy.

[INSERT TABLE 8 HERE]

Fourth, we re-estimate our main DID regression specification by treating health and retirement as the only exogenous turnover events (Eisfeldt and Kuhnen, 2013; Sarkar *et al.*, 2019; Betzer *et al.*, 2020). The results presented in Appendix 4 show that our main inferences remain unchanged. All innovation related variables are positively and significantly related to *NEW CEO_POST* except R&D which loses its significance.

5. Further Analysis

In this section, we aim to understand the channels through which CEO turnover influences firm-level innovation. To this end, we exploit CEO characteristics since prior literature suggests that CEO-specific variables are associated with innovation and R&D spending. We use CEO gender, age, education, overseas experience, stock holdings and overconfidence (Barker III and Mueller, 2002; Galasso and Simcoe, 2011; Lin *et al.*, 2011; Sunder *et al.*, 2017; Islam and Zein, 2020) to test the differences in these attributes between departing and successor CEOs. We perform univariate and regression analysis to examine the

differences between departing and successor CEOs in terms of personal attributes and their impact on innovation in conjunction with CEO turnover.

The results of our univariate analysis are presented in Table 9. We find significant differences in gender, age, stock holding, overseas experience and overconfidence[11] between the departing and successor CEOs. For instance, the successor CEOs are more likely to be younger (on average 3 year) than the departing CEOs. This could affect post-turnover innovation as the literature suggest that younger CEOs are more likely to be successful in innovation (Barker III and Mueller, 2002; Sunder *et al.*, 2017). The successor CEOs hold significantly more overseas experience (education or working) compared to the departing ones, which could lead to higher innovation due to the spillover effects of foreign education and experience (Yuan and Wen, 2018). In terms of stock ownership, the successor CEOs hold significantly higher stock ownership compared to their departing counterparts leading to reduced agency problems and enhanced long-term orientation, both of which are likely to be positively associated with innovation (Galasso and Simcoe, 2011). Finally, successor CEOs are more overconfident than the departing CEOs and overconfidence has been shown to be an important predictor of innovation in the literature (Galasso and Simcoe, 2011; Hirshleifer *et al.*, 2012; Sunder *et al.*, 2017). Overall, results from our univariate analysis suggest that the successor CEOs possess different persoanl attributes compared to the departing CEOs in our sample.

[INSERT TABLE 9 HERE]

After the above univariate analysis, we use CEO related attributes in our DID analysis to examine the impact, if any, of the CEO-specific attributes on innovation post-turnover. We

[11] We follow Malmendier and Tate (2005, 2008) approach to measure overconfidence by creating a dummy variable, overconfidence, which equals to one when a CEO holds an option until its final year of duration and the option is at least 40% during his/her entire tenure. This approach has been widely used in other financial papers as well, such as Malmendier et al. (2011); Huang et al., (2016).

interact, in turn, each of the CEO attributes (gender, age, education, overseas experience, stock holdings and overconfidence) with *NEW CEO_Post* in our DID analysis framework. Our variable of interest is the interaction term between each of the CEO attributes and *NEW CEO_Post*. The relevant results using *Ln (Inven+1)* as a dependent variable are presented in Table 10. We suppress control variables for the sake of brevity. The results suggest that successor CEOs' education, overseas experience and overconfidence are significantly positively related to innovation measured by the invention patents.[12] The coefficient on interaction between age and *NEW CEO_Post* is negative and significant suggesting that successor younger CEOs enhance innovation in post-turnover periods. Although our univariate analysis shows significant differences in gender and stock holding between the departing and successor CEOs, these attributes are not significant in our DID regression framework. Overall, findings from our analysis suggest that certain personal attributes of successor CEOs are likely to drive innovation performance after the CEO turnover.

[INSERT TABLE 10 HERE]

6. Conclusion

In this paper, we examine the effects of CEO turnover on one of the firms' most important corporate policies i.e. innovation. Contrary to the existing literature which focuses on CEO turnover and firm performance in developed markets, we study whether CEO turnover affects innovation in Chinese listed firms? A closer look at CEO turnover-innovation relationship in China is relevant, since China has emerged as one of the most innovative countries in the last decade. Furthermore, China is an interesting setting because of the lack of well-defined property rights, underdeveloped investor protection legislation and weaker institutions.

[12] Our results remain unchanged using *Ln (Inven+Utility+1)*, *Ln (R&D)* and *Citation_Adjusted* as proxies of innovation.

