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Does managerial ability facilitate corporate innovative success?☆

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ABSTRACT

This paper examines whether managerial ability facilitates corporate innovative success. First, we show that managerial ability is positively associated with innovative output. Second, we show that the positive association between managerial ability and innovative output is weaker for older CEOs and managers who stay in the same job for longer, suggesting a preference for a 'quiet life' by long serving CEOs. Third, we find that the equity market values patents generated by more able managers more positively, suggesting that equity holders deem better skilled managers more effective at converting innovative ideas into valuable new products. Finally, we show that managerial ability is positively associated with more 'radical' innovations, which are outside of the firm's knowledge base. Overall, our results suggest that managerial ability is an essential component of corporate innovative success.

I think that [executive salaries are] problematic because they're giving entrepreneurial returns for managerial conduct. They are basically running an organization that already exists, that probably will exist long after they've departed. And so to compensate them with entrepreneurial style returns without having them take entrepreneurial style risks is inappropriate.

Charles Elson, Business Ethics (August 2, 2006)

1. Introduction

The compensation of executives has long been a topic of great public attention. As the above quote by Charles Elson suggests, many in the profession perceive managerial remuneration to be unjustifiably high. In light of the ever increasing executive compensation

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packages (Murphy and Zabojnik, 2004), one has to question whether managers are indeed mere rent extracting agents or whether their salaries are justified by their superior skill which adds value to the firm. Assuming that managerial skill is necessary for the long-term success of a corporation, paying high salaries to attract the most skilled managers is justified. Otherwise, if Charles Elson is indeed correct in asserting that executives merely manage what has already been established and therefore great skill is not required of them, high executive salaries represent rents at the expense of shareholders. Although there is some evidence showing that managerial ability improves certain aspects of corporate activity, the relevance of managerial skill for corporate success remains largely unresolved.[3]

We contribute to this literature by being the first to examine the role that managerial ability plays in corporate innovative success. Since corporate innovation is one of the most important drivers of organizational long-term success (Holmstrom, 1989), the absence of research on how managerial ability affects innovation outcomes is a material oversight.[4] Our paper makes the first major attempt to fill this void in the literature.

There are two competing views on how managerial ability affects corporate innovation. The first view is that managerial ability has little or no effect on corporate innovative success. After all, innovation outcomes are highly uncertain and idiosyncratic in nature (Holmstrom, 1989), with even the best managers unable to predict which investments will eventually lead to commercially successful products and which will not. Innovation, therefore, has lottery-type features, with luck being potentially more important than skill (Chen et al., 2014). It is this feature of innovation that can discourage rational managers from investing in innovation (Hirshleifer et al., 2012). It is therefore possible that firm specific factors such as institutional ownership (Aghion et al., 2013), product market competition (Aghion et al., 2005), or analyst coverage (He and Tian, 2013), rather than managerial-level ability that are the key determinants of corporate innovative success.

A competing view is that managerial ability is essential to the innovative process. There are a number of reasons which support this view. First, more able managers are likely to be better trusted by shareholders and other stakeholders (Baik et al., 2011; Demerjian et al., 2013). As a consequence, able managers are less likely to be discouraged from investing in risky innovation projects within the Narayanan (1985) career concerns context, since they can signal their superior skill through other non-innovation related decisions. Furthermore, higher trust will also result in lower financing costs, which will make investments in innovation easier. Second, more able managers can influence innovative outcomes by creating the most optimal framework for research staff to maximize their creative potential. Prior literature has shown that employee compensation (Chang et al., 2015) and employee treatment (Chen et al., 2015) are key factors affecting innovative success. It is therefore possible that even though top executives have little influence over innovative outcomes per se, they play an essential role in creating an environment which extracts the most value from the firm's human capital.

We test these two competing views utilizing a large sample of 42,754 firm-year observations spanning the period 1993–2006. We use the Demerjian et al. (2012) proxy of managerial ability and perform robustness checks using Chief Executive Officer (CEO) awards and media citations. The Demerjian et al. (2012) measure of managerial ability is based on the efficiency with which managers convert resource inputs into outputs. Their approach first estimates total firm efficiency, where efficient firms are those that generate more revenues from a given set of inputs. They then partition firm efficiency between firm and manager, and verify that the component attributed to the manager is associated with the price reaction to management departures. We measure innovative output as the number of patents and patent citations generated by firms. This approach is consistent with the recent literature on corporate innovation (Aghion et al., 2013; Fang et al., 2014; He and Tian, 2013; Hirshleifer et al., 2012).

Our baseline results show a positive association between managerial ability and innovative output. These results are obtained after controlling for R&D capital, standard firm-level factors, as well as industry and year fixed effects. This positive association is robust to alternate measures of managerial ability, varying sample sizes, and model specifications. In addition, the baseline results are not sensitive to the inclusion of addition control variables which take account of CEO-specific characteristics, corporate governance, local–cultural values pertaining to gambling-preferences and risk-taking, as well as M&A activity. Overall, our main results show that managerial ability is an important factor contributing to enhanced corporate innovative success.

In additional tests, we find that the positive association between managerial ability and corporate innovative output diminishes with CEO age and tenure. This observation is consistent with the "quiet life" hypothesis of Bertrand and Mullainathan (2003), which states that managers have an incentive to pursue a course of action which leads to the fewest problems. Clearly, while managerial ability is important to corporate innovative success, longer-serving CEOs are less inclined to use their superior skill to pursue difficult and risky innovative projects.

Our empirical tests also show that the market's valuation of a firm's patents is higher when an able manager is at the helm. This result suggests that the market perceives skillful managers as being more effective in converting patented ideas into commercially successful products. Finally, in the last set of tests on the association between managerial ability and patenting strategies, we find that managerial ability is positively associated with patents which are unrelated to firm's existing knowledge base. This observation suggests that managerial skill is not only related to a higher volume of patent generation, but that the patents which are generated by firms with able managers at the helm tend to be more unique in nature, which gives the firm a greater edge over its competitors. Overall, our results show that managerial skill is an important factor in determining a company's innovative success.

Our paper makes two major contributions to the managerial ability literature. Our first contribution is to the literature on the effect that managerial ability has on corporate decision making. There are a number of theoretical models which show the relevance of

[3] Baik et al. (2011) document that managerial ability is related to earnings forecasts, Demerjian et al. (2013) show that managerial ability improves earnings quality, and Attig and Cleary (2014) examine the relation between managerial ability and cash-flow sensitivity of investment.

[4] A recent study by Accenture, titled "Innovation Efforts Falling Short Despite Increased Investment" shows that 93% of CEOs believe that the long-term success of their organization depends on their ability to innovate.

managerial ability towards achieving corporate success. For example, Murphy and Zabojnik (2004) show that the expertise required of managers is evolving over time which justified the increase in managerial remuneration (in real terms) over the previous three decades. Berk and Stanton (2007) demonstrate that managerial skill is essential in determining the close-end fund discount, while Holcomb et al. (2009) demonstrate the importance of managerial ability in value creation through better utilization of resources. The empirical literature on this question is much more sparse and narrowly focused, largely limited to earnings forecasting (Baik et al., 2011), earnings quality (Demerjian et al., 2012), and the cash-flow sensitivity of investment (Attig and Cleary, 2014). We make a significant contribution to this literature by being the first to examine the role of managerial ability on corporate innovation. Given the significant role of innovation in corporate success, our analysis paints a broader picture about the role of managerial ability in driving organizational success.

Our second contribution is to the literature on the drivers of corporate innovation. A growing body of empirical literature has recently emerged on the factors which drive innovative output. For example, innovation outcomes have been shown to be related to managerial behavioral biases (Galasso and Simcoe, 2011; Hirshleifer et al., 2012), investor loss aversion (Tian and Wang, 2014), the gambling preferences surrounding corporate headquarters (Chen et al., 2014), institutional ownership (Aghion et al., 2013), product market competition (Aghion et al., 2005), and analyst coverage (He and Tian, 2013). Our paper is most closely related to Galasso and Simcoe (2011) and Hirshleifer et al. (2012) in that they also look at the role of the CEO in the innovation process. However, while these two studies consider the role of an irrational behavioral trait, we concentrate on the role of ability in the corporate innovative process.

