This study develops and tests a comprehensive framework that explains what, when, and how CEO characteristics influence firms’ innovation outcomes in R&D-intensive industries. Empirical evidence from 109 CEOs from 87 U.S.-based pharmaceutical firms over the period 2001–2013 reveals that research-oriented CEOs – those with ability and motivation for science and technology – increase their firms’ innovation outcomes. The results indicate that the CEO–innovation relationship strongly depends on the extent of CEOs’ managerial discretion, which is shaped by the organizational context. We contribute to a more comprehensive understanding of the role of CEOs in firms’ innovation performance differentials.

1. Introduction

Understanding how CEOs influence firm strategies and outcomes have received growing research interest recently (Burgelman et al., 2018; Liu et al., 2018). A rise in the importance of CEOs’ general managerial skills has been observed as one of the most striking trends in the past half century (Crossland et al., 2014), and stemming from this observation, recent research has shown that S&P 1500 firms with ‘generalist’ CEOs exhibit higher innovation outcomes (Custódio et al., 2017). Simultaneously, however, many firms have shifted from a strategic orientation of ‘R&D as a driver of growth’ to ‘R&D as an expense’. This is exemplified by a steady decline in R&D intensity and reduced innovation outcomes (Cummings and Knott, 2018). This decrease in innovation may be explained by a lack of CEOs with context-specific skills (Simsek et al., 2015; Cummings and Knott, 2018) such as technological domain expertise in R&D-intensive industries (Felix and Bistrova, 2015).

Indeed, the pharmaceutical industry has experienced a decline in innovation outcomes (Scannell et al., 2012), even though the exploration of cutting-edge technology is critical to a firm’s sustained profits and even existence (Roberts, 1999). The innovation literature has emphasized innovation from a competence perspective, by attributing performance differentials to differences in firms’ underlying
innovation capabilities (Henderson and Cockburn, 1994; Ahuja et al., 2008). This literature offers no explanation, however, why firms make different innovation strategy choices in the first place (Ahuja and Lampert, 2001). In this respect, the innovation literature misses out on the role of critical strategic and organizational conditions in which such innovation capabilities reside (Talke et al., 2010). As a result, we lack a comprehensive understanding of the strategic choices and processes through which CEOs influence firms’ innovation outcomes.

To address this issue, we study what, when, and how CEO characteristics impact firms’ innovation outcomes in the pharmaceutical industry. Drawing on the upper echelons theory (Hambrick and Mason, 1984; Hambrick, 2007), we first argue that CEOs exhibit considerable heterogeneity in their ability and motivation in relation to science and technology. This aids us in explaining the differences between firms in innovation outcomes. A comparison of former Genentech CEO Arthur Levinson, who enjoyed a distinguished career in scientific research, and Robert Hugin, an MBA graduate who is specialized in corporate finance in emerging technologies before becoming Celgene’s CEO, illustrates the diversity between CEOs. To capture such heterogeneity among CEOs and show what CEO characteristics impact firms’ innovation outcomes in R&D-intensive industries, we introduce the notion of CEO research orientation, which we define as the array of career experiences in the domains of research, science, and technology that an executive had, prior to becoming a CEO.

To assess when CEOs with a research orientation influence firms’ innovation outcomes, we argue that the organizational context in which CEOs operate, determines their managerial discretion or latitude for action (Hambrick and Finkelstein, 1987; Busenbark et al., 2016). Specifically, we examine whether CEOs’ structural power as a board chairperson, the availability of slack resources for experimentation, and the presence of inertial forces in older firms affect the extent to which a CEO’s research orientation spurs a firm’s innovation. To detail one mediating mechanism how research-oriented CEOs influence innovation, we argue that those CEOs who strategically choose an R&D-intensive investment strategy and who have a better understanding of how to effectively implement such a strategy, positively affect their firm’s innovation outcomes (Bromiley and Rau, 2016; Liu et al., 2018). Taken together, this study proposes a comprehensive framework that indicates that through their research orientation and operating in a given context, CEOs shape their firm’s strategic choice of R&D resource allocation and attendant innovation outcomes. We find considerable support for our model by utilizing a panel dataset involving 109 CEOs from 87 U.S. pharmaceutical firms over the period 2001 to 2013.

This study adds to the upper echelons theory by explaining and testing the complex causal chain between CEOs and firms’ innovation outcomes. This study moves beyond merely observing a direct relationship between CEO characteristics and innovation (Balsmeier and Buchwald, 2014; Custódio et al., 2017; Cummings and Knott, 2018). Instead, it explicitly examines when and how CEO strategic choices fuel subsequent processes that result in firms’ innovation outcomes. We thereby respond to recent calls by developing and testing comprehensive models that examine CEO influence on firm outcomes such as innovation (Busenbark et al., 2016; Liu et al., 2018). This study also contributes to the innovation literature by studying the role of the CEO as an important yet often overlooked factor that influences firms’ innovation outcomes (Talke et al., 2010).

2. Theory and hypotheses

2.1. CEO research orientation and firms’ innovation outcomes

People’s career paths provide much insight into with respect to their ability and motivation in general as well as with regard to their preferences, beliefs, skill sets, values, goals, and search for meaning in particular (Judge et al., 1995; Sullivan and Baruch, 2009). In a similar vein, CEOs’ careers reflect their unique abilities and motivations (Crossland et al., 2014; Busenbark et al., 2016). The core of the upper echelons theory holds that, faced with competing tasks and limited attentional resources (Cyert and March, 1963), CEOs make strategic choices through highly personalized lenses that arise from their experiences, motives, and personalities (Hambrick and Mason, 1984; Hambrick, 2007). Much research has subsequently shown that the specific ‘orientations’ that CEOs bring to the firm shape strategic decision making and organizational outcomes (Finkelstein et al., 2009, p. 49). In this study, we argue that CEOs have a certain level of research orientation – that is, ability and motivation for science and technology. Such orientation is revealed by their career experiences in the domains of research, science, and technology prior to their becoming a CEO. Specifically, we postulate that CEOs who (1) have a PhD degree in science or engineering, (2) have academic experience,
Three mechanisms explain why research-oriented CEOs are more likely to create a supportive organizational context for innovation. First, their experience in research, science, and technology provides them with complex ‘cognitive schemas’ that enable them to develop a more comprehensive awareness of new opportunities and to better understand new technologies at earlier stages of development and in times of technological uncertainty (Nadkarni and Chen, 2014). As a result, CEOs with a research orientation are better able to discover and comprehend technological opportunities and subsequently develop a clearer vision for technological advancement (Kaplan and Tripsas, 2008).

Second, recent studies show that CEO personality and strategic leadership behaviors influence innovation through the development of a socio-cultural context (Elenkov and Manev, 2005; O’Reilly et al., 2014). Here, research-oriented CEOs are likely to create a context of shared norms, values, and beliefs that are supportive of an innovation culture (Berson et al., 2008; Giberson et al., 2009). For instance, they can create and foster such a culture through leadership activities, standard operating procedures, reward systems, and evaluation criteria, all of which can be used to steer, reward, and control innovation activities (Wu et al., 2005).