We exploit plausibly exogenous variations in CEO turnover generated by contract expiration, health issues and retirement in order to mitigate the challenges posed by the endogenous CEO changes. Using a large sample of listed firms, we find that CEO turnover is associated with significant improvements in post-turnover innovation. Firms experiencing an exogenous CEO turnover subsequently experience increase in patents applications, R&D spending and citations received to their patents compared to matched firms which do not experience a CEO change. Our results are robust to a battery of tests including placebo effect, additional controls for CEO and corporate governance related attributes, and alternative estimation approaches. Having established that CEO turnovers are associated with significant increase in innovation, we examine the channels through which successor CEOs increase innovation. Our analysis reveals that personal characteristics of successor CEOs account for a significant improvement in post-turnover innovation. We, particularly, identify that successor CEOs' age, education, overseas experience and overconfidence are important for improvements in innovation in the post-turnover periods.

Overall, we interpret our results as evidence that CEO turnovers are more likely to initiate significant changes in firms' innovation strategies. We provide new evidence that CEO changes are not only associated with firm performance but also with innovation which is a key driver of performance. While our results highlight that the successor CEOs enhance quantity (numbers) and quality (citations) of patents, our data does not allow us to study the particular innovative strategies (i.e. radical or disruptive) that these incoming CEOs follow. Therefore, further research into the innovative strategies adopted by the successor CEOs is warranted to provide helpful insights on the determinants of firm-level innovation.

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Table 1. Summary Statistics

This table reports the innovation information across all industries in Panel A. Distribution of CEO turnover and the exogenous reasons in each year in Panel B and summary statistics for the variables in Panel C. The sample period is between 2008 and 2017. All variables are defined in Appendix 1.

Panel A. Yearly CEO Turnover Distribution

	Total Firm Year Observation	Total Turnover Firm Year Observation	% of Turnover	Contract Expiration	Health	Retired
2008	83	6	7.23%	6	0	0
2009	172	24	13.95%	22	1	1
2010	236	63	26.69%	57	2	4
2011	352	88	25.00%	77	3	8
2012	536	158	29.48%	137	5	16
2013	612	183	29.90%	154	8	21
2014	632	212	33.54%	174	11	27
2015	673	228	33.88%	192	14	32
2016	678	275	40.56%	216	19	39
2017	796	297	37.31%	231	25	41
Total	4,770	1,534	32.16%	1,266	88	189

Panel B. Sample Descriptive Statistics

	(1) Treatment Group N=1,534		(2) Control Group N=3,236		(3) All Sample N=4,770	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Dependent Variables						
Inven	9.798	17.435	8.145	14.278	8.676	15.380
Inven+Utility	20.528	35.517	17.388	29.007	18.397	31.279
R&D	84.792	102.392	56.688	73.187	65.732	84.717
Citation Adjusted	0.932	0.123	0.924	0.013	0.926	0.799
Firm Characteristics						
Firm Size	3370.205	3308.131	3170.558	3724.002	3878.153	4418.358
Firm Age	16.826	4.175	14.624	4.388	15.334	4.441
Leverage	0.394	0.169	0.318	0.164	0.342	0.169
ROA	0.051	0.042	0.065	0.042	0.061	0.043
Book to Market	0.007	0.005	0.005	0.004	0.006	0.004
SOE	0.038	0.110	0.027	0.105	0.031	0.107

Table 2. Correlation Matrix

This table reports the correlation matrix of our variables. The sample period is between 2007 and 2008. All variables are defined in Appendix 1.

* Represents significant at 5% level

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Ln (1+Inven)	(1)	1										
Ln (1+Inven+Utility)	(2)	0.902*	1									
Ln (R&D)	(3)	0.459*	0.468*	1								
Citation Adjusted	(4)	0.299*	0.329*	0.140*	1							
NEW CEO_POST	(5)	0.020*	0.009*	0.006*	0.031*	1						
Firm Size	(6)	0.157*	0.131*	0.260*	0.009	0.090*	1					
Firm Age	(7)	-0.053*	-0.039*	-0.136*	-0.073*	0.070*	0.230*	1				
Leverage	(8)	0.021	0.024*	0.004	0.019	0.078*	0.507*	0.147*	1			
ROA	(9)	0.056*	0.046*	0.070*	0.048*	-0.102*	-0.169*	-0.156*	-0.381*	1		
Book to Market	(10)	-0.038*	-0.023*	-0.085*	-0.019	0.076*	0.532*	0.099*	0.525*	-0.393*	1	
SOE	(11)	0.060*	0.074*	0.156*	0.006	0.024*	0.103*	-0.120*	0.091*	-0.003	0.094*	1

Table 3. Difference-in-Difference Estimation

This table reports the difference-in-difference regression analysis results by addressing the endogeneity concerns between CEO turnover and corporate innovation. We use patent application number (*Ln (Inven+1), Ln (Inven+Utility+1)*), citation number (Citation Adjusted) and R&D expense (*Ln (R&D)*) as the dependent variable. CEO turnover firms are matched with the firms of similar size (+/- 30% of total asset, log), similar performance (+/- 30% of ROA), same industry and year. The sample period is between 2008 and 2017. Column (1)-(4) illustrate the results of univariate regression, while column (5)-(8) display the multivariate regression results. All regressions control for year and firm fixed effects whose coefficients are suppressed. All variables are defined in Appendix A. The t-test statistics are shown in parentheses below coefficient estimates based on the standard errors clustered by firms.