2. Theory and hypotheses

The role of top executives in corporate management is generally explored within the agency theory framework. Agency theory (Jensen and Meckling, 1976) focuses on control issues resulting from conflicts of interest between shareholders and managers and conceptualizes controls in the form of optimal contracts designed to correct these conflicts. In the context of corporate innovation, agency theory argues that top executives have an incentive to forgo risky and uncertain innovation projects in favor of projects which yield immediate gain (Beatty and Zajac, 1994; Fong, 2010; Manso, 2011; Tosi and Gomez-Mejia, 1989). Indeed, one of the more seminal works on this issue by Narayanan (1985), demonstrates that rational managers concerned about their career prospects have an incentive to forgo innovative projects, which have highly uncertain outcomes and are hard for external investors to ascertain their viability. Instead, these managers are in favor of short term projects which send positive signals to outside investors about their ability much quicker. Consistent with this view, Ederer and Manso (2013) show that standard pay-for-performance contracts stifle innovation. In fact, Manso (2011) shows that given the existence of agency conflicts between managers and shareholders, as well as the unique characteristics of innovation projects, incentive programs which aim to promote innovation must be based on tolerance of early failure and reward on long-term success (stock options with long vesting periods).

Although existing research shows that managerial incentive contracts play an important role in driving the level of corporate innovation, concentrating exclusively on managerial incentive schemes assumes managerial homogeneity and ignores any differences in managerial quality. After all, incentive contracts indirectly affect firm performance by altering managerial behavior (Devers et al., 2007), but have no effect on altering the managers' ability. The central question explored in this paper, namely whether managerial ability is a relevant factor in determining a firm's level of corporate innovative success, is not addressed within the agency conflict framework.

Although existing theory does not provide us with an unambiguous *ex-ante* expectation of the role that managerial ability plays in corporate innovation, there are two competing views which can be formed by the existing body of relevant literature. The first view is based on an emerging literature which highlights the important role of rank-and-file employees in driving innovative output. This literature shows that the main determinant of a firm's innovative output is not the strategic decisions made by top executives, but rather how productive rank-and-file employees are. For example, Chang et al. (2015) show that non-executive incentive schemes in the form of stock option grants significantly increase the number of patents and patent citations generated by the firm. Furthermore, Chen et al. (2014) show that the social norms surrounding corporate headquarters, to which firm employees are exposed, plays a more significant effect on corporate innovation compared with behavioral biases of top executives. Likewise, Chen et al. (2015) show that employee treatment schemes improve the number and significance of innovative inventions as well as the stock market's valuation of these inventions. Coupled with studies on the firm-specific drivers of corporate innovation (Aghion et al., 2005, 2013; He and Tian, 2013), these papers suggest that managerial ability is spurious toward corporate innovative success.

In contrast, the second view is based on an emerging literature which documents that managerial ability is associated with greater firm transparency. For example, Baik et al. (2011) show that more able managers are better at forecasting future earnings, while Demerjian et al. (2013) find that the financial reports of more able managers are less likely to be manipulated. As a consequence of higher transparency, firms with more able managers should have lower financing costs, which should be conductive towards investment in innovation. Furthermore, a more able manager is expected to better understand the underlying factors which derive the greatest returns from the firm's resources. In the context of corporate innovation, the main resource input are highly skilled employees which account for over 50% of R&D expenditure (Hall, 2002). As a result, better skilled managers are expected to put in place effective employee schemes which ensure that research oriented employees maximize their true potential.

The above discussion shows that the existing theoretical and empirical literature does not offer a coherent view on how managerial ability affects corporate innovation, with this remaining an empirical question. Based on our preceding discussion, we formulate two alternate hypotheses, which we test in this paper:

Managerial irrelevance hypothesis: Managerial ability is unrelated to corporate innovative output.

Managerial significance hypothesis: Managerial ability promotes higher levels of corporate innovative output.

3. Data, methodology and summary statistics

The sample used in our empirical analysis is at the intersection of the National Bureau of Economic Research (NBER) Patent database, Compustat database, and Execucomp database. To avoid sample selection problems, we include all firms in the Compustat database which are in the same 2-digit Standard Industrial Classification (SIC) code industry as the firms listed in the NBER patent database.[5] Innovation output is measured using patent data obtained from the NBER patent database. Firm-level accounting data is obtained from Compustat. A number of our empirical tests employ CEO specific information obtained from ExecuComp.

After merging the relevant datasets, our final sample consists of 42,754 firm-year observations between 1993 and 2006. The 2006 cut off year is predicated upon data availability; with NBER currently not providing patent data for the post-2006 period.

3.1. Measuring managerial ability

We utilize the measure of managerial ability (*MA score*) developed by Demerjian et al. (2012).[6] This measure has been extensively used in accounting research (Baik et al., 2011; Demerjian et al., 2012), finance research (Albuquerque et al., 2013), and management research (Attig and Cleary, 2014). The Demerjian et al. (2012) proxy of managerial ability is based on the notion that higher quality managers do a better job of converting firms' resources—such as capital, labor, and other assets—to generate revenue. They use data envelopment analysis (DEA) to estimate firm efficiency within industries, comparing the sales generated by each firm, conditional on the resource inputs used by the firm. The firm efficiency measure generated using the DEA methodology is attributable to both the firm and manager. The firm specific component of the DEA efficiency measure is separated from the manager specific component by running a Tobit regression model by industry which controls for firm specific factors such as size, free cash flow, competition, and age. The residual from their Tobit model is the management ability score.

In addition to the Demerjian et al. (2012) measure, we also employ two other measures of managerial ability following Milbourn (2003), Rajgopal et al. (2006), Francis et al. (2008), and Baik et al. (2011). The first of these two measures is an indicator variable equal to one if the CEO is recognized as one of the “top” CEOs in calendar year *t*. Several business publications develop such annual lists, including *Worth's* list of the “Best CEOs”, the *Financial Times* list of the “World's Most Respected Business Leaders”, *Fortune's* list of the “World's Most Popular Women in Business”, and *Time's* list of “The Times/CNN 25 Most Influential CEOs”. The second alternative measure of managerial ability is media citations. The intuition behind using media citations as a proxy of managerial ability is that CEOs who are perceived to be experts are more likely to be interviewed. Thus, the press-based measure of managerial ability reflects the market's assessment of a CEO's perceived ability. We obtain the data of the two measures from Baik et al. (2011). We use the Demerjian et al. (2012) measure of managerial ability in our baseline tests, and the two additional measures as robustness checks to validate the main findings.

3.2. Measuring innovative activity

Consistent with the extant literature on corporate innovation (Aghion et al., 2013; Chen et al., 2014; He and Tian, 2013; Hirshleifer et al., 2012; Tian and Wang, 2014), we rely on patenting data from the NBER patent database to measure innovative output. We use the 2006 edition of the NBER patent database (Hall et al., 2001), which covers over 3.2 million patent grants and 23.6 million patent citations from 1976 to 2006. The database contains information about patent assignee names and their Compustat-matched identifiers, the number of citations received by each patent, the technology class of the patents, and similar details. Patents are included in the database only if they are eventually granted. We utilize this data to construct our first measure of innovative activity as the number of patents applied for (and subsequently granted) in a given year *t* by firm *i*.

While the number of patents a firm applies for in a given year is a sound measure of the firm's innovative activity, patents on their own do not measure the significance of new inventions. As a result, patents which are relatively insignificant are weighted the same as those which are revolutionary in nature. For this reason, as a second measure of innovative output, we utilize citations-per-patent. The idea behind the second proxy of innovative output is that more significant and revolutionary patents will be cited more frequently compared with the more trivial patents. However, owing to the finite length of the sample, citations suffer from a truncation bias. Because citations are received for many years after a patent is created, patents created in later years have less time to accumulate citations than patents created in earlier years. To address this issue, we adjust the patent citation count of each patent using the weighting index from Hall et al. (2001), which is provided in the NBER patent database. The weighting index is created using a quasi-structural approach where the shape of the citation-lag distribution is econometrically estimated. We set firms with missing innovation data as having zero patents and citations and use the natural log of one plus the two innovative measures in the regression.