Finally, research-oriented CEOs are likely to hire and attract like-minded personnel who share their technological vision and skills. As human capital is a key element of innovation, the selection and retention of research-oriented people are paramount (Zucker et al., 1998). The resulting innovation culture not only stimulates innovation activity (as discussed) but also strengthens the attraction, selection, and departure of organizational members on the basis of their fit with a socio-cultural context focused on innovation (Elenkov and Manev, 2005; Berson et al., 2008). Combining these three mechanisms explains why research-oriented CEOs are more likely to enable firms’ innovation outcomes, which results in the following hypothesis:

**Hypothesis 1:** CEO research orientation is positively related to firms’ innovation outcomes.

### 2.2. Organizational context, managerial discretion, and CEO influence

The extent to which CEOs are able to influence their firms’ strategies and outcomes depends on the organizational context in which CEOs operate (Busenbark et al., 2016). That context is shaped by firm-level factors related to organizational structures, resources, and routines that enhance or hinder CEOs’ managerial discretion or latitude for action (Hambroek and Finkelstein, 1987; Liu et al., 2018). Therefore, we consider three contextual factors that determine managerial discretion and thus explain when CEOs can influence firms’ innovation outcomes: CEO formal power, availability of slack resources, and organizational age.

First, the amount of formal power that a CEO has, is an important predictor of a CEO’s influence on organizational activities and outcomes. Here, the CEO’s structural position relative to the board effectively reflects such structural (i.e., formal) power (Finkelstein et al., 2009; Chin et al., 2013). Specifically, CEO-chair duality has been consistently found to raise such CEO power (Krause et al., 2014). It effectively determines how (un)constrained a CEO is in shaping strategy. Hence, we expect that research-oriented CEOs who also chair the board are more able to formulate an innovation strategy that is in line with personal aspirations.

**Hypothesis 2a:** CEO duality positively moderates the positive relationship between CEO research orientation and firms’ innovation outcomes.

Second, slack resources may offer CEOs more leeway in steering the organization in line with personal preferences (Jensen and Meckling, 1976). In this respect, slack resources may free up managerial resources (e.g., time, effort, and attention). This may facilitate experimentation and increase the ability to pursue risky innovation projects (Chen, 2008; Nohria and Gulati, 1996). Slack may also decrease the pressure for short-term performance from shareholders (Walrave et al., 2011). As a result, CEOs with a research orientation and slack resources are able to better pursue their innovative ideas and research. We, therefore, expect that the relation between CEO research orientation and firms’ innovation outcomes is positively influenced by the availability of slack resources.

**Hypothesis 2b:** Firm slack resources positively moderate the positive relationship between CEO research orientation and firms’ innovation outcomes.

Finally, firm age affects the influence that CEOs have on their firms’ activities and outcomes. As firms develop specific routines, competences, and norms over time (Hannan and Freeman, 1984), R&D processes, incentive systems, and resource-allocation processes tend to become increasingly routinized and therefore difficult to change (Kapoor and Klueter, 2015) – even by the CEO. An older firm’s innovation activities, such as the search for new technological knowledge, are therefore often constrained by its
2.3. CEO strategic choices and allocation of resources to R&D

To examine in more detail how research-oriented CEOs’ strategic influence fuels subsequent organizational processes and ultimately innovation outcomes, we argue here that resource allocation to R&D partially mediates the CEO-innovation relationship. CEOs have significant control over their firms’ strategy formulation processes and R&D resource-allocation processes (Bromley and Rau, 2016). Prior research shows that CEOs who have advanced science-related degrees and extensive experience in engineering and technology spend more R&D dollars per employee (Barker and Mueller, 2002). CEOs with technological domain expertise have a tendency to use R&D and science as a universal response to organizational failure and to achieve corporate growth objectives (Cummings and Knott, 2018). They are also more likely to be inclined to employ more people with a high level of education and technical background (Zucker et al., 1998). This may lead research-oriented CEOs to choose an R&D-intensive investment strategy to pursue their technological vision for innovation.

While investment in R&D is not a guarantee of innovation success, it is certainly an important input. It helps firms to attract, train, and retain R&D employees as well as to acquire other R&D resources that are required to develop an absorptive capacity and innovation capability (Zucker et al., 1998). Especially in technology-intensive industries, R&D investments are a primary source of innovation output (Hagedoorn and Cloodt, 2003). Studies show that R&D intensity positively impacts patent output or related types of innovation outcomes (e.g., Griliches, 1990). Hence, we argue that one of the mechanisms through which research-oriented CEOs influence firms’ innovation outcomes is through intensifying R&D investments. Specifically, we hypothesize that CEO research orientation increases firms’ innovation outcomes because they increase firms’ investments in R&D, which increases innovation outcomes.

Hypothesis 3: Firm R&D intensity partially mediates the positive relationship between CEO research orientation and firms’ innovation outcomes.

2.4. The CEO’s role in the implementation of an R&D-intensive investment strategy

Another explanation for how research-oriented CEOs spur firms’ innovation outcomes is through effective strategy implementation. Successful implementation of a firm’s strategy through daily leadership activities is one of the CEO’s primary tasks (Burgelman et al., 2018; Simsek et al., 2015). Prior research shows that R&D-intensive firms achieve higher productivity and economic returns when they are managed by CEOs with technical expertise and a propensity for innovation (Beal and Yasai-Ardekani, 2000; Pan, 2015). In this respect, research-oriented CEOs can effectively steer the implementation of an R&D-intensive strategy. They are able to process more technical information and they are motivated to solve complex research-related problems, which facilitates fast strategic decision making (Barker and Mueller, 2002; Katila et al., 2017). Given their strong attentional focus on the present and the future (Nadkarni and Chen, 2014), they are also more likely to detect links among technological developments over time (Brown and Eisenhardt, 1997). Research-oriented CEOs are therefore more capable to strategically steer for the detection and development of new technologies and achieve a higher frequency of innovation outcomes for each R&D dollar invested. As such, we hypothesize that CEO research orientation positively moderates the relation between R&D intensity and innovation outcomes.

Hypothesis 4: CEO research orientation positively moderates the positive relationship between a firm’s R&D intensity and its innovation outcomes.

3. Method

3.1. Sample and data

We studied U.S. research-based pharmaceutical firms to test our hypotheses (Standard Industrial Classification [SIC] codes: 2833, 2834, 2835, and 2836) (Caner et al., 2017). Especially in R&D-intensive
environments, CEO characteristics become reflected in organizational outcomes because these environments demand action of a more strategic kind, offer a wide range of strategic options, and provide CEOs with more discretion (Wu et al., 2005; Gerstner et al., 2013). We limited our scope to publicly list U.S. firms that were among the hundred largest employers, as recorded by Compustat, at any time during the period between 2001 and 2013. We identified the CEOs for these firms and years in BoardEx and Execucomp and applied four selection criteria to increase our study’s internal validity. First, a CEO’s first year in office was the first year in which he or she served for more than half the calendar year. Second, we included only CEOs who served at least two full years, to observe at least a minimally potential effect of their research orientation on corporate strategy and innovation (Chin et al., 2013). Third, we excluded CEOs who had previously served as CEO somewhere else, as our measure of CEO research orientation was based on each CEO’s ‘pre-CEO’ experiences (Chin et al., 2013). Fourth, we excluded firms that focused only on generics or reformulations and did not actively engage in pharmaceutical innovation to maintain our focus on research-intensive firms (Kapoor and Kluter, 2015). This procedure resulted in a sample consisting of 109 CEOs at 87 firms and 711 firm-year observations.