***, ** and * represent significant level at 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep.	*Ln (Inven+1)*	*Ln (Inven+Utility+1)*	*Ln (R&D)*	*Citation Adjusted*	*Ln (Inven+1)*	*Ln (Inven+Utility+1)*	*Ln (R&D)*	*Citation Adjusted*
NEW CEO_POST	0.177***	0.167***	0.348***	0.087***	0.173***	0.168**	0.100*	0.093**
	(3.32)	(2.80)	(5.43)	(2.60)	(2.98)	(2.52)	(1.95)	(2.44)
Firm Size					0.221***	0.282***	0.305***	0.117***
					(6.55)	(7.08)	(8.68)	(5.34)
Firm Age					-2.355***	-2.886***	-1.627***	-1.014***
					(-5.10)	(-5.49)	(-4.04)	(-3.63)
Leverage					0.272	0.390	0.550***	0.191
					(1.32)	(1.64)	(3.07)	(1.47)
ROA					2.877***	3.105***	2.296***	1.422**
					(3.46)	(3.26)	(2.72)	(2.50)
Book to Market					-4.403***	-6.655***	-0.747	-1.580***
					(-5.63)	(-7.14)	(-0.87)	(-2.95)
SOE					0.132	0.144	0.402*	0.238
					(0.50)	(0.50)	(1.79)	(1.28)
Constant	1.411***	1.958***	3.378***	0.910***	-7.759***	-9.397***	-3.554***	-3.095***
	(145.69)	(179.65)	(289.97)	(149.02)	(-4.81)	(-5.11)	(-2.59)	(-3.17)
Year Effect	YES	YES	YES	YES	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES
N	4,770	4,770	4,770	4,770	4,770	4,770	4,770	4,770
Adj-R^2	0.455	0.310	0.160	0.266	0.154	0.189	0.539	0.276

Table 4. Placebo Test of CEO Turnover on Year Level

This table reports the placebo test of CEO turnover on year level by using the whole sample between 2008 and 2017. We falsely defined to be exactly one year before the actual turnover date and rematch the sample. CEO turnover firms are matched with the firms of similar size (+/- 30% of total asset, log), similar performance (+/- 30% of ROA), same industry and year. We repeat the whole matching procedure nine-times and present the results in column (1)-(9) respectively, because the CEO turnover happens in each year among different firms. The dependent variable is invention patent application number (*Ln (Inven+1)*). All regressions control for year and firm fixed effects whose coefficients are suppressed. All variables are defined in Appendix A. The t-test statistics are shown in parentheses below coefficient estimates based on the standard errors clustered by firms.

***, ** and * represent significant level at 1%, 5% and 10% level, respectively.

Dep. Ln (Inven+1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
NEW CEO_POST	0.155	0.462	0.278	0.028	0.091	0.128	0.364	0.520	0.062
	(1.28)	(1.48)	(0.93)	(0.34)	(0.97)	(1.15)	(1.08)	(1.30)	(0.81)
Firm Size	0.301***	0.537**	0.884**	0.378***	0.391***	0.355***	0.471***	0.470***	0.365***
	(4.28)	(2.56)	(2.63)	(4.08)	(4.37)	(4.44)	(5.16)	(4.87)	(4.60)
Firm Age	-0.257	-4.112	-5.315	0.011	-0.320	0.078	-0.502	-0.712	-0.334
	(-0.64)	(-1.23)	(-1.47)	(0.03)	(-0.80)	(0.24)	(-1.51)	(-1.55)	(-0.88)
Leverage	-0.262	-0.516	-1.449	0.113	0.045	-0.361*	-0.069	-0.141	-0.352*
	(-1.44)	(-0.47)	(-1.07)	(0.56)	(0.21)	(-1.87)	(-0.32)	(-0.61)	(-1.96)
ROA	0.334	-0.974	-2.240	1.213***	1.011**	-0.143	0.591	0.617	0.299
	(0.88)	(-0.71)	(-1.47)	(2.91)	(2.47)	(-0.36)	(1.30)	(1.29)	(0.77)
Book to Market	-0.238	-12.494	-9.165	1.321	2.489	3.529	5.866	7.600	-2.055
	(-0.04)	(-1.00)	(-0.62)	(0.21)	(0.42)	(0.64)	(1.08)	(1.51)	(-0.40)
SOE	-0.055	-0.491	-2.684**	-0.092	0.063	0.233	-0.199	-0.106	0.039
	(-0.30)	(-0.57)	(-2.84)	(-0.54)	(0.35)	(1.20)	(-1.05)	(-0.54)	(0.20)
Constant	-0.289	8.915	11.005	-1.950*	-1.289	-1.837**	-1.434	-1.048	-0.800
	(-0.29)	(0.98)	(1.16)	(-1.92)	(-1.25)	(-2.02)	(-1.56)	(-0.89)	(-0.80)
Year Effect	YES	YES	YES	YES	YES	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	4,133	4,008	3,839	4,111	3,922	4,183	4,177	3,829	4,442
Adj-R^2	0.238	0.390	0.441	0.293	0.280	0.283	0.292	0.294	0.232