3.3. Firm-level variables

We collect a number of standard firm level variables which have been shown to affect innovative activity. Specifically, Hall and Ziedonis (2001) find that firm size and capital intensity are key determinants of innovative activity. Firm size is defined as the natural logarithm of sales, while capital intensity is measured as the natural logarithm of the ratio of net property, plant, and equipment over

[5] This approach is standard across finance and economics studies employing the NBER Patent database (Aghion et al., 2005, 2013; Chen et al., 2014; He and Tian, 2013; Hirshleifer et al., 2012).

[6] We obtain the managerial ability data from Sarah McVay's webpage (URL: http://faculty.washington.edu/smcvay/abilitydata.html).

the number of employees. Consistent with the extant literature on corporate innovation (Chang et al., 2015; He and Tian, 2013; Hirshleifer et al., 2012), we also collect data on return on assets (ROA), book leverage, cash holdings, sales growth, and Tobin's Q. ROA is the ratio of operating income over book assets. Book leverage is the ratio of total debt over book assets. Cash holdings are measured as cash and assets readily convertible to cash scaled by book assets. Sales growth is the annual sales growth rate. Tobin's Q is the ratio of market assets over book assets.

We also collect data on some additional firm level variables, which the literature has shown to be relevant for corporate innovation. The first is product market competition as measured by the Lerner index. Leading industrial organization models of product market competition and innovation predict that more intense product market competition reduces posterity rents and therefore reduces the level of innovation in the market (Dixit and Stiglitz, 1977; Salop, 1977). Aghion et al. (2005), in turn, report an inverted U-shaped relation between product market competition and innovation. Following prior research in the industrial organizations literature (Domowitz et al., 1986; Lindenberg and Ross, 1981) as well as Aghion et al. (2005), we construct a product market pricing power measure based on the Lerner index which is also referred to as the price-cost margin scaled by sales.

Consistent with Aghion et al. (2013) who find that institutional ownership is related to R&D spending and research output, we also collect data on institutional ownership. Institutional ownership data are based on quarterly common stock holdings of 13 (f) institutions. Institutional ownership is the number of shares held by institutions divided by the total shares outstanding.

We also collect data on analyst coverage as He and Tian (2013) find that firms covered by a larger number of analysts generate fewer patents with lower impact. The data on analyst coverage come from the Institutional Brokers' Estimate System (I/B/E/S) Historical Summary File, and are available on a monthly basis beginning in 1976. For each firm-year observation, analyst coverage is set equal to the average number of I/B/E/S analysts who provide earnings estimates over the four quarters of each calendar year. We set firms with missing analyst coverage data as having zero analysts and use the natural log of one plus the number of analysts in the regression.

3.4. CEO characteristics

In some of our empirical tests, we either control for CEO specific characteristics or interact the managerial ability variable with CEO-level variables. These variables include CEO overconfidence, age, tenure, and incentive variables including equity compensation delta and vega. To identify overconfidence, Malmendier and Tate (2008) exploit the overexposure of CEOs to the idiosyncratic risk of their firms through their holdings of stock options. Following Malmendier and Tate (2008), we define a CEO as overconfident once he postpones the exercise of vested options that are at least 67% in-the-money (Holder 67). The Holder 67 variable takes the value of one when the CEO is identified as overconfident, and zero otherwise. In our tests, the CEO overconfidence measures are lagged by one period with respect to the dependent variable.

Since we do not have detailed data on CEO's option holdings and exercise prices for each option grant, we follow Campbell et al. (2011) in calculating an average moneyness of the CEO's option portfolio for each year. First, for each CEO-year, we calculate the average realizable value per option by dividing the total realizable value of the options by the number of options held by the CEO. The strike price is calculated as the fiscal year end stock price minus the average realized value. The average moneyness of the options is then calculated as the stock price divided by the estimated strike price. As we are only interested in options that the CEO can exercise, we include only the vested options held by the CEO.

Consistent with Hirshleifer et al. (2012), who show that CEO characteristics play a decisive role in innovative activity, we also control for CEO age, tenure and incentives. We define CEO age as a count variable taking the value of zero if the CEO is below 35 years of age, a value of one if the CEO is between 36 and 45 years of age, a value of two if the CEO is between 46 and 55 years of age, and a value of three if the CEO is over 55 years of age. We define CEO tenure as the number of years since the current CEO became CEO. We capture CEO incentives using CEO delta and vega. Delta is defined as the dollar change in a CEO's stock and option portfolio for a 1% change in stock price and measures the CEO's incentives to increase the stock price. Vega is the dollar change in a CEO's option holdings for a 0.01 unit change in stock return volatility. Vega measures the risk-taking incentives generated by the CEO's option holdings. Manso (2011) argues that employment contracts which encourage risk taking are necessary to motivate innovation. We therefore expect to observe a positive relation between vega and innovative activity. We use the log transformation of CEO tenure, delta, and vega in the regression.

3.5. Descriptive statistics

We present the descriptive statistics of our main variables in Table 1. Table 1 provides the mean, standard deviation and median for each variable as well as the top and bottom quintile. Consistent with the literature on corporate innovation, we take the natural logarithm of one plus patent count and one plus citations-per-patent to overcome significant skewness in the data.

The average MA score is 0.001 with a standard deviation of 0.14. The average natural logarithm of sales is 5.71, and 3.71 for capital intensity. Average ROA for sample firms is 7%, with the book leverage representing 22% of total assets. The average sales growth in our sample is 15% with the average Tobin's Q being 1.31. On a scale from 0 to 1, the average Lerner index in our sample is 0.16, which indicates that on average firms do not operate in highly concentrated industries.[7] The average natural logarithm of analyst following is 1.64, while the average level of institutional ownership is 61%. On average 35% of sample CEOs are classified as overconfident with

[7] As discussed in Aghion et al. (2005) the Lerner index is a good measure of a firms' relative market power, with values closer to zero representing relatively little market power.

Table 1
Descriptive statistics.
This table reports the descriptive statistics of the key variables of interest. The sample period is from January 1993 to December 2006. Patent data is from the NBER patent database, while accounting data is from Compustat. CEO specific data is obtained from ExecuComp. Variable definitions are presented in Appendix A.

	Mean	Std. dev	P25	Median	P75
Ln (1 + Patents)	0.35	1.09	0	0	0.69
Ln (1 + Citations/Patent)	0.22	0.81	0	0	0
MA score	0.001	0.14	−0.086	−0.008	0.081
Ln (Sales)	5.71	2.13	4.32	5.66	7.08
Ln (PPEMP)	3.71	1.37	2.86	3.54	4.32
ROA	0.07	0.28	0.03	0.11	0.17
Book leverage	0.22	0.22	0.03	0.18	0.34
Sales growth	0.15	0.41	0.002	0.10	0.25
Tobin's Q	1.31	5.83	0.21	0.93	1.91
Lerner index	0.16	0.14	0.06	0.13	0.23
Ln (1 + Analysts)	1.64	0.75	1.04	1.54	2.17
Total IO	0.61	14.87	0.22	0.44	0.67

the average CEO age of 51.78 and a standard deviation of 14.39. The average natural logarithm of CEO tenure is 1.42. The average logarithm of the incentive variables, namely option delta and vega, is 4.18 and 5.41 respectively.

4. Main results

4.1. Baseline results

We examine the effect that managerial ability has on innovative output using the baseline model as follows:

$$Ln\left(1+Innovation_{i,t}\right) = \alpha + \beta MAscore_{i,t-1} + \vartheta X_{i,t\text{-}1} + \delta Year_t + \theta Industry + \varepsilon_{i,t}. \tag{1}$$

In the above equation, *Innovation* refers to our innovation measures (patent count, citation-per-patent count) of firm *i* in year *t*. The key explanatory variable is *MA score*, measured at the end of year $t-1$. To reduce skewness of our innovation measures, we use the natural logarithm of one plus the innovation variables. *X* represents the set of firm-level control variables defined in the previous section.