Although the sample of firms is not large in an absolute sense, it represents the vast majority of the population of U.S. research-based pharmaceutical companies over a period not studied before. It is also larger than the samples used in related studies of this industry (e.g., Gerstner et al., 2013). In addition to increasing the study’s internal validity, the study design resulted in a handcrafted sample that enabled detailed measurement of heterogeneity among CEOs’ research orientation and extensive data collection using a variety of data sources. Data on CEO characteristics and experiences were collected using the BoardEx and Execucomp databases. Where information was missing, we consulted numerous other sources, such as SEC filings, corporate websites, press releases, Thomson Reuters Eikon, Lexis Nexis, and Marquis Who’s Who, and several other online directories containing information on executive backgrounds (e.g., Bloomberg Executive Profile and Biography, The Wall Street Transcript, and Equilar) to make our database complete. The accounting data were obtained from Compustat and the patent data were collected from the U.S. Patent and Trademark Office (USPTO). We used USPTO data because they match with our sample of U.S. publicly listed firms. Since the USPTO assigns patents to both parent firms and their subsidiaries, we constructed detailed family trees that included historical company names of all firms using Securities and Exchange Commission (SEC) 10-K filings and company websites. We matched company names, legal forms, and country data to USPTO assignees on patent applications. Eventually, all 9,953 patents of subsidiaries were aggregated at the parent-company level, which resulted in a total of 37,086 patent applications for the 87 firms under observation.

3.2. Dependent variables

We measured each firm’s yearly innovation outcomes by counting the number of patent applications per year (dated by patent application date). Especially in the pharmaceutical industry, where firms have a strong incentive to file for patents, patent activity is commonly used for studies on innovation (Hagedoorn and Cloodt, 2003; Grigoriou and Rothaermel, 2014; Caner et al., 2017). We used USPTO patent data because the USPTO recently made datasets available on patents granted from 1976 onward and on patent applications published from 2001 onward (i.e., patent applications with a pending instead of granted status). This allows us to count all patent applications (i.e., granted and pending applications) of the firms in our sample, filed for during the period of study.

We adopted patent applications as opposed to granted patents, as each application represents a valuable kind of technology that results from the innovation process (Balsmeier and Buchwald, 2014). Notably, patent applications are especially suited to study a CEO’s most immediate impact on a firm’s technological innovation outcomes. Whether a patent is filed for a given invention is determined mainly by the firm’s own decision making, whereas the grant of a patent is dependent on the substantially delayed outcome of a third party’s appraisal of the invention, the patent office. This choice implies that we forgo the potential of granted patents to proxy invention quality at the benefit of a more direct causal chain (Grigoriou and Rothaermel, 2014) – in both time and space. This approach follows recent work (e.g., Balsmeier and Buchwald, 2014). Additional analyses using granted patents, as a robustness test, resulted in highly similar results (see Online Appendix A).

To test the mediation effect, we measured R&D intensity as a firm’s R&D expenditure divided by the number of employees. Dollars spent by the firm on R&D were converted to the year 2000 U.S. dollars using the consumer price index published by the U.S. Bureau of Labor Statistics (Barker and Mueller, 2002). In upper echelons studies, the amount of R&D dollars invested per employee is the standard and most robust measure of a firm’s investments in intellectual human capital for research and innovation.
(Baysinger, Kosnik, and Turk, 1991; Barker and Mueller, 2002). A firm’s R&D investments relative to its number of employees are a strong indicator of the strategic importance of innovation for a firm because human capital is critical to firms’ capabilities necessary to innovate (Zucker et al., 1998; Kor, 2006).

3.3. Independent variable
We coded CEO research orientation using four indicators that are indicative of a CEO’s ability and motivation in relation to science and technology. More specifically, based on a person’s career experiences prior to becoming CEO, we coded whether: (1) the CEO holds a PhD degree in science or engineering; (2) the CEO has academic experience; (3) the CEO’s dominant functional experience is in R&D; and (4) the CEO holds any patents. We specifically looked at those experiences because they effectively reflect abilities and motivations that are of particular relevance to strategic leadership in technological innovation (Judge et al., 1995; Zucker et al., 1998). Reliability analysis and factor analysis showed that the four indicators reflect a latent construct that we call CEO research orientation (see Online Appendix B). Subsequently, we calculated the main independent variable CEO research orientation, per CEO, as the sum of the mentioned indicators because the indicators had similar means and variances, and all varied between 0 and 1. The resulting variable ranges between 0 = no research orientation and 4 = high research orientation. We determined a CEO’s research orientation prior to the CEO becoming CEO of the focal firm, to make sure that our operationalization was consistent with the causal logic of our arguments (Chin et al., 2013).

3.4. Moderator variables
Three contextual factors that determine CEOs’ managerial discretion served as moderator variables to test Hypotheses 2a–c. CEO duality was measured as a dummy variable, indicating that whether the CEO was also board chairperson for each year (Chin et al., 2013). We measured slack resources as each firm’s financial slack by dividing its current assets by its current liabilities (Nohria and Gulati, 1996). Firm age was measured as the difference between the observation year and the year of firm incorporation (Wu et al., 2005). These variables were lagged by one year in all regressions compared to the dependent variable.

3.5. Control variables
To control for potentially confounding factors, we included multiple managerial and firm variables that have been widely used in research on upper echelons and innovation. Based on prior studies that relate firm differences in R&D investments and firm patenting to CEO characteristics (Carpenter et al., 2004; Cummings and Knott, 2018), we controlled for CEO tenure (the total number of years a CEO had held office), founder (dummy variable indicating whether a CEO was a founder of the focal firm), CEO ownership (the percentage of stock owned by the CEO), and insider (dummy variable indicating whether the current CEO had been hired from inside the company rather than from outside of it). We controlled for the board independence (the number of inside directors to the total number of directors on the board) because of inside directors’ influence through their monitoring and advising roles (Walrave et al., 2014). At the firm level, we controlled for firm size (the logarithm of the number of employees) and financial performance (return on assets; net income divided by total assets) because these may influence a firm’s innovation potential (Ahuja and Lampert, 2001). As a firm’s ownership influences CEO behavior and innovation (Baysinger et al., 1991), we included institutional ownership (the total percentage of shares owned by external nonmanagement shareholders who individually owned at least five percent of company shares).

All independent variables were lagged one year in all regressions compared to the dependent variable. We also included SIC and year dummy variables in all models to account for industry heterogeneity, macroeconomic conditions, and unobserved time effects.

3.6. Analysis
We used the generalized estimating equations’ (GEEs) regression method because our investigation focuses on CEOs who are clustered within firms by analyzing longitudinal data with nonnormal response variables (Liang and Zeger, 1986). This method accounts for firm heterogeneity and autocorrelation by estimating the within-subject correlation of repeated responses on dependent variables. GEE regressions also offer the flexibility to cope with the different distributions of the two dependent variables in our models. In the models predicting patent applications, we specified a negative binomial distribution and used a log link function to calculate the variance because the number of patents takes on nonnegative integer values and is zero for some firms in some years. The goodness-of-fit and likelihood-ratio tests confirm that the distribution of this patent count variable shows overdispersion. In the models predicting R&D intensity (see Models 7 and 8 in Table 4), we
specified a Gaussian distribution and used an identity link function to calculate the variance because this variable is a ratio measure, and thus of a nondiscrete nature. We chose an exchangeable correlation structure as our study design resulted in unbalanced observations with unequal spacing. Finally, we used Huber–White–sandwich standard errors to correct for heteroscedasticity.

We constructed a presample patent stock variable as the accumulated number of granted patents of each focal firm and its subsidiaries from the year 1975 until a firm’s first observation year using a 15% annual depreciation rate of knowledge. We also included a dummy that indicates when a firm has zero presample patent applications. In contrast to the presample patent-stock variable, this presample dummy variable controls for the fact that some firms do not have a history of filing patents. This approach enables us to use the full variation in the sample (Balsmeier and Buchwald, 2014) and to control for the possibility that firms may enter the sample with inherently different innovation-generating capabilities (Ahuja and Lampert, 2001). This ensures that our estimates are consistent despite the hierarchical panel-data structure (i.e., repeated observations of CEOs nested in firms).