Table 5. Placebo Test of CEO Turnover on Firm Level

This table reports the placebo test of CEO turnover on firm level by using the whole sample between 2008 and 2017. We exclude the firm that actually experience the CEO turnover event, and apply the falsification at the firm level by choosing a random firm from control group (non-CEO turnover firms) and consider it as a treated firm (with a CEO change), and repeating this procedure five times since each of the treatment firms have at least five different firms in the control group. CEO turnover firms are matched with the firms of similar size (+/- 30% of total asset, log), similar performance (+/- 30% of ROA), same industry and year. We repeat the whole matching procedure nine-times and present the results in column (1)-(9) respectively, because the CEO turnover happens in each year among different firms. The dependent variable is invention patent application number (*Ln (Inven+1)*). All regressions control for year and firm fixed effects whose coefficients are suppressed. All variables are defined in Appendix A. The t-test statistics are shown in parentheses below coefficient estimates based on the standard errors clustered by firms.

***, ** and * represent significant level at 1%, 5% and 10% level, respectively.

Dep. Ln (Inven+1)	(1)	(2)	(3)	(4)	(5)
NEW CEO_POST	0.004	0.016	0.014	-0.046	-0.037
	(0.06)	(0.27)	(0.21)	(-0.81)	(-0.65)
Firm Size	0.350***	0.254***	0.344***	0.393***	0.289***
	(5.72)	(4.22)	(4.66)	(6.30)	(4.27)
Firm Age	-0.125	0.007	-0.094	-0.093	-0.089
	(-0.33)	(0.02)	(-0.26)	(-0.26)	(-0.25)
Leverage	-0.208	-0.205	-0.400**	-0.273	-0.272
	(-1.20)	(-1.18)	(-2.19)	(-1.54)	(-1.55)
ROA	0.457	0.467	0.313	0.502	0.903**
	(1.25)	(1.41)	(0.89)	(1.52)	(2.56)
Book to Market	-3.206	-1.437	-6.436	-0.333	1.911
	(-0.53)	(-0.24)	(-0.97)	(-0.07)	(0.30)
SOE	-0.104	-0.278	-0.094	-0.121	-0.245
	(-0.43)	(-1.09)	(-0.27)	(-0.39)	(-1.00)
Constant	-1.232	-0.857	-1.106	-1.643*	-0.954
	(-1.33)	(-0.93)	(-1.17)	(-1.86)	(-1.07)
Year Effect	YES	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES	YES
N	4,664	4,563	4,444	4,631	4,516
Adj-R^2	0.215	0.233	0.240	0.245	0.243