In addition to the firm-level variables discussed earlier, we also include R&D capital as a control variable. Controlling for R&D capital is essential, as innovative output is highly sensitive to the level of corporate investment in innovation. Furthermore, since the variable *MA score* in the Demerjian et al. (2012) setting uses R&D expenditure as an input, controlling for R&D investment ensures that the relation is not mechanical. R&D capital is defined as the five-year cumulative R&D expenses assuming an annual depreciation rate of 20% as in Chan et al. (2001) and Lev et al. (2005) in fiscal year ending $t-2$. We concentrate on R&D capital rather than R&D expenditure over a single year, since innovation requires a number of years before inputs are converted into outputs. R&D capital is therefore expected to be of more relevance to investors than simple R&D. In addition to the variable of interest (interaction term) we also control for managerial ability and R&D capital. We also include two-digit SIC industry and year fixed effects in the model.

Panel A of Table 2 reports the results of our baseline regressions in Eq. (1). We find that *MA score* is positively and significantly associated with both measures of innovation, with *t*-statistics of 3.48 and 2.03, respectively. Economically, increasing *MA score* from its 25th percentile (−0.086) to the 75th percentile (0.081) increases the value of *Ln (1 + Patents)* by over 6% from its mean. Similarly, increasing *MA score* from its 25th percentile to the 75th percentile increases the value of *Ln (1 + Citations/Patents)* by over 10%.[8] These results show that increases in managerial ability are associated with material increases in innovative output.

As far as control variables are concerned we find a strong positive relation between R&D capital and innovative output. Clearly, those firms which spend more on innovation generate a higher number of absolute patents and patent citations. Book leverage is negatively related to innovative output while cash holdings are positively related to innovative output. The negative relation between book leverage and patenting activity suggests that firms which are more highly geared are averse to dedicating resources into innovation and therefore generate lower output. Likewise, those firms which have higher cash holdings have more freedom from the capital market, and can therefore invest more resources into innovation and generate higher output. We find that sales growth and analyst following are positively associated with innovative output and that analyst following. The results showing a positive association between analyst following and innovative output are consistent with He and Tian (2013), who also show that when industry fixed effects are included the association is positive, while the association turns negative when firm fixed effects are included. Since, both our innovation measure and *MA score* are highly persistent variables, we only include industry fixed effects rather than firm fixed effects in our regression model.

[8] The observation that moving from an *MA score* at the 25th percentile to the 75 percentile increases innovative output by between 6% and 10% is comparable to the economic significance reported in other studies on the determinants of corporate innovation. For example, He and Tian (2013) report that an increase in analyst following from the 25th percentile to the 75th percentile is associated with a decrease in innovative output of 10.2%. Similarly, Chen et al. (2014) find that a one-standard-deviation increase in the *CP ratio*, a proxy for local gambling preferences, is associated with an increase in innovative output of between 8% and 12%.

Table 2
Managerial ability and innovative output.
This table presents the regression results on the association between innovative outcomes (patent count and citations-per-patent) and managerial ability. The results are presented in two panels. Panel A provides the baseline results and panel B reports the robustness tests. All independent variables are lagged by two years. Industry is defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors are corrected for clustering of observations at the firm and county level (t-statistics are in parentheses). Variable definitions are presented in Appendix A.

Panel A: Baseline model

	Ln (1 + Patents)	Ln (1 + Citations/Patent)
	(1)	(2)
MA score	0.13	0.13
	(3.48***)	(2.03**)
Ln (R&D *Capital*)	0.27	0.16
	(26.53***)	(31.46***)
Ln (Sales)	0.08	−0.01
	(6.21***)	(−0.40)
Ln (PPEMP)	0.06	0.02
	(6.07***)	(2.56**)
ROA	−0.09	0.02
	(−2.63***)	(0.69)
Book leverage	−0.17	−0.21
	(−4.67***)	(−6.28***)
Cash holdings	0.55	0.36
	(8.52***)	(7.41***)
Sales growth	0.07	0.07
	(5.23***)	(5.18***)
Tobins Q	0.01	−0.01
	(0.81)	(−0.67)
Lerner index	−0.21	−0.30
	(−2.33**)	(−4.22***)
Ln (1 + Analyst)	0.10	0.13
	(3.81***)	(8.60***)
Total IO	−0.01	0.01
	(−0.54)	(0.86)
Industry fixed-effects	Yes	Yes
Year fixed-effects	Yes	Yes
Observations	42,754	42,754
Adjusted R^2	0.40	0.27

Panel B: Robustness tests

	Ln (1 + Patents)			Ln (1 + Citations/Patent)		
	Coef.	*t*-stat	Obs.	Coef.	*t*-stat	Obs.
(1) Use CEO award	0.08	2.04**	12,007	0.01	1.20	12,007
(2) Use media citations	0.04	1.90*	12,007	0.05	4.44***	12,007
(3) Exclude 2005 and 2006	0.24	2.64***	27,969	0.10	1.68*	37,969
(4) Exclude observations with zero R&D	0.25	1.90*	17,489	0.08	1.68*	17,489
(5) Use Tobit model	0.91	3.20***	42,754	0.96	2.89***	42,754
(6) Fama–MacBeth regression	0.18	1.87*	42,629	0.11	1.59	42,629
(7) Exclude Silicon-Valley firms	0.07	1.85*	40,035	0.10	1.81*	40,035
(8) Exclude firms in innovative industries	0.06	1.71*	24,022	0.07	1.82*	24,022

* Significance at the 10% level.
** Significance at the 5% level.
*** Significance at the 1% level.

4.2. Robustness tests

We perform a number of additional tests to ensure that our main results are robust to alternate model specifications and variable definitions. For the sake of brevity, we only tabulate the coefficients of key variables in Panel B of Table 2. In rows (1) and (2) of Panel B, we validate the results reported in the baseline tests using our alternate proxies of managerial ability: CEO awards and media citations. With respect to the relation between managerial ability and patent count, we find a positive relation when both these proxies are used. The results are somewhat weaker for the *CEO* award variable when citations-per-patent is the dependent variable. Nevertheless, for both measures of CEO ability, we observe a positive relation between innovative activity and managerial ability, consistent with the baseline results.

In row (3), we exclude the years 2005 and 2006. The NBER patent database reports the application date of all patents that were subsequently granted. There is on average a two-year lag between patent application and patent grant. Since the latest year in the database is 2006, patents applied for in 2005 and 2006 may not appear in the database. As suggested by Hall et al. (2001), we restrict the sample period to end in 2004 to overcome this potential truncation bias. This limits the sample to 1993–2004. The results are qualitatively unchanged in this more restricted sample.

Another potential concern with the results is the large number of zero patents in the sample. As a result, the findings can be driven by a jump from zero to a positive number. This concern is addressed in two ways. First, in row (4), observations with zero patents are removed from the sample. Although this introduces sample selection into the estimation, this approach ensures that the results are not a consequence of a jump from zero to a positive number. Second, in row (5), a Tobit model is employed. The benefit of employing a Tobit model is that it can explicitly account for a jump in the distribution at zero. The results in rows (4) and (5) are consistent with the baseline results.

To account for within-firm autocorrelation, in row (6) we employ the Fama–Macbeth regression. This approach offers an alternate way of adjusting standard errors for within sample clustering of observations. The results remain qualitatively consistent with the baseline results. In rows (7) and (8) we test whether the results are entirely driven by firms which are research intensive. Specifically, in row (7) we exclude those firms which are located in Silicon Valley, which has the greatest cluster of innovative firms. Following Gompers et al. (2005), we define Silicon Valley as the Alameda, San Mateo, and Santa Clara counties in California. We find that the coefficient estimate on the *MA score* remains positive statistically significant in this sub-sample, even though the economic and statistical significance is reduced. These results suggest that even though managerial ability plays a proportionately greater role in spurring innovation in firms located in Silicon Valley, managerial ability is nevertheless also important for firms outside of Silicon Valley.