This presample variable approach also limits the threat of endogeneity. Furthermore, we tried to control for endogeneity by closely following the approach of recent upper echelons studies (e.g., Chin et al., 2013; Gerstner et al., 2013). As the results of these efforts were unsatisfactory (see Online Appendix C), we decided to include a rich and fine-grained set of controls to limit the threat of endogeneity. Further concerns for endogeneity were addressed by constructing the CEO research-orientation variable based on pre-CEO appointment experiences only, by accounting for a possible dynamic process of the innovation activity by including the lagged values of patent applications as a control, and by lagging all explanatory variables by a one-year period to reduce possible simultaneity biases as well as to allow for the influence of the explanatory variables to become observable in a firm’s innovation outcomes.

4. Results

Tables 1 and 2 report the means, standard deviations, and correlations among all variables. The mean variance inflation factor (VIF) of 1.69 is well below 3, and the VIF of each variable is far below 10, indicating very limited multicollinearity. The observed firms have a median size of 525 employees and are 15 years old. Regarding the distribution of CEO research orientation, 12 CEOs score 4, 17 CEOs score 3, 4 CEOs score 2, 11 CEOs score 1, and 65 CEOs score 0. For illustration, and providing face validity for this construct, Genentech’s Arthur Levinson has a research orientation of 4 and Celgene’s Robert Hugin received a score of 0. These descriptive statistics indicate that CEOs exhibit considerable heterogeneity in their research orientation.

Models 1 to 6 in Table 3 provide the results for H1 (i.e., the what question) and H2a–c (i.e., the when questions), while Models 7 to 12 in Table 4 provide the results related to H3 and H4 (i.e., the how questions). We report Wald chi-square statistics to test the overall model significance and further include the quasi-likelihood under the independence model (QIC) criterion to compare models (Cui and Qian, 2007). Models 1 and 7 only include the control variables and the lagged dependent variable. Model 1 shows that the firm size is positively related to firm patent applications and firm age is negatively related to them. Model 7 illustrates that R&D intensity is significantly and positively influenced by financial slack and board independence, while firm size has a significant negative effect.

Model 2 shows that CEO research orientation is significantly and positively associated with a firm’s number of patent applications (β = 0.159, P = .002). This translates into an average change in firms’ patent applications of 17 percent when CEO research orientation increases by one unit. This supports Hypothesis 1’s postulation that increasing CEO research orientation increases firms’ innovation outcomes. Models 3 to 5 indicate that CEO influence depends on the organizational context. In these models, the coefficient of the main effect (H1) becomes insignificant (except in Model 5), suggesting that moderation is present. More specifically, the effect of CEO research orientation increases, as anticipated, in the case of CEO duality (Model 3), when more financial slack is present (Model 4), or when the firm is younger (Model 5). However, when we simultaneously include all moderation effects in Model 6, the interaction effect of firm age becomes insignificant. Similar findings are obtained for Models 10 and 12, which also include R&D intensity as a mediator. Thus, we find strong support for H2a and H2b, and moderate support for H2c.

We further investigated Hypothesis 2a and 2b by plotting their marginal effects and calculating the predictive margins. Figure 1 shows that when a CEO with a research orientation of 4 is also board chairperson, the number of patent applications increases by 39 percent. Figure 2 illustrates that an increase of financial slack by one standard deviation (5.69) from the mean (5.24), for firms with a research-oriented CEO (score 4), results in a 15 percent increase in patent applications.
Hypothesis 3 predicts that firm R&D intensity partially mediates the relationship between CEO research orientation and firms’ innovation outcomes. To test for mediation, we first followed Baron and Kenny (1986). Their procedure indicates that there might indeed be mediation of R&D intensity because: (1) Model 8 reveals that CEO research orientation is significantly related to R&D intensity, (2) Model 9 shows that R&D intensity, in turn, is significantly related to firms’ patents, and (3) the relationship between CEO research orientation and innovation drops in strength (from $\beta = 0.157$ in Model 2 to $\beta = 0.153$ in Model 9). Yet, such a relatively small drop in the effect size indicates that R&D intensity only partially mediates the CEO–innovation relation. To further assess the significance of this mediation effect we applied the Sobel test to the focal coefficients and their standard errors, which shows a marginally significant mediation effect ($z$-value $= 1.72$, $P = .085$). These findings offer moderate support for Hypothesis 3.

In contrast to Hypothesis 4, Models 11 and 12 reveal a significantly negative coefficient of the interaction term of R&D intensity and CEO research orientation. Figure 3 illustrates the marginal effects of this moderation. It can be observed that the R&D intensity-innovation relationship becomes less strong and even changes sign when a CEO has a research orientation of 3 or 4. For firms with a CEO with a research orientation of 1, increasing R&D intensity by one standard deviation (163.17) from the mean (151.28) increases patent applications by 46 percent. For firms with a CEO with a research orientation of 4, increasing R&D intensity from low to high decreases patent applications by 17%. However, it is important to note that the patent output of firms led by more research-oriented CEOs is always higher for equal levels of R&D intensity.

4.1. Additional analyses

It might be the case that CEOs with a higher research orientation steer their organization toward developing patents of a higher quality, emphasizing less the actual number of patents. To investigate this, we conducted additional analyses using alternative dependent variables that account for such quality: (1) the granted patent count and (2) a forward citation-weighted patent count (using a 2001 to 2010 sample). With these dependent variables, the moderation effect of CEO research orientation on the R&D-innovation relationship turns insignificant. CEOs with a low research orientation achieve higher R&D productivity (i.e., number of patents for each invested R&D dollar) as far as number of patents is concerned, but this productivity advantage disappears when accounting for the quality of the patents. The other results of these additional analyses are highly similar to the ones reported in the paper, which lends confidence to our main conclusions. We also ran a robustness test with respect to the operationalization of CEO research orientation and lag structure in our models. The results of these analyses are consistent with the reported findings in our main analyses.

Table 1. Descriptive statistics

|   | Mean | SD    | Min  | Median | Max    |
|---|------|-------|------|--------|--------|
| 1 | Innovation outcomes | 36.67 | 89.18 | 0.00   | 8.00   | 715.00 |
| 2 | R&D intensity      | 149.76| 160.67| 1.28   | 108.74 | 1967.55|
| 3 | CEO research orientation | 1.14 | 1.51  | 0.00   | 0.00   | 4.00   |
| 4 | Firm size\(^1\)    | 8,911.56| 22,798.33| 11.00   | 525.00 | 122,200.00 |
| 5 | Firm age           | 19.58 | 15.45 | 2.00   | 15.00  | 62.00  |
| 6 | Financial slack    | 5.22  | 5.71  | 0.49   | 3.57   | 64.14  |
| 7 | Financial performance | -0.10 | 0.29  | -3.17  | -0.02  | 0.76   |
| 8 | Institutional ownership | 29.31 | 18.61 | 0.00   | 28.93  | 92.38  |
| 9 | Board independence | 0.22  | 0.12  | 0.00   | 0.20   | 0.88   |
| 10| CEO tenure         | 8.05  | 7.10  | 0.00   | 5.81   | 36.02  |
| 11| Founder            | 0.31  | 0.46  | 0.00   | 0.00   | 1.00   |
| 12| CEO duality        | 0.58  | 0.49  | 0.00   | 1.00   | 1.00   |
| 13| CEO ownership      | 0.85  | 2.34  | 0.00   | 0.11   | 27.39  |
| 14| Insider            | 0.52  | 0.50  | 0.00   | 1.00   | 1.00   |
| 15| Presample patent stock | 194.18 | 487.20 | 0.00   | 20.79  | 3178.40|
| 16| Presample dummy    | 0.03  | 0.17  | 0.00   | 0.00   | 1.00   |

