Are Overconfident CEOs Better Innovators?

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29. April 2010

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Revised April 2010

Using options- and press-based proxies for CEO overconfidence (Malmendier and Tate 2005a, 2005b, 2008), we find that over the 1993-2003 period, firms with overconfident CEOs have greater return volatility, invest more in innovation, obtain more patents and patent citations, and achieve greater innovative success for given research and development (R&D) expenditure. Overconfident managers only achieve greater innovation than non-overconfident managers in innovative industries. Overconfidence is not associated with lower sales, ROA, or Q.

We thank Sanaz Aghazadeh, Robert Bloomfield, SuJung Choi, Peng-Chia Chiu, Major Coleman, Shane Dikolli, Lucile Faurel, Xuan Huang, Fei Kang, Kevin Koh, Brent Lao, Richard Mergenthaler, Alex Nekrasov, Mort Pincus, Devin Shanthikumar, and participants in the Merage School of Business, UC Irvine Workshop in Psychology and Capital Markets, the brown bag workshop at Nanyang Business School, Nanyang Technical University, and "The Intersection of Economics and Psychology in Accounting Research Conference" at the McCombs School of Business, University of Texas at Austin for very helpful comments, and Peng-Chia Chiu and Xuan Huang for excellent research assistance.

1 Introduction