Similar results are reported in row (8), where we stratify the sample based on whether the firm belongs to an industry that can be classified as innovative or not. We measure industry innovativeness in accordance with Hirshleifer et al. (2012). Specifically, an innovative industry is defined as one whose average citations-per-patent in a given year is above the median across all industries for that particular year. Industries are classified at the 4-digit SIC code level. The coefficient estimates on the *MA score* in the non-innovative industry sub-sample are again weaker in scope and statistical significance compared with the baseline results, but nevertheless remains positive and significant.

4.3. Omitted variable bias

Although we document a strongly positive association between managerial ability and innovation output, the results are potentially subject to a specific form of endogeneity, namely omitted variable bias. The Demerjian et al. (2012) managerial ability variable used in the baseline setting is a residual from a Tobit model which identifies the firm specific components of firm performance. As a residual, the managerial ability measure is subject to the criticism that it may also capture other factors that affect corporate innovation including CEO characteristics, corporate governance, and corporate culture. To address this omitted variable bias concern, we explicitly describe issues related to potential related variables that we can think of, and design specific tests to address them. We tabulate the results in Table 3. While all control variables in Eq. (1) are still included in the new tests, we only report the coefficient of *MA score* and the newly added variables for brevity.

Managerial ability might be highly correlated with CEO specific characteristics, such as overconfidence, age, tenure, as well as remuneration. These CEO specific factors may in turn also be correlated with corporate innovation. For example, Hirshleifer et al. (2012), show that CEO overconfidence is an important determinant of a firm's innovative success. Furthermore, Manso (2011) shows that executive incentive schemes play an important role in determining innovation. Since remuneration contracts can be correlated with managerial ability, it is important to control for managerial incentives.

For this reason, in Panel A of Table 3 we control for a number of CEO characteristics. This reduces the sample to 8986 firm-year observations. The coefficient estimate on *Holder 67*, which measures CEO overconfidence, is positive and statistically significant, which is consistent with the observation reported in Hirshleifer et al. (2012) that CEO overconfidence spurs innovation. In addition, we find that *Ln (Delta)* is negatively association with innovation, which suggests that when managerial remuneration is more sensitive to changing stock values, managers are more reluctant to actively engage in innovation. Most importantly, our main results still hold, which means that the positive association between managerial ability and corporate innovation is independent of CEO specific factors.

In Panel B of Table 3, we control for numerous corporate governance factors including the entrenchment index (*E-index*) compiled by Bebchuk et al. (2009), the portion of independent directors sitting on the board (we define independent outside directors as directors who are not current or past employees of the corporation, do not have substantial business or family ties with management, nor have potential business ties with the firm), and an indicator variable equal to one if the CEO and Chairman of the Board are the same person (*CEO dual*). We find that the *E-index* and the CEO duality variable are unrelated with corporate innovation, while the portion of independent board members is positively association with corporate innovation. We find that the coefficient estimate on the *MA score* variable remains positive and significant, which suggests that the baseline results are not driven by corporate governance factors jointly correlated with managerial ability and corporate innovation.

It is also possible that local culture surrounding the firm's headquarters can influence the results. For example, Chen et al. (2014) show that the gambling preferences surrounding the firm's headquarters have significant influence on the level of corporate innovation. Similarly, Hilary and Hui (2009) show that the level of religiosity in the county where the company is headquartered plays is important for the firm's strategic decisions. For this reason, in Panel C of Table 3, we control for local gambling preferences (*CP ratio*) as captured by the Catholics-to-Protestant ratio developed by Kumar et al. (2011), county-level religiosity (*Rel*), and the natural logarithm of the county's population. All county-level variables are significantly related with corporate innovation. Consistent with Chen et al. (2014), the *CP ratio* variable is positively and significantly related with innovation. The religiosity ratio is negatively association with corporate innovation. This is in line with Hilary and Hui (2009) who document that firms located in counties with higher levels of religiosity tend to be more risk-averse. Finally, our results show that firms located in smaller counties

Table 3
Tests for omitted variables.
This table presents the regression results on the association between innovative outcomes (patent count and citations-per-patent) and managerial ability. The results are presented in four panels. Panel A provides regression results after controlling for CEO-specific factors. Panel B reports regression results are controlling for corporate governance. Panel C reports regression results after controlling for local cultural factors. Finally, Panel D reports regression results after controlling for M&A activity. The table only reports the coefficient estimates on variables of interest, but the tests are based on the same set of controls as those reported in Table 2. Standard errors are corrected for clustering of observations at the firm and county level (t-statistics are in parentheses). Variable definitions are presented in Appendix A.

	Ln (1 + Patents)	Ln (1 + Citations/Patent)
	(1)	(2)
Panel A: Controlling for CEO characteristics (N = 8986)		
MA score	0.19	0.08
	(1.86*)	(1.72*)
Holder 67	0.08	0.06
	(3.13***)	(3.73***)
CEO age	−0.01	−0.01
	(−0.73)	(−0.92)
Ln (Tenure)	−0.03	−0.01
	(−2.87***)	(−1.30)
Ln (Delta)	−0.03	−0.02
	(−2.40**)	(−1.98**)
Ln (Vega)	0.01	0.01
	(1.21)	(0.37)
Panel B: Controlling for corporate governance (N = 6628)		
MA score	0.13	0.15
	(1.73*)	(1.98**)
E-index	−0.01	0.01
	(−0.33)	(0.82)
% of independent directors	0.41	0.16
	(3.54***)	(2.93***)
CEO duality	−0.04	−0.02
	(−1.45)	(−0.99)
Panel C: Control for local cultural factors (N = 34,646)		
MA score	0.21	0.08
	(1.65*)	(1.72*)
CP ratio	0.09	0.07
	(7.50***)	(7.18***)
Religiosity ratio	−0.73	−0.60
	(−4.91***)	(−4.78***)
Ln (Population)	−0.05	−0.04
	(−3.55***)	(−3.42***)
Panel D: Control for M&A activity (N = 42,754)		
MA score	0.32	0.13
	(2.65***)	(1.75*)
M&A activity dummy	0.06	0.02
	(2.84***)	(1.52)

* Significance at the 10% level.
** Significance at the 5% level.
*** Significance at the 1% level.

are better innovators. More importantly, Panel C of Table 3 reveals that these additional county-level control variables do not affect our main results.

Finally, in Panel D of Table 3 we control for M&A activity. Specifically, we include an indicator variable into our empirical analysis which is assigned a value of one if the firm was involved in M&A activity over the previous two years to account for the impact of takeovers. For example, it is possible that more able managers are capable of internalizing their operating processes thus being less inclined to make takeover bids. Less able managers might therefore have a higher propensity to pursue takeovers, with the efficiency with which firms innovate being adversely affected by greater internal instability caused by frequent acquisitions. We find this not to be the case, with the coefficient estimate on the *MA score* remaining positive and significant even after controlling for M&A activity.

5. Further analysis

5.1. CEO characteristics and managerial ability

The results discussed in the previous section indicate that more skillful managers facilitate corporate innovation. In this section, we address two issues. First, we examine whether the effect that managerial ability has on innovative output changes with CEO age and tenure. Narayanan (1985) argues that due to the inherent uncertainty and long-term nature of innovative projects, rational managers will tend to underinvest in innovation due to career concerns. Managers will therefore have an incentive to pursue projects which generate payoffs sooner and with greater certainty (even if their NPV is below innovative projects) to signal their ability to the market. The managerial signaling story developed by Narayanan (1985) should be less important for managers who have developed a track record over time. As a result, one would expect the positive relation between managerial ability and innovative activity to be stronger when CEOs are older and have been appointed for longer.

A competing possibility is that as CEOs develop a track record and reputation over time, they develop a preference for a 'quiet life' as in Bertrand and Mullainathan (2003). They will therefore avoid high risk projects in favor of simple and low risk projects which do not cause them any trouble. According to the second view, the positive relation between managerial ability and innovative activity is weaker for older CEOs and those CEOs who have been appointed for a longer time.