\(\text{\textsuperscript{711}}\) observations.  
\(\text{\textsuperscript{1}}\)Log transformed variable but original values reported here.
Table 2. Correlation matrix

|       | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | 13    | 14    | 15    |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1 Innovation outcomes |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 2 R&D intensity | -0.16 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 3 CEO research orientation | -0.11 | 0.23  |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 4 Firm size | 0.62  | -0.43 | -0.23 |       |       |       |       |       |       |       |       |       |       |       |       |
| 5 Firm age | 0.56  | -0.25 | -0.24 | 0.72  |       |       |       |       |       |       |       |       |       |       |       |
| 6 Financial slack | -0.14 | 0.22  | 0.22  | -0.33 | -0.28 |       |       |       |       |       |       |       |       |       |       |
| 7 Financial performance | 0.21  | -0.39 | -0.18 | 0.46  | 0.37  | -0.08 |       |       |       |       |       |       |       |       |       |
| 8 Institutional ownership | -0.38 | 0.23  | 0.27  | -0.46 | -0.46 | 0.13  | -0.25 |       |       |       |       |       |       |       |       |
| 9 Board independence | -0.04 | -0.09 | 0.05  | -0.10 | -0.14 | 0.10  | -0.02 | 0.11  |       |       |       |       |       |       |       |
| 10 CEO tenure | -0.10 | 0.00  | 0.16  | -0.07 | -0.04 | 0.10  | 0.01  | 0.05  | 0.03  |       |       |       |       |       |       |
| 11 Founder | -0.17 | 0.04  | 0.38  | -0.24 | -0.33 | 0.24  | -0.17 | 0.15  | 0.07  | 0.45  |       |       |       |       |       |
| 12 CEO duality | 0.25  | -0.21 | 0.00  | 0.39  | 0.27  | -0.10 | 0.17  | -0.26 | 0.07  | 0.19  | 0.11  |       |       |       |       |
| 13 CEO ownership | -0.11 | -0.10 | 0.02  | -0.16 | -0.13 | 0.05  | -0.03 | -0.06 | 0.13  | 0.31  | 0.33  | 0.02  |       |       |       |
| 14 Insider | 0.22  | -0.14 | -0.02 | 0.26  | 0.27  | -0.12 | 0.22  | -0.14 | -0.03 | -0.36 | -0.33 | 0.17  | -0.22 |       |       |
| 15 Presample patent stock | 0.83  | -0.15 | -0.13 | 0.64  | 0.68  | -0.17 | 0.22  | -0.37 | -0.04 | -0.16 | -0.20 | 0.21  | -0.12 | 0.25  |       |
| 16 Presample dummy | -0.07 | -0.04 | 0.01  | -0.09 | -0.13 | -0.06 | -0.05 | 0.18  | -0.09 | -0.07 | -0.11 | -0.06 | -0.04 | 0.10  | -0.07 |

Correlations <.07 are significant at \( P < .05 \) and those <.10 are significant at \( P < .01 \).
5. Discussion

For a long time, scholars have been interested in understanding why firms differ in their innovation performance (Ahuja et al., 2008). Whereas prior research has predominantly emphasized a firm’s capability to develop successful innovations, this study’s focus is on the role of a firm’s CEO as a key antecedent of variation in a firm’s innovation strategy and its innovation outcomes. We introduce the

Table 3. Results of when CEO research orientation affects innovation

| Dependent variable | Innovation outcomes |
|--------------------|---------------------|
| CEO research orientation | 0.16*** 0.04 0.09 0.26*** 0.02 |
| CEO RO*CEO duality | 0.16** (0.07) |
| CEO RO*Financial slack | 0.01*** (0.00) |
| CEO RO*Firm age | −0.00** (0.00) |
| Firm size | 0.48*** 0.51*** 0.52*** 0.52*** 0.51*** 0.52*** |
| Firm age | −0.02*** −0.02* −0.02* −0.02*** −0.01 −0.02* |
| Financial slack | 0.01* 0.01 0.01 −0.02* 0.01 −0.02*** |
| Financial performance | −0.10 −0.15 −0.16 −0.11 −0.14 −0.12 |
| Institutional ownership | 0.00 0.00 0.00 0.00 0.00 0.00 |
| CEO tenure | 0.00 0.00 0.00 −0.00 0.00 0.01 |
| Founder | 0.13 −0.15 −0.18 −0.19 −0.22 −0.27 |
| CEO duality | −0.02 −0.14 −0.32** −0.23*** −0.15 −0.46*** |
| CEO ownership | 0.01 0.01 0.00 −0.00 0.01 0.01 |
| Insider | −0.07 −0.12 −0.10 −0.21* −0.16 −0.20* |
| Board independence | −0.12 −0.15 −0.18 −0.30 −0.21 −0.35 |
| Presample patent stock | 0.00*** 0.00* 0.00 0.00* 0.00 0.00 |
| Presample dummy | −1.97*** −2.04*** −2.17*** −2.15*** −2.10*** −2.32*** |
| Lagged dependent variable (patents) | 0.01*** 0.01*** 0.01*** 0.01*** 0.01*** 0.01*** |
| Constant | −1.23** −1.42*** −1.05** −1.41*** −1.05** |
| Observations | 711 711 711 711 711 711 |
| QIC | 5178.4 5118.0 5105.9 5116.3 5119.1 5103.3 |
| Wald chi-square | 546.0*** 586.7*** 589.9*** 794.9*** 619.6*** 799.3*** |

Robust standard errors in parentheses. All models include SIC and time dummies. Significance levels of two-tailed tests:
*P < .10; **P < .05; ***P < .01.
Table 4. Results of how CEO research orientation affects innovation