Table 6. CEO Turnover and Corporate Innovation with Additional Controls

This table reports the estimation of ordinary least square (OLS) regression analysis with including additional control variables. We use patent application number (*Ln (Inven+1), Ln (Inven+Utility+1)*), citation number (Citation Adjusted) and R&D expense (*Ln (R&D)*) as the dependent variable. The sample period is between 2008 and 2017. All regressions control for year and firm fixed effects whose coefficients are suppressed. All variables are defined in Appendix A. The t-test statistics are shown in parentheses below coefficient estimates based on the standard errors clustered by firms. ***, ** and * represent significant level at 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)
Dep.	*Ln (Inven+1)*	*Ln (Inven+Utility+1)*	*Ln (R&D)*	*Citation Adjusted*
NEW CEO_POST	0.079*	0.092*	0.099**	0.132**
	(1.77)	(1.83)	(1.98)	(2.04)
CEO Gender	-0.342*	-0.438**	-0.122	-0.106
	(-1.95)	(-2.20)	(-0.68)	(-0.46)
CEO Age	0.748***	1.131***	0.764***	0.304
	(3.06)	(4.39)	(3.12)	(0.88)
CEO Education	0.131**	0.197***	0.152***	0.040
	(2.32)	(3.27)	(2.87)	(0.47)
CEO Overseas Experience	-0.100	-0.109	-0.137	-0.173
	(-1.09)	(-1.19)	(-1.52)	(-0.91)
CEO Stock Holding	-0.584**	-0.474	-0.267	0.275
	(-2.09)	(-1.55)	(-1.06)	(0.61)
CEO Overconfidence	-0.146	-0.129	-0.050	0.053
	(-0.94)	(-0.71)	(-0.29)	(0.20)
Board Size	-0.370***	-0.333***	-0.109***	-0.052
	(-9.03)	(-6.97)	(-3.50)	(-0.84)
Independent Director	0.029	0.062	0.191*	0.113
	(0.19)	(-0.38)	(1.80)	(0.50)
Duality	-0.133	-0.103	-0.072	-0.102
	(-1.61)	(-1.13)	(-0.99)	(-0.84)
Firm Size	0.228***	0.280***	0.301***	0.026
	(8.33)	(9.11)	(11.46)	(0.68)
Firm Age	-0.861	-2.183	-0.380	-0.788
	(-0.63)	(-1.19)	(-0.34)	(-0.65)
Leverage	0.215	0.089	0.584***	0.086
	(1.39)	(0.51)	(3.96)	(0.36)
ROA	2.981***	3.999***	2.355***	0.484
	(4.50)	(5.26)	(4.01)	(0.47)
Book to Market	-2.925***	-6.188	-5.193	-9.296
	(-6.01)	(-1.09)	(-0.84)	(-1.33)
SOE	0.108	0.341*	0.480**	0.001
	(0.64)	(1.75)	(2.57)	(0.02)
Constant	-1.471	-2.318**	-0.545	2.789**
	(-1.48)	(-2.17)	(-0.55)	(1.98)
Year Effect	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES
N	4,770	4,770	4,770	4,770
Adj-R^2	0.181	0.243	0.587	0.159

Table 7. Alternative Model Specification

This table reports the estimation of poisson and tobit regression model. The sample period is between 2008 and 2017. We use patent application number (*Ln (Inven+1), Ln (Inven+Utility+1)*), citation number (Citation Adjusted) and R&D expense (*Ln (R&D)*) as the dependent variable. All regressions control for year and firm fixed effects whose coefficients are suppressed. All variables are defined in Appendix A. The t-test statistics are shown in parentheses below coefficient estimates based on the standard errors clustered by firms.
***, ** and * represent significant level at 1%, 5% and 10% level, respectively.

	(1)		(2)		(3)		(4)	
Dep.	*Ln (Inven+1)*		*Ln (Inven+Utility+1)*		*Ln (R&D)*		*Citation Adjusted*	
	Poisson Model	Tobit Model	Poisson Model	Tobit Model	Poisson Model	Tobit Model	Poisson Model	Tobit Model
NEW CEO_POST	0.125***	0.129**	0.082**	0.098*	0.027*	0.071**	0.103**	0.068*
	(3.01)	(2.32)	(2.40)	(1.71)	(1.81)	(1.99)	(2.53)	(1.95)
Firm Size	0.146***	0.287***	0.138***	0.282***	0.079***	0.328***	0.126***	0.142***
	(5.59)	(9.23)	(6.41)	(8.74)	(8.11)	(15.69)	(4.81)	(7.37)
Firm Age	-1.593***	-0.490*	-1.426***	-0.603**	-0.480***	-0.541***	-1.042***	-0.000
	(-4.68)	(-1.87)	(-5.23)	(-2.17)	(-4.09)	(-2.77)	(-3.35)	(-0.00)
Leverage	0.231	0.238	0.275**	0.299	0.124**	0.606***	0.214	0.079
	(1.53)	(1.25)	(2.12)	(1.50)	(2.43)	(4.72)	(1.47)	(0.67)
ROA	2.117***	5.372***	1.619***	5.105***	0.621**	2.622***	1.620**	2.343***
	(3.18)	(6.20)	(2.94)	(5.71)	(2.54)	(4.73)	(2.38)	(4.35)
Book to Market	-2.734***	-4.078***	-3.230***	-3.219***	-0.279	-1.383**	-1.498**	-2.252***
	(-4.66)	(-4.96)	(-6.35)	(-3.80)	(-1.12)	(-2.57)	(-2.40)	(-4.41)
SOE	0.187	0.592**	0.165	0.605**	0.154*	0.111	0.324	0.401***
	(0.82)	(2.55)	(0.91)	(2.54)	(1.92)	(0.72)	(1.39)	(2.80)
Constant	-2.446***	-1.015	-1.684***	-0.741	-1.544***	0.207	-4.613***	0.533
	(-6.94)	(-1.12)	(-5.75)	(-0.77)	(-4.42)	(0.31)	(-9.11)	(0.96)
Year Effect	YES	YES	YES	YES	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES
N	4,770	4,770	4,770	4,770	4,770	4,770	4,770	4,770