Second, we examine the interaction between managerial ability and CEO overconfidence. The outcomes of innovative projects are inherently uncertain and idiosyncratic. As a consequence, even the most able managers cannot predict all future outcomes. Prior literature has shown that tolerance for risk (Chen et al., 2014; Tian and Wang, 2014) and overconfidence (Galasso and Simcoe, 2011; Hirshleifer et al., 2012) are necessary to overcome the inherent disincentives against innovation. One would therefore expect that the positive relation between managerial ability and innovative activity will increase with CEO overconfidence. A competing possibility, however, is that more able managers invest more in innovation due to the fact that they are capable of better managing the risks associated with innovation. If this were true, then we should observe CEO overconfidence having no effect on the relation between managerial ability and innovative activity.

The interaction regression results are presented in Table 4. The dependent variables are the two innovation variables (*Ln (1 + Patents)* and *Ln (1 + Citations/Patent)*). The same set of firm and CEO specific controls as in Table 2 is utilized with all regressions including industry and year fixed-effects. In columns (1) to (3) of Table 4, the dependent variable is *Ln (1 + Patents)*, while in columns (4) to (6) the dependent variable is *Ln (1 + Citations/Patent)*. In columns (1) and (4), we report results from the interaction of the MA score with CEO age, while in columns (2) and (5), we report results from the interaction of the MA score with CEO tenure. Finally, in columns (3) and (6), we report results from the interaction of MA score and CEO overconfidence.

The results reported in Table 4 provide strong support for the "quiet life" hypothesis. The coefficient estimates on the interaction terms in columns (1) and (2) are negative and statistically significant at the 1% and 5% levels, respectively. This suggests that managerial ability has a less positive effect on innovative output as CEOs become older and as they hold the same post for longer. The results in columns (4) and (5), where the dependent variable is *Ln (1 + Citations/Patent)* are consistent with the results reported in columns (1) and (2). Overall, the results suggest that managerial skill is more relevant for innovative activity when CEOs are relatively younger and during the first few years of their appointment.

In columns (3) and (6), we find that CEO overconfidence has no influence on the way that managerial ability affects innovative output. These findings are consistent with the observation in Table 3 that CEO overconfidence does not affect the way in which managerial ability affects innovative activity.

Table 4
Patenting activity, managerial ability and CEO characteristics.
This table presents the regression results on the interaction between managerial ability and CEO characteristics. The dependent variables are Ln (1 + Patents) and Ln (1 + Citations/Patent). All independent variables are lagged by two years. All regressions include year and industry fixed-effects, defined based on 2-digit SIC codes. All independent variables from the most robust model specification in Table 2 are included in all regression specifications. Intercepts are not reported. Standard errors are corrected for clustering of observations at the firm and county level (t-statistics are in parentheses). Variable definitions are presented in Appendix A.

	Ln (1 + Patents)			Ln (1 + Citations/Patent)		
	(1)	(2)	(3)	(4)	(5)	(6)
MA score	1.08	0.46	0.15	0.29	0.39	0.08
	(3.36***)	(2.89***)	(1.39)	(1.83*)	(2.73***)	(1.10)
MA score × CEO age	−0.42			−0.11		
	(−3.13***)			(−1.68*)		
MA score × Ln (Tenure)		−0.19			−0.22	
		(−2.56**)			(−3.02***)	
MA score × Holder 67			0.02			−0.07
			(0.12)			(−0.65)
CEO age	0.001	−0.005	−0.006	−0.01	−0.01	−0.01
	(0.05)	(−0.40)	(−0.27)	(−0.94)	(−0.82)	(−0.89)
Ln (Tenure)	−0.02	−0.02	−0.03	−0.01	−0.005	−0.01
	(−1.31)	(−1.33)	(−1.39)	(−0.95)	(−0.48)	(−0.99)
Holder 67	0.08	0.08	0.08	0.07	0.07	0.07
	(2.06**)	(2.06**)	(1.99**)	(3.16***)	(3.14***)	(3.20***)
Full set of controls	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8986	8986	8986	8986	8986	8986
Adjusted R^2	0.46	0.46	0.46	0.40	0.40	0.40

* Significance at the 10% level.
** Significance at the 5% level.
*** Significance at the 1% level.

5.2. Market valuation of patents

The baseline results presented in this paper show that managerial ability is an important determinant of the volume of patents generated by the firm. Nevertheless, our analysis on innovative output is limited by data availability which only allows us to examine a firm's innovative activity up to the idea generation phase. In reality, firms innovate to create new products and processes which allow them to stay competitive. While we do not have a direct way of measuring the success with which firms convert their innovative inventions (as measured by patent output) into competitive advantage, we address this important question in an indirect manner. Specifically, we assume that the market provides the most unbiased estimate of the value of a firm's patents. In order to gauge how managerial ability affects the markets valuation of patents, we interact a firm's patent count with managerial ability, in a regression where the dependent variable is market valuation. Specifically, we regress market valuation on the interaction between managerial ability and patent count. The interaction term tells us whether the market values patents generated by firms with able managers more positively compared with firms with less skilled managers. In addition to the variable of interest (interaction term) we also control for managerial ability and patent count. Market valuation is measured using the natural logarithm of market equity to book equity.

Further to the variable of interest, we include controls for the reciprocal of book equity, abnormal earnings, and the tax shield associated with R&D expenditure. Controls for advertising and capital expenditure are also included. The model employed to test the effect that managerial ability has on the market's valuation of patents as well as the choice of control variables in the model is consistent with Hirshleifer et al. (2013). The regression model is an adaptation of an accounting-based asset valuation model developed in Ohlson (1995) and used by Sougiannis (1994) and Hirshleifer et al. (2013). Industry and year fixed-effects are included in all regressions. The results are reported in Table 5.

In columns (1) and (2) of Table 5, the dependent variable is contemporaneous market valuation (defined as market to book ratio), while in columns (3) and (4), the dependent variable is market valuation at $t + 1$. In columns (1) and (3) fixed-effects are not included, while in columns (2) and (4), we include industry and year fixed-effects.

Across all model specifications, we find a positive and significant coefficient estimate on the interaction term. This observation indicates that the market values patents generated by firms with skillful managers at the helm more highly compared with the patents generated by firms with less skilled managers. Clearly, the market believes that skillful managers are essential in ensuring that new inventions are not wasted, but instead converted into new products or processes which will give the

Table 5
Market valuation of patents and managerial ability.
This table regresses market valuation on the interaction between managerial ability and patent output. Market valuation is measured using the market-to-book ratio, defined as the end of year market equity divided by the end of year book equity. Book equity is the Compustat book value of stockholder's equity, plus balance sheet deferred taxes and investment tax credit, minus the book value of preferred stock. All independent variables are lagged by one year. 1/BE is one divided by book equity. Abnormal earnings are defined as $\frac{E^B_{i,t}(1-\tau_{i,t})-r_t BE_{i,t-1}}{BE_{i,t}}$, where $E^B_{i,t}$ is earnings after extraordinary items before expensing R&D expenses and less preferred dividends for firm i in year t, and r_t is the one year Treasury bill rate in year t. Tax shield denotes R&D expenditure multiplied by tax rate, scaled by book value of equity. Ln (1 + AD/ME) is the natural logarithm of one plus annual advertising expenditure divided by year-end market equity. Ln (1 + CAPEX/ME) is the natural logarithm of one plus annual capital expenditure divided by year end market equity. The inclusion of year and industry fixed-effects is indicated at the bottom of the table. Industry is defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors are corrected for clustering of observations at the firm level (t-statistics are in parentheses).