| Dependent variable | R&D intensity | Innovation outcomes |
|--------------------|---------------|---------------------|
|                    | 7             | 8                   | 9      | 10     | 11      | 12     |
| CEO research orientation | 8.62** (4.27) | 0.16*** (0.05) | 0.03   | 0.00*** (0.08) | 0.25*** (0.05) | 0.00 *** (0.08) | 0.11 |
| R&D intensity       | 0.00*** (0.00) | 0.00*** (0.00) | 0.00*** (0.00) | 0.00*** (0.00) | 0.00*** (0.00) | 0.00*** (0.00) |
| CEO RO*CEO duality  | 0.18** (0.07) | 0.18*** (0.07) | 0.01  | 0.01*** (0.00) | 0.01*** (0.00) | 0.01*** (0.00) |
| CEO RO*Financial slack | 0.01*** (0.00) | 0.01*** (0.00) | 0.00 | 0.00 *** (0.00) | 0.00 *** (0.00) | 0.00 *** (0.00) |
| CEO RO*Firm age     | −0.00* (0.00) | −0.00 (0.00) | 0.00 | 0.00*** (0.00) | 0.00*** (0.00) | 0.00*** (0.00) |
| R&D intensity*CEO RO | −0.00*** (0.00) | −0.00*** (0.00) | −0.00 | −0.00*** (0.00) | −0.00*** (0.00) | −0.00*** (0.00) |
| Firm size           | −23.53*** (5.64) | −22.07*** (5.42) | 0.56*** (0.07) | 0.56*** (0.06) | 0.56*** (0.07) | 0.56*** (0.06) |
| Firm age            | 0.83 (0.54) | 0.83 (0.53) | −0.02*** (0.01) | −0.02* (0.01) | −0.01* (0.01) | −0.01* (0.01) |
| Financial slack     | 1.64*** (0.68) | 1.45*** (0.71) | 0.01 | −0.02** (0.01) | 0.01 | −0.02*** (0.01) |
| Financial performance | 29.72* (16.85) | 30.56* (16.86) | 0.00 | 0.00*** (0.13) | 0.00*** (0.14) | 0.00*** (0.13) |
| Institutional ownership | 0.44** (0.19) | 0.38** (0.19) | 0.00 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| CEO tenure          | −0.52 (0.86) | −0.58 (0.81) | 0.00 | 0.00 (0.01) | 0.00 (0.01) | 0.00 (0.01) |
| CEO founder         | 7.51 (11.03) | −3.55 (10.25) | −0.13 | −0.26 (0.16) | −0.07 (0.17) | −0.19 (0.14) |
| CEO duality         | −9.02 (9.66) | −10.29 (9.53) | −0.15 | −0.47*** (0.10) | −0.16 (0.12) | −0.45*** (0.09) |
| CEO ownership       | −1.54 (0.94) | −1.55 (0.97) | 0.01 | −0.01 (0.01) | 0.00 (0.01) | −0.01 (0.01) |
| Insider             | 6.88 (12.96) | 2.05 (12.33) | −0.14 | −0.22* (0.11) | −0.08 (0.13) | −0.16 (0.10) |
| Board independence  | −30.43 (30.69) | −29.32 (31.26) | −0.17 | −0.37 (0.38) | −0.23 (0.36) | −0.40 (0.37) |
| Presample patent stock | 0.02* (0.01) | 0.02 (0.01) | 0.00 | 0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) |
| Presample dummy     | −41.55* (23.50) | −43.61*** (19.04) | −1.93*** (0.38) | −2.21*** (0.39) | −1.80*** (0.37) | −2.09*** (0.37) |
| Lagged dependent variable (R&D) | 0.43*** (0.05) | 0.43*** (0.05) | 0.01*** (0.00) | 0.01*** (0.00) | 0.01*** (0.00) | 0.01*** (0.00) |
| Lagged dependent variable (patents) | 0.01*** (0.00) | 0.01*** (0.00) | 0.01*** (0.00) | 0.01*** (0.00) | 0.01*** (0.00) | 0.01*** (0.00) |
| Constant            | 133.59*** (39.10) | 126.83*** (36.57) | −1.68*** (0.54) | −1.31** (0.52) | −1.83*** (0.54) | −1.48*** (0.51) |
| Observations        | 711 | 711 | 711 | 711 | 711 | 711 |
| QIC                 | 5277543.5 | 5118918.3 | 5083.8 | 5073.8 | 5072.0 | 5061.6 |
| Wald chi-square     | 1698*** | 2119*** | 586.7*** | 812.7*** | 689.6*** | 966.3*** |

Robust standard errors in parentheses. All models include SIC and time dummies. Significance levels of two-tailed tests:
*P < .10; **P < .05; ***P < .01.
concept of CEO research orientation, which reflects CEOs’ ability and motivation for science and technology, to examine what CEO characteristics relate to firm heterogeneity in firms’ innovation outcomes. Using a longitudinal sample of U.S. pharmaceutical firms, we found that CEO research orientation is positively associated with firms’ innovation outcomes. Moreover, the extent to which CEO research orientation influences innovation outcomes increases when (1) the CEO is also the chair of the board and (2) slack resources are available to the firm. We also found that R&D intensity partially explains how research-oriented CEOs achieve higher levels of innovation: they invest more in R&D compared to CEOs with a low research orientation. This might indicate that CEOs with a low research orientation achieve higher R&D productivity based on the number of patents per R&D dollar but not when accounting for the quality of those patents.

These findings have several important implications on the upper echelons and innovation literature. First, we show that research-oriented CEOs are associated with higher innovation outcomes for firms. This insight contributes to the longstanding debate on whether and how much CEOs impact their firms’ outcomes (Hambrick and Mason, 1984; Quigley and Hambrick, 2015). There is growing evidence that CEOs are important to their firms’ adaptation to technological discontinuities (Eggers and Kaplan, 2009; Gerstner et al., 2013). We extend this line of research by highlighting that CEO human capital not only underlies the dynamic capabilities for organizational adaptation and strategic change (Helfat and Martin, 2015) but also initiates the ‘evolution of technology’ by directing the firm’s innovation development toward promising new research areas (Kaplan and Tripsas, 2008). Thus, some CEOs are more inclined to the development of new technologies and the creation of new products (Nadkarni and Chen, 2014), while others have a stronger orientation toward the commercialization of existing technologies and products.

Second, when CEOs influence innovation outcomes strongly depends on the organizational context. In this study, we found that a CEO’s structural power and a firm’s slack resources determine to what extent the CEO’s research orientation becomes reflected in innovation outcomes. By the integrating aspects of CEO characteristics and organizational context, we contribute to a more comprehensive understanding of CEO effects on firm performance (Busenbark et al., 2016; Liu et al., 2018). We show that CEOs’ unique characteristics, notably their research orientation, might not be enough on their own to stimulate innovation; CEOs may also need power and resources to influence firm strategy and outcomes. Given sufficient managerial discretion (Hambrick and Finkelstein, 1987), research-oriented CEOs may shape R&D resource-allocation processes and support organizational processes that steer their firms toward groundbreaking research and technology development.

Figure 1. Moderation impact of CEO duality on the marginal effect of CEO research orientation on innovation.

Figure 2. Moderation impact of financial slack on the marginal effect of CEO research orientation on innovation.

Figure 3. Moderation impact of CEO research orientation on the marginal effect of R&D intensity on innovation.
Third, this study also contributes to the literature by shedding more light on a hitherto key source of unobserved heterogeneity that affects a firm’s innovation capabilities. We show that a CEO constitutes through his or her research orientation, a key antecedent of variation in a firm’s innovation-strategy choices and its attendant performance consequences. Whereas the dominant emphasis in the literature has been on the ability to innovate (Ahuja and Lampert, 2001), this study’s focus on the role of a CEO’s research orientation is also indicative of the firm’s motivation to innovate (Ahuja et al., 2008). In this way, the findings suggest that firms also differ in their motivation to pursue innovation because some CEOs are more research oriented and allocate more resources to R&D in comparison to their counterparts at other firms.

However, there are also potential downsides to highly research-oriented CEOs. This insight comes from the surprising finding of a negative moderation effect of CEO research orientation on the R&D-innovation relationship. In this respect, a research-oriented CEO may be less effective in the implementation of substantial R&D investments which could be the result of micromanagement by the CEO, which stifles innovation, or of inexperience due to a CEO’s substantial technical training and experience having come at the cost of that CEO having less developed managerial skills. As a result, a research-oriented CEO might over-invest in R&D, despite increases in innovation outcomes, only to position himself or herself as the inventor of a new technology or because of personal interests. However, the productivity differences in R&D investments related to a CEO’s research orientation seem to disappear when accounting for the quality of patent applications. Gaining more insight into this pattern of findings constitutes an interesting avenue for further research.

5.1. Managerial implications

This study also has important managerial implications. For CEOs and executive teams, our results confirm the idea that top managers may enable innovation and influence firm performance, through R&D investments. Furthermore, the results presented in this paper may help to identify CEOs who are most likely to focus on innovation as well as create the conditions under which they operate best. More specifically, executives with a technical background are more likely to spur innovation, especially when the organizational context increases their managerial discretion and provides them with slack resources.