Table 8. CEO Turnover and Corporate Innovation with Alternative Matching

This table reports the estimation of difference-in-difference model by using more restrict matching range. We use patent application number (*Ln (Inven+1), Ln (Inven+Utility+1)*), citation number (Citation Adjusted) and R&D expense (*Ln (R&D)*) as the dependent variable. CEO turnover firms are matched with the firms of similar size (+/- 10% of total asset, log), similar performance (+/- 10% of ROA), same industry and year. The sample period is between 2008 and 2017. All regressions control for year and firm fixed effects whose coefficients are suppressed. All variables are defined in Appendix A. The t-test statistics are shown in parentheses below coefficient estimates based on the standard errors clustered by firms. ***, ** and * represent significant level at 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)
Dep.	*Ln (Inven+1)*	*Ln (Inven+Utility+1)*	*Ln (R&D)*	*Citation Adjusted*
NEW CEO_POST	0.123*	0.218***	0.091	0.076*
	(1.84)	(2.79)	(1.64)	(1.65)
Firm Size	0.230**	0.202*	0.214***	0.124***
	(2.02)	(1.65)	(6.18)	(4.94)
Firm Age	-0.061*	-0.085**	-1.047***	-0.537**
	(-1.96)	(-2.48)	(-2.88)	(-2.46)
Leverage	0.181	0.077	1.217***	0.103
	(0.58)	(0.23)	(5.28)	(0.56)
ROA	2.081**	2.264**	1.434***	6.691***
	(2.16)	(2.26)	(3.33)	(17.17)
Book to Market	-3.938***	-6.013***	-5.122***	-4.189**
	(-3.70)	(-5.05)	(-4.90)	(-2.07)
SOE	0.107	0.058	0.329	0.064
	(0.34)	(0.21)	(0.99)	(0.36)
Constant	-1.561**	-1.374*	-1.903	-1.372
	(-2.28)	(-1.87)	(-1.34)	(-1.61)
Year Effect	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES
N	3,292	3,292	3,292	3,292
Adj-R^2	0.127	0.153	0.412	0.183

Table 9. Univariate analysis of CEO Characteristics

This table reports the comparison results of innovation and CEO characteristics among different sub-groups. Panel A shows the difference between departure and incoming CEOs. Panel B displays the difference between treatment (firms with CEO turnover) and control group (firms without CEO turnover). Sample period is between 2008 and 2017. All variables are defined in Table A.1(Appendix).

***, ** and * represent significance levels at 1%, 5% and 10%, respectively.

Differences between Pre and Post CEO Turnover Event

	Post-CEO Change		Pre-CEO Change		t-test
	Mean	Std. Dev.	Mean	Std. Dev.	
CEO Characteristics					
CEO Gender	0.964	0.188	0.930	0.255	3.12***
CEO Age	47.177	5.98	50.298	5.732	-10.97***
CEO Education	0.424	0.494	0.424	0.495	-0.02
CEO Overseas Experience	0.079	0.269	0.043	0.203	3.09***
CEO Stock Holding	0.313	0.464	0.000	0.000	19.77***
CEO Overconfidence	0.642	0.176	0.622	0.158	3.99***

Table 10. New CEO Characteristics and Firm Innovation

This table reports the regression analysis results considering the effects of new CEO's characteristics on innovation after firm replaces the CEO. We use patent application number (*Ln (Inven+1)*) as the dependent variable. And using interaction term between CEO_POST and characteristics to capture the post treatment effect of new CEO characteristics. CEO turnover firms are matched with the firms of similar size (+/- 30% of total asset, log), similar performance (+/- 30% of ROA), same industry and year. The sample period is between 2008 and 2017. All regressions control for year and firm fixed effects whose coefficients are suppressed. All variables are defined in Appendix A. The t-test statistics are shown in parentheses below coefficient estimates based on the standard errors clustered by firms.