	$Ln(MTB_t)$		$Ln(MTB_{t+1})$	
	(1)	(2)	(3)	(4)
MA score	0.38	0.39	0.32	0.33
	(8.84***)	(9.32***)	(7.27***)	(7.67***)
MA score × Ln(1 + Patents)	0.15	0.13	0.07	0.07
	(3.92***)	(3.60***)	(1.76*)	(1.82*)
Ln(1 + Patents)	0.06	0.07	0.08	0.09
	(10.59***)	(11.50***)	(12.49***)	(13.77***)
1/BE	0.02	0.02	0.006	0.006
	(5.05***)	(5.07***)	(4.62***)	(4.64***)
Abnormal earnings	−0.0006	−0.0006	0.0002	0.0001
	(−0.59)	(−0.57)	(0.52)	(0.45)
Tax Shield	−0.004	−0.004	0.0008	0.0003
	(−0.74)	(−0.77)	(0.49)	(0.16)
Ln (1 + AD/ME)	−0.56	−0.52	−0.16	−0.13
	(−5.63***)	(−5.72***)	(−1.38)**	(−1.24)
Ln (1 + CAPEX/ME)	−1.73	−1.67	−1.07	−1.00
	(−32.86***)	(−33.87***)	(−16.23***)	(−15.97***)
Industry fixed-effects	No	Yes	No	Yes
Year fixed-effects	No	Yes	No	Yes
Observations	42,754	42,754	42,754	42,754
Adjusted R^2	0.22	0.25	0.07	0.11

* Significance at the 10% level.
** Significance at the 5% level.
*** Significance at the 1% level.

company a competitive edge. Collectively, our results show that managerial ability is an important driver of corporate innovation.

5.3. Managerial ability and patenting strategies

In this section, we examine the effect that managerial ability has on a firm's patenting strategy. Corporate innovative strategies are highly heterogeneous, with patenting volume not capturing this heterogeneity. It is therefore important to understand whether higher levels of innovative output observed by firms high on the employee treatment index scale are due to these firms producing a lot of patents closely related to the firms existing business activity and knowledge base, or does the higher level of innovative output involve a high level of radical innovation outside of the firm's knowledge base.

We utilize two measures of patenting strategies consistent with Gao et al. (2014). The first measure of innovative heterogeneity captures the portion of firm's patents which is closely related to the firm's existing knowledge and expertise. Following Benner and Tushman (2002) and Gao et al. (2014), a patent is categorized as being based on the firm's existing knowledge if 60% or more of its citations are based on the combination of a firm's portfolio of patents and citations made by its portfolio of patents in the past. In contrast, the second measure of innovative heterogeneity captures the portion of firm's patents which are outside of the firms existing knowledge and expertise. As such, a patent is categorized as being based outside of the firm's existing knowledge if 60% or more of its citations are outside of the firms existing knowledge base. We divide the number of patents falling into each category for each firm-year by the total number of patents applied for by the firm in a given year.

We regress the measures of innovative heterogeneity on managerial ability and the full set of firm level controls from Eq. (1). The regression results are reported in Table 6. The dependent variables in Table 6 are as follows: in column (1) the portion of patents based on the firm's existing knowledge; and in column (2) the portion of patents based outside of the firms knowledge. The regressions include industry and year fixed-effects, and standard errors are clustered at the firm-level.

The coefficient estimate on the *MA score* variable in column (1) is negative and significant. This means that firms with more skillful management teams are less likely to pursue inventions which are highly dependent on previous inventions generated by the firm. The results in column (2) confirm this observation, with the coefficient estimate on the *MA score* variable being positive and significant.

Table 6
Managerial ability and patenting strategies.
This table presents the regression results of the effect that managerial ability has on patenting strategies. Patents based on existing knowledge are defined as those patents where over 60% of its citations are the firm's previous patents. Patents outside of existing knowledge are defined as those patents where over 60% of citations are not related to the firm's earlier patents. All independent variables are lagged by one year. The regressions include year and industry fixed effects, where industry is defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors are corrected for clustering of observations at the firm level (t-statistics are in parentheses). Variable definitions are presented in Appendix A.

	Portion of patents based on existing knowledge	Portion of patents outside on existing knowledge
	(1)	(2)
MA score	−0.05	0.03
	(−2.25**)	(1.78*)
Ln(R & *D Capital*)	0.02	−0.02
	(12.86***)	(−15.18***)
Ln (Sales)	−0.02	0.02
	(−9.29***)	(9.26***)
Ln (PPEMP)	0.03	−0.03
	(8.35***)	(−8.46***)
ROA	−0.10	0.10
	(−4.24***)	(4.19***)
Book leverage	−0.01	0.01
	(−0.29)	(0.36)
Cash Holdings	0.09	−0.09
	(5.28***)	(−4.77***)
Sales growth	0.02	−0.01
	(2.15**)	(−1.59)
Tobins Q	0.01	−0.01
	(0.77)	(−0.60)
Lerner index	−0.04	0.06
	(−1.05)	(1.55)
Ln (1 + Analyst)	0.02	−0.02
	(5.31***)	(−5.37***)
Total IO	−0.01	0.01
	(−1.06)	(1.02)
Industry fixed-effects	Yes	Yes
Year fixed-effects	Yes	Yes
Observations	14,109	14,109
Adjusted R^2	0.14	0.13

* Significance at the 10% level.
** Significance at the 5% level.
*** Significance at the 1% level.

These results show that firms with more skilled managers are more likely to pursue more radical innovations which better allow the firm to develop a competitive edge relative to their competitors. Taken in their entirety, the results presented in this paper show that not only do able managers facilitate higher volume of patents, but also that these patents tend to be more unique in nature. Overall, managerial ability is shown to have a strong positive effect on corporate innovation.

6. Conclusions

This paper is the first to examine the role that managerial ability plays in corporate innovation. We find that those firms which have better skilled managers at the helm generate significantly higher volumes of patents and patent citations compared with firm's which have less skillful managers at the helm. This positive association is robust to alternate measures of managerial ability, variations in sample size, and alternate model specifications. Furthermore, the results are not sensitive to controlling for CEO characteristics, corporate governance, cultural factors, and M&A activity.

Further tests reveal that the positive association between managerial ability and corporate innovation diminishes with CEO tenure and age. This observation suggests that although managerial ability is relevant to the long-term success of a corporation by enhancing a firm's innovative output, the incentive of corporate managers to seek a 'quiet life', documented by Bertrand and Mullainathan (2003), diminishes some of the benefits of managerial ability in long-serving CEOs.

In addition, we show that the market perceives patents generated by firms with skillful managers to be more valuable than those generated by firms with less skilled managers. This result suggests that managerial skill is important not only in developing new ideas, but also converting them into commercially successful products. The final set of results show that managerial ability is associated with a greater propensity to pursue inventions which are not purely based on the firm's existing knowledge. Such inventions, which are more unique and novel, are more likely to enhance the firm's relative competitiveness. This final observation further highlights the important role that managerial ability plays in implementing an effective and successful corporate innovative strategy.

The results presented in this study show that managerial skill is essential to corporate innovative success. The implication is that managerial ability is relevant to the long-term success of an organization, and therefore firms are justified in offering very high remuneration packages to attract the best quality managers. Our results have significant implications for the ongoing debate on the merits of large executive remuneration.

Appendix A. Variable description

Variables	Description
Dependent variables	
Patents	Number of patents applied for during the year.
Citations/patent	Total number of citations summed across all patents applied for during the year. Each patents number of citations is multiplied by the weighting index from Hall et al. (2005).
Independent variables	
MA score	Managerial ability metric developed by Demerjian et al. (2012). Their measure of managerial ability generates an estimate of how efficiently managers use their firms' resources.
R&D capital	Five year cumulative R&D expenses assuming an annual depreciation rate of 20%.
Sales	Firm sales in millions of dollars.
PPEMP	Net property, plant, and equipment per employee in thousands of dollars.
ROA (%)	Ratio of operating income before depreciation to book assets.
Book leverage (%)	Ratio of the sum of short term debt long term debt to book assets.
Sales growth (%)	Log transformation of sales divided by prior year sales.
Tobin's Q	Ratio of market value to book value of assets.
Lerner index	Price-cost margin scaled by sales. Calculated as sales less cost of goods sold less general and administrative expenses, all divided by sales.
Total IO	Percentage of shares outstanding held by 13-F institutions.
Analysts	The average number of analysts following the firm over the year.
Holder 67	Options based measure of CEO overconfidence. Indicator variable equals 1 for all years after a CEO holds options that are at least 67% in the money, and 0 otherwise.
CEO age	An ordinal variable equal to zero for CEOs with age below 35, one for CEOs with age between 36 and 45, two for CEOs with age between 46 and 55, and three for CEOs with age above 55.
Tenure	The number of years since the current CEO became CEO.
Delta	Dollar change in CEO stock and option portfolio for a 1% change in stock price.
Vega	Dollar change in CEO option holdings for a 1% change in stock return volatility.