Our findings are important to supervisory boards, as agents that safeguard shareholder value, and therefore hire and fire executive team members (incl. the CEO). Assigning a research oriented CEO in combination with allowing for an innovation friendly context may serve long-term shareholder value through innovation. Also, firms facing times of discontinuities, that require exploration and adaptation, might benefit from a research oriented CEO as an enabler of innovation (Walrave et al., 2017). Such a strategy, however, requires strong boards, which can withstand the substantial short-term pressure for results generated by some (large) investors.

Board directors should, of course, remain cautious about the possibility of CEOs aiming for technological success over commercial success. In this respect, our findings suggest that a research oriented CEO should ideally be linked to an executive (e.g., Chief Operational Officer) with strong organizational and implementation skills. This idea resonates with the organizational structure of SpaceX where Elon Musk, as visionary and research oriented CEO, is linked to Gwynne Shotwell – president and COO at SpaceX – who is tasked with the execution of such ideas.

Finally, these findings are also relevant to investors as CEO characteristics, in relation to organizational context, may serve as an important indicator for innovation and thereby long-term firm performance. Especially for investors active in the pharmaceutical industry, our results allow for better informed (long-term) investment portfolio choices.

5.2. Limitations and future research

This study has a number of limitations, which provide directions for future research. First, although this study’s findings may be generalizable to other R&D-intensive industries such as semiconductors and chemicals, future research should examine whether our proposed theory is transferable to other industries. The strategic process of increasing firms’ innovation outcomes through R&D investments might even be stronger in other industries, compared to the weak mediation effect we found, because R&D investment intensity is ‘the norm’ for research-based firms in the pharmaceutical industry. Second, although this is one of the first studies that explicitly tests for a potential mediating mechanism that links CEO characteristics to firms’ innovation outcomes, we only focused on one underlying mechanism and, therefore, could only partially open the black box of this relationship. The finding of a weak partial mediation effect suggests the plausibility of additional mechanisms that could be examined and tested.
empirically. Third, while we controlled for potential endogeneity in all ways available to us, it remains a central issue to upper echelons studies in general. We avoided problems with the causality of the studied relationship by incorporating different lag structures that ensure that our antecedent variables temporally precede the dependent variable, by constructing the CEO research orientation variable based on pre-CEO appointment experiences only, by including rich and fine-grained control variables, and by adding a pre-sample patent-stock control variable. Moreover, the theoretical mechanisms introduced and tested by the complex interaction effect are difficult to explain by reverse causality logic. Thus, the statistical techniques employed here confirm the hypothesis that the degree of CEO research orientation is positively associated with innovation. A further limitation arises from the sample size. While our sample size is perhaps small in the absolute sense, it does represent a substantial part of the U.S. research-based pharmaceutical companies over the studied period. In this respect, our sample size approaches the population size for this particular industry. This approach follows recent work studying the same industrial context (e.g., Gerstner et al., 2013). Moreover, the coefficients of our controls resonate strongly with previous work on this sector (Caner et al., 2017), further increasing our confidence in both analyses and results. Future research may gather data from a different industry with a larger population (or combine data from several industries) to replicate and further uncover the influence of CEO research orientation on innovation and firm performance.

References

Ahuja, G. and Lampert, C.M. (2001) Entrepreneurship in the large corporation: a longitudinal study of how established firms create breakthrough inventions. Strategic Management Journal, 22, 6–7, 521–543.

Ahuja, G., Lampert, C.M., and Tandon, V. (2008) Moving beyond Schumpeter: management research on the determinants of technological innovation. Academy of Management Annals, 2, 1–98.

Balsmeier, B. and Buchwald, A. (2014) Who promotes more innovations? Inside versus outside hired CEOs. Industrial and Corporate Change, 24, 5, 1013–1045.

Barker, V. and Mueller, G. (2002) CEO characteristics and firm R&D spending. Management Science, 48, 6, 782–801.

Baron, R.M. and Kenny, D.A. (1986) The moderator-mediator variable distinction in social the moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology, 51, 6, 1173–1182.

Baysinger, B.D., Kosnik, R.D., and Turk, T.A. (1991) Effects of board and ownership structure on corporate R&D strategy. Academy of Management Journal, 34, 1, 205–214.

Beal, R. and Yasai-Ardekani, M. (2000) Performance implications of aligning CEO functional experiences with competitive strategies. Journal of Management, 26, 4, 733–762.

Beckman, C.M. (2006) The influence of founding team company affiliations on firm behavior. Academy of Management Journal, 49, 4, 741–758.

Beckman, C.M. and Burton, M.D. (2008) Founding the future: Path dependence in the evolution of top management teams from founding to IPO. Organization Science, 19, 1, 3–24.

Berson, Y., Oreg, S., and Dvir, T. (2008) CEO values, organizational culture and firm outcomes. Journal of Organizational Behavior, 29, 5, 615–633.

Bromiley, P. and Rau, D. (2016) Social, behavioral, and cognitive influences on upper echelons during strategy process: a literature review. Journal of Management, 42, 1, 174–202.

Brown, S. and Eisenhardt, K. (1997) The art of continuous change: linking complexity theory and time-paced evolution in relentlessly shifting organizations. Administrative Science Quarterly, 42, 1, 1–34.

Burgelman, R.A., Floyd, S.W., Laamanen, T., Mantere, S., Vaara, E., and Whittington, R. (2018) Strategy processes and practices: dialogues and intersections. Strategic Management Journal, 39, 3, 531–558.

Busenbark, J.R., Krause, R., Boivie, S., and Graffin, S.D. (2016) Toward a configurational perspective on the CEO: a review and synthesis of the management literature. Journal of Management, 42, 1, 234–268.

Caner, T., Cohen, S.K., and Pil, F. (2017) Firm heterogeneity in complex problem solving: a knowledge-based look at invention. Strategic Management Journal, 38, 1791–1811.

Carpenter, M.A., Geletkanz, M.A., and Sanders, W.G. (2004) Upper echelons research revisited: antecedents, elements, and consequences of top management team composition. Journal of Management, 30, 6, 749–778.

Chen, W. (2008) Determinants of firms’ backward- and forward-looking R&D search behavior. Organization Science, 19(4), 609–622.

Chin, M.K., Hambrick, D.C., and Trevino, L.K. (2013) Political ideologies of CEOs: the influence of executives’ values on corporate social responsibility. Administrative Science Quarterly, 58, 2, 197–232.

Crossland, C., Zvyung, J., Hiller, N.J., and Hambrick, D.C. (2014) CEO career variety: effects on firm-level strategic and social novelty. Academy of Management Journal, 57, 3, 652–674.

Cui, J. and Qian, G. (2007) Selection of working correlation structure and best model in GEE analyses of longitudinal data. Communications in Statistics – Simulation and Computation, 36, 5, 987–996.

Cummins, T. and Knott, A.M. (2018) Outside CEOs and innovation. Strategic Management Journal, 39, 8, 1–25.
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Custódio, C., Ferreira, M., and Matos, P. (2017) Do general managerial skills spur innovation? Management Science, 65, 2, 1–18.

Cyert, R. and March, J. (1963) A Behavioral Theory of the Firm. NJ, Prentice-Hall: Englewood Cliffs.

Eggers, J.P. and Kaplan, S. (2009) Cognition and renewal: comparing CEO and organizational effects on incumbent adaptation to technical change. Organization Science, 20, 2, 461–477.

Elenkov, D.S. and Manev, I.M. (2005) Top management leadership and influence on innovation: the role of sociocultural context. Journal of Management, 31, 3, 381–402.