***, ** and * represent significant level at 1%, 5% and 10% level, respectively.

Dep. Ln (Inven+1)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
NEW CEO POST	0.128**	0.122**	0.398*	0.162*	0.173**	0.116*	0.214**
	(2.19)	(2.09)	(1.86)	(1.96)	(2.03)	(1.93)	(2.02)
Gender		-0.506*					
		(-1.88)					
NEW CEO_POST×Gender		-0.041					
		(-0.15)					
Age			-1.697***				
			(-4.24)				
NEW CEO_POST×Age			-0.821*				
			(-1.75)				
Education				0.158**			
				(2.01)			
NEW CEO_POST×Education				0.235***			
				(3.05)			
Overseas					1.222***		
					(2.72)		
NEW CEO_POST×Overseas					0.278*		
					(1.67)		
Stock Holding						-0.272	
						(-1.58)	
NEW CEO_POST×Stock Holding						-0.202	
						(-1.02)	
Overconfidence							0.101*
							(1.73)
NEW CEO_POST×Overconfidence							0.522**
							(2.03)
Controls	YES	YES	YES	YES	YES	YES	YES
Year Effect	YES	YES	YES	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES	YES	YES	YES
N	4,770	4,770	4,770	4,770	4,770	4,770	4,770
Adj-R^2	0.189	0.181	0.183	0.182	0.183	0.189	0.171

Appendix 1

Reasons of CEO Turnover

This table illustrates the twelve reasons for CEO turnover in our sample. We obtain the reasons based on the CSMAR database and double checked with the firm's annual report. In case of conflict between CSMAR and firm's annual report, we use the information from the annual report.

Reasons	Explanation
Personal reasons	A situation where a CEO leaves his/her position due to some personal circumstances not related to the job.
Contract Expiration	A case where CEO whose contract period (tenure) has reached the maximum and no longer eligible to become a CEO in a short period via the company's nomination or election.
Health	A situation where CEO leaves due to the poor health
Retirement	CEO reaches the retirement age according to the Chinese Labour Law.
Corporate Governance Restructuring	A company replace the CEO due to the requirement of the corporate governance restructuring.
Job Transfer	A CEO has been transferred to another position within the company.
Agent-related termination	A situation where the incoming CEO is acting temporary to help the company in the transaction period and will be replace once the period is terminated.
Change of the Controlling Right	A company changes its ownership structure and consequently replaces the CEO
Dismissed	A CEO has been dismissed/fired by the company
Resignation	A CEO has voluntarily resigned from his/her post
Case Involve	A CEO is under investigation for criminal activities

Appendix 2

Variable Definition	
Variable Name	Explanation
Corporate Innovation (Dependent Variable)	
Ln(1+Inven)	Natural logarithm of one plus the total invention patent applications
Ln(1+Inven+Utility)	Natural logarithm of one plus the sum of invention and utility patent applications
Ln (R&D)	Natural Logarithm of the R&D Spending
Citation Adjusted	Number of forward citations per invention patent scaled by the average citations for the same year and industry cohort.
CEO Turnover (Main Independent Variable)	
NEW CEO_POST	A dummy variable equal to 1 when and after a firm experiences a CEO turnover at year t, and 0 otherwise.
Firm Characteristics (Control Variables)	
Firm Size	Natural logarithm of the total asset
Firm Age	Natural logarithmic of the firm operation year plus one
Leverage	Total debt divided by total asset
ROA	Net income divided by total asset
Book to Market	Firm's book value divided by market value
SOE	Percentage ownership held by the state
CEO Characteristics (Additional Control Variables)	
CEO Gender	Dummy variable, =1 when a CEO is male, and 0 otherwise
CEO Age	Natural logarithm of each CEO's actual age
CEO Education	Dummy variable, =1 when a CEO has a Master Degree or above, and 0 otherwise
CEO Overseas Experience	Dummy variable, =1 when a CEO has overseas experience (either education or working), and 0 otherwise
CEO Stock Holding	Percentage of the company shares hold by each CEO
CEO Overconfidence	Dummy variable, =1 when a CEO holds an option until its final year of duration and the option is at least 40% during his/her entire tenure, and 0 otherwise
Board Characteristics (Additional Control Variables)	
Board Size	Natural logarithm of the total number of board members
Independent Director	The percentage of independent director on board
Duality	Dummy variable, =1 if CEO is also the Chairman of the board, and zero otherwise.