References

Aghion, P., Bloom, N., Blundell, R., Griffith, R., Howitz, P., 2005. Competition and innovation: an inverted-U relationship. Q. J. Econ. 120, 701–728.

Aghion, P., Van Reenan, J., Zingales, L., 2013. Innovation and institutional ownership. Am. Econ. Rev. 103, 277–304.

Albuquerque, A., Franco, G., Verdi, R., 2013. Peer choice in CEO compensation. J. Financ. Econ. 108, 160–181.

Attig, N., Cleary, S., 2014. Organizational capital and investment-cash flow sensitivity: the effect of management quality practices. Financ. Manag. 43, 473–504.
Baik, B., Farber, D., Lee, S., 2011. CEO ability and management earnings forecast. Contemp. Account. Res. 28, 1645–1668.
Beatty, R., Zajac, E., 1994. Managerial incentives, monitoring, and risk bearing: a study of executive compensation, ownership, and board structure in initial public offerings. Admin. Strat. Q. 39, 313–335.
Bebchuk, L., Cohen, A., Ferrell, A., 2009. What matters in corporate governance? Rev. Financ. Stud. 22, 783–827.
Benner, M., Tushman, M., 2002. Process management and technological innovation: a longitudinal study of the photography and paint industries. Admin. Strat. Q. 47, 676–706.
Berk, J., Stanton, R., 2007. Managerial ability, compensation, and the closed-end fund discount. J. Financ. 62, 529–556.
Bertrand, M., Mullainathan, S., 2003. Enjoying the quiet life? Corporate governance and managerial preferences. J. Polit. Econ. 111, 1043–1075.
Campbell, C., Gallmeyer, M., Johnson, S., Rutherford, J., Stanley, B., 2011. CEO optimism and forced turnover. J. Financ. Econ. 101, 695–712.
Chan, L., Lakonishok, J., Sougiannis, T., 2001. The stock market valuation of research and development expenditures. J. Financ. 56, 2431–2456.
Chang, X., Fu, K., Low, A., Zhang, W., 2015. Non-executive employee stock options and corporate innovation. J. Financ. Econ. 115, 168–188.
Chen, Y., Podolski, E., Rhee, G., Veeraraghavan, M., 2014. Local gambling preferences and corporate innovative success. J. Financ. Quant. Anal. 49, 77–106.
Chen, C., Chen, Y., Podolski, E., 2015. Employee Satisfaction and Corporate Innovation. Working Paper.
Demerjian, P., Lev, B., McVay, S., 2012. Quantifying managerial ability: a new measure and validity tests. Manag. Sci. 58, 1229–1248.
Demerjian, P., Lev, B., Lewis, M., McVay, S., 2013. Managerial ability and earnings quality. Account. Rev. 88, 463–498.
Devers, C., Cannella, A., Reilly, G., Yoder, M., 2007. Executive compensation: a multidisciplinary review of recent developments. J. Manag. 33, 1016–1072.
Dixit, A., Stiglitz, J., 1977. Monopolistic competition and optimum product diversity. Am. Econ. Rev. 117, 297–308.
Domowitz, I., Hubbard, R., Petersen, B., 1986. Business cycles and the relationship between concentration and price-cost margins. RAND J. Econ. 17, 1–17.
Ederer, F., Manso, G., 2013. Is pay-for-performance detrimental to innovation? Manag. Sci. 59, 1496–1513.
Fang, V., Tian, X., Tice, S., 2014. Does stock liquidity enhance or impede firm innovation? J. Financ. 69, 2085–2125.
Fong, E., 2010. Relative CEO underpayment and CEO behaviour towards R&D spending. J. Manag. Stud. 47, 1095–1122.
Francis, J., Huang, A., Rajgopal, S., Zang, A., 2008. CEO reputation and earnings quality. Contemp. Account. Res. 25, 109–147.
Galasso, A., Simcoe, T., 2011. CEO overconfidence and innovation. Manag. Sci. 57, 1469–1484.
Gao, H., Hsu, P., Li, K., 2014. Managerial short-termism and corporate innovation strategies. Working Paper.
Gompers, P., Lerner, J., Scharfstein, D., 2005. Entrepreneurial spawning: public corporations and the genesis of new ventures, 1986 to 1999. J. Financ. 60, 577–614.
Hall, B., 2002. The financing of research and development. Oxf. Rev. Econ. Policy 18, 35–51.
Hall, B., Ziedonis, R., 2001. The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979-1995. RAND J. Econ. 32, 101–128.
Hall, B., Jaffe, A., Trajtenberg, M., 2001. The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools. NBER Working Paper Series.
Hall, B., Jaffe, A., Trajtenberg, M., 2005. Market value and market citations. RAND J. Econ. 36, 16–38.
He, J., Tian, X., 2013. The dark side of analyst coverage: the case of innovation. J. Financ. Econ. 109, 856–878.
Hilary, G., Hui, K., 2009. Does religion matter in corporate decision making in America? J. Financ. Econ. 93, 455–473.
Hirshleifer, D., Low, A., Teoh, S.H., 2012. Are overconfident managers better innovators? J. Financ. 67, 1457–1498.
Hirshleifer, D., Hsu, P., Li, D., 2013. Innovative efficiency and stock returns. J. Financ. Econ. 107, 632–654.
Holcomb, T., Holmes, M., Connelly, B., 2009. Making the most of what you have: managerial ability as a source of resource value creation. Strateg. Manag. J. 30, 457–485.
Holmstrom, B., 1989. Agency costs and innovation. J. Econ. Behav. Organ. 12, 305–327.
Jensen, M., Meckling, W., 1976. Theory of the firm: managerial behavior, agency costs and ownership structure. J. Financ. Econ. 3, 305–360.
Kumar, A., Page, J., Spalt, O., 2011. Religious beliefs, gambling attitudes, and financial market outcomes. J. Financ. Econ. 102, 671–708.
Lev, B., Sarath, B., Sougiannis, T., 2005. R&D reporting biases and their consequences. ontemp. Account. Res. 22, 977–1026.
Lindenberg, E., Ross, S., 1981. Tobin's q ratio and industrial organization. J. Bus. 54, 1–32.
Malmendier, U., Tate, G., 2008. Who makes acquisitions? CEO overconfidence and the market's reaction. J. Financ. Econ. 89, 20–43.
Manso, G., 2011. Motivating innovation. J. Financ. 66, 1823–1860.
Milbourn, T., 2003. CEO reputation and stock-based compensation. J. Financ. Econ. 68, 233–262.
Murphy, K., Zabojnik, 2004. CEO pay and appointments: a market-based explanation for recent trends. Am. Econ. Rev. 94, 192–196.
Narayanan, M., 1985. Managerial incentives for short-term results. J. Financ. 40, 1469–1484.
Ohlson, J., 1995. Earnings, book values, and dividends in equity valuation. Contemp. Account. Res. 11, 661–687.
Rajgopal, S., Shevlin, T., Zamora, V., 2006. CEOs' outside employment opportunities and the lack of relative performance evaluation in compensation contracts. J. Financ. 61, 1813–1844.
Salop, S., 1977. The noisy monopolist: Imperfect information, price dispersion, and price discrimination. Rev. Econ. Stud. 94, 393–406.
Sougiannis, T., 1994. The accounting based valuation of corporate R&D. Account. Rev. 69, 44–68.
Tian, X., Wang, T., 2014. Tolerance for failure and corporate innovation. Rev. Financ. Stud. 27, 211–255.
Tosi, H., Gomez-Mejia, L., 1989. The decoupling of CEO pay and performance: an agency theory perspective. Adm. Sci. Q. 34, 169–189.