Felix, B. and Bistrova, J. (2015) Many CEOs aren’t breakthrough innovators (and that’s OK). Harvard Business Review. Available at https://hbr.org/2015/09/many-ceos-aren’t-breakthrough-innovators-and-thats-ok/.

Finkelstein, S., Hambrick, D.C., and Cannella, A.A. (2009) Strategic Leadership: Theory and Research on Executives. Top Management Teams, and Boards. New York, NY: Oxford University Press.

Fleming, L. (2001) Recombinant uncertainty in technological search. Management Science, 47, 1, 117–132.

Gerstner, W.-C., Konig, A., Enders, A., and Hambrick, D.C. (2013) CEO narcissism, audience engagement, and organizational adoption of technological discontinuities. Administrative Science Quarterly, 58, 2, 257–291.

Giberson, T.R., Resick, C.J., Dickson, M.W., Mitchelson, J.K., Randall, K.R., and Clark, M.A. (2009) Leadership and organizational culture: linking CEO characteristics to cultural values. Journal of Business and Psychology, 24, 2, 123–137.

Grigoriou, K. and Rothaermel, F.T. (2014) Structural microfoundations of innovation: the role of relational stars. Journal of Management, 40, 4, 586–615.

Griliches, Z. (1990) Patent statistics as economic indicators: a survey. Journal of Economic Literature, 28, 4, 1661–1707.

Hagedoorn, J. and Cloodt, M. (2003) Measuring innovative performance: is there an advantage in using multiple indicators? Research Policy, 32, 2, 1365–1379.

Hambrick, D.C. (2007) Upper echelons theory: an update. Academy of Management Review, 32, 2, 334–343.

Hambrick, D.C. and Finkelstein, S. (1987) Managerial discretion: a bridge between polar views of organizational outcomes. Research in Organizational Behavior, 9, 369–406.

Hambrick, D.C. and Mason, P.A. (1984) Upper echelons: the organization as a reflection of its top managers. Academy of Management Review, 9, 2, 193–206.

Hannan, M.T. and Freeman, J. (1984) Structural inertia and organizational change. American Sociological Review, 49, 2, 149–164.

Helfat, C.E. and Martin, J.A. (2015) Dynamic managerial capabilities: review and assessment of managerial impact on strategic change. Journal of Management, 41, 5, 1281–1312.

Henderson, R.M. and Cockburn, I. (1994) Measuring competence? Exploring firm effects in pharmaceutical research. Strategic Management Journal, 15, 63–84.

Jensen, M.C. and Meckling, W.H. (1976) Theory of the firm: managerial behavior, agency costs and ownership structure. Journal of Financial Economics, 3, 4, 305–360.

Judge, T.A., Cable, D.M., Boudreau, J.W., and Bretz, R.D. (1995) An empirical-investigation of the predictors of executive career success. Personnel Psychology, 48, 3, 485–519.

Kaplan, S. and Tripsas, M. (2008) Thinking about technology: applying a cognitive lens to technical change. Research Policy, 37, 5, 790–805.

Kapoor, R. and Kluter, T. (2015) Decoding the adaptability-rigidity puzzle: evidence from pharmaceutical incumbents’ pursuit of gene therapy and monoclonal antibodies. Academy of Management Journal, 58, 4, 1180–1207.

Katila, R., Thatchenkery, S., Christensen, M., and Zenios, S. (2017) Is there a doctor in the house? Expert product users, organizational roles, and innovation. Academy of Management Journal, 21, 1, 1–52.

Kor, Y.Y. (2006) Direct and interaction effects of top management team and board compositions on R&D investment strategy. Strategic Management Journal, 27, 11, 1081–1099.

Krause, R., Semadeni, M. and Cannella, A.A. (2014) CEO duality: a review and research agenda. Journal of Management, 40, 1, 256–286.

Liang, K.-Y. and Zeger, S. (1986) Longitudinal data analysis using generalized linear models. Biometrika, 73, 13–22.

Liu, D., Fisher, G. and Chen, G. (2018) CEO attributes and firm performance: a sequential mediation process model. Academy of Management Annals, 12, 2, 789–816.

Nadkarni, S. and Chen, J. (2014) Bridging yesterday, today, and tomorrow: CEO temporal focus, environmental dynamism, and rate of new product introduction. Academy of Management Journal, 57, 6, 1810–1833.

Nohria, N. and Gulati, R. (1996) Is slack good or bad for innovation? Academy of Management Journal, 39, 5, 1245–1264.

O’Reilly, C.A. III, Caldwell, D.F., Chatman, J.A., and Doerr, B. (2014) The promise and problems of organizational culture: CEO personality, culture, and firm performance. Group & Organization Management, 39, 6, 595–625.

Pan, Y. (2015) The determinants and impact of executive-firm matches. Management Science, 63(1), 185–200.

Quigley, T.J. and Hambrick, D.C. (2015) Has the “CEO effect” increased in recent decades? A new explanation for the great rise in America’s attention to corporate leaders. Strategic Management Journal, 36, 812–830.

Roberts, P.W. (1999) Product innovation, product-market competition and persistent profitability in the U.S. pharmaceutical industry. Strategic Management Journal, 20, 7, 655–670.

Scannell, J.W., Blanckley, A., Boldon, H., and Warrington, B. (2012) Diagnosing the decline in pharmaceutical R&D efficiency. Nature reviews Drug discovery, 11(3), 191–200.
Simsek, Z., Jansen, J.P., Minichilli, A., and Escriba-Esteve, A. (2015) Strategic leadership and leaders in entrepreneurial contexts: a nexus for innovation and impact missed? *Journal of Management Studies*, 52, 4, 463–478.

Sorensen, J.B. and Stuart, T.E. (2000) Aging, obsolescence, and organizational innovation. *Administrative Science Quarterly*, 45, 1, 81–112.

Sullivan, S.E. and Baruch, Y. (2009) Advances in career theory and research: a critical review and agenda for future exploration. *Journal of Management*, 35, 6, 1542–1571.

Talke, K., Salomo, S., and Rost, K. (2010) How top management team diversity affects innovativeness and performance via the strategic choice to focus on innovation fields. *Research Policy*, 39, 7, 907–918.

Walrave, B., van Oorschot, K.E. and Romme, A.G.L. (2011) Getting trapped in the suppression of exploration: a simulation model. *Journal of Management Studies*, 48, 8, 1727–1751.

Walrave, B., van Oorschot, K.E. and Romme, A.G.L. (2014) How to counteract the suppression of exploration in publicly traded corporations. *R&D Management*, 45, 5, 1–18.

Walrave, B., Romme, A.G.L., van Oorschot, K.E., and Langerak, F. (2017) Managerial attention to exploitation and exploration: toward a dynamic perspective on ambidexterity. *Industrial and Corporate Change*, 26, 6, 1145–1160.

Wu, S., Levitas, E., and Priem, R.R.L. (2005) CEO tenure and company invention under differing levels of technological dynamism. *Academy of Management Journal*, 48, 5, 859–873.

Zucker, L.G., Darby, M.R., and Brewer, M.B. (1998) Intellectual human capital and the birth of U.S. biotechnology enterprises. *American Economic Review*, 88, 1, 290–306.

**Note**

1. Given that we collected the patent data at the beginning of 2016, we used a sample that covers the years 2001 to 2010 to correct for the two years that elapse on average between the patent application date and the grant date and to allow for a five-year lag period between patent activity and other observations in order to reduce truncation bias in relation to patent citations (Fleming, 2001).

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