Appendix 3

Trends in innovation measures for Treated and Control firms: Mean and median comparisons

This table reports the mean and median yearly changes in innovation for firms in both treated and control groups three-year ahead before the exogenous turnover. All changes in these measures are calculated relative to the value of the measure at the year of the turnover (t=0). Innovation measures are invention patent application numbers, defined as ln (1+number of the invention patent application number), invention and utility patent application number, defined as ln (1+number of the invention and utility patent application number), R&D, defined as ln (R&D expense), Citation Adjust, defined as each firm's citation counts divide by the average amount of patent citation in the same cohort. The first row presents the changes of innovation in three-year ahead before the exogenous turnover. In particular, the difference has been calculated between innovation at t=-3 (three years prior to the turnover) and t=0 (the exogenous turnover event year). The table also reports p-values associated with test statistics for differences in means (standard t-test) and medians (Wilcoxon-Mann-Whitney test) across treated and control groups.
*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Time Horizon	Control Mean [Median]	Treatment Mean [Median]	p-value of difference t-test [Wilcoxon-Mann-Whitney test]	Control Mean [Median]	Treatment Mean [Median]	p-value of difference t-test [Wilcoxon-Mann-Whitney test]	Control Mean [Median]	Treatment Mean [Median]	p-value of difference t-test [Wilcoxon-Mann-Whitney test]	Control Mean [Median]	Treatment Mean [Median]	p-value of difference t-test [Wilcoxon-Mann-Whitney test]
	Ln (Inven+1)			*Ln (Inven+Utility+1)*			*Ln (R&D)*			*Citation Adjusted*		
3 years prior to turnover	0.104	0.191	-0.515	0.107	0.141	-0.179	0.619	0.777	-0.845	0.062	0.132	-0.622
	[0.000]	[0.000]	[0.686]	[0.00]	[0.000]	[0.748]	[0.403]	[0.427]	[0.939]	[0.000]	[0.000]	[0.529]
2 years prior to turnover	0.206	0.111	0.782	0.200	0.159	0.289	0.311	0.250	0.859	0.114	0.085	0.773
	[0.000]	[0.000]	[0.348]	[0.000]	[0.000]	[0.466]	[0.372]	[0.230]	[0.409]	[0.000]	[0.000]	[0.278]
1 years prior to turnover	0.203	0.148	0.448	0.254	0.203	0.360	0.231	0.179	0.171	0.109	0.040	0.915
	[0.000]	[0.000]	[0.465]	[0.000]	[0.000]	[0.409]	[0.369]	[0.296]	[0.428]	[0.000]	[0.000]	[0.253]

Appendix 4

CEO Turnover and Firm Innovation (Only Health and Retirement Reasons)

This table reports the estimation of ordinary least square (OLS) regression analysis of the relationship between CEO turnover and firm innovation by only considering health and retirement reasons for CEO turnover. We use patent application number (*Ln (Inven+1), Ln (Inven+Utility+1)*), citation number (*Ln (Citation+1)*) and R&D expense (*Ln (R&D)*) as the dependent variable. The sample period is between 2008 and 2017. Column (1)-(4) illustrate the results of univariate regression, while column (5)-(8) display the multivariate regression results. All regressions control for year, industry and province fixed effects whose coefficients are suppressed. All variables are defined in Appendix A. The t-test statistics are shown in parentheses below coefficient estimates based on the standard errors clustered by firms.

***, ** and * represent significant level at 1%, 5% and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Ln (Inven+1)	*Ln (Inven+Utility+1)*	*Ln (R&D)*	*Citation Adjusted*	*Ln (Inven+1)*	*Ln (Inven+Utility+1)*	*Ln (R&D)*	*Citation Adjusted*
Turnover	0.141**	0.135*	0.320***	0.074*	0.181**	0.190**	0.106	0.105**
	(1.98)	(1.71)	(3.87)	(1.69)	(2.25)	(2.05)	(1.46)	(2.06)
Firm Size					0.226***	0.283***	0.313***	0.110***
					(6.06)	(6.60)	(8.01)	(4.41)
Firm Age					-2.305***	-3.040***	-2.082***	-1.005***
					(-3.94)	(-4.57)	(-4.52)	(-2.87)
Leverage					0.313	0.398	0.455**	0.253*
					(1.40)	(1.55)	(2.42)	(1.74)
ROA					3.266***	3.382***	2.449***	1.223*
					(3.53)	(3.24)	(2.70)	(1.85)
Book to Market					-5.148***	-7.450***	-1.608*	-2.087***
					(-5.53)	(-6.71)	(-1.68)	(-3.21)
SOE					0.353	0.308	0.047	0.431**
					(1.29)	(1.08)	(0.17)	(1.99)
Constant	1.437***	1.980***	3.390***	0.918***	-7.575***	-9.936***	-5.211***	-3.031**
	(145.82)	(180.37)	(296.41)	(149.31)	(-3.72)	(-4.27)	(-3.35)	(-2.48)
Year Effect	YES	YES	YES	YES	YES	YES	YES	YES
Firm Fixed Effect	YES	YES	YES	YES	YES	YES	YES	YES
N	3,614	3,614	3,614	3,614	3,614	3,614	3,614	3,614
Adj-R^2	0.201	0.136	0.116	0.131	0.154	0.192	0.334	0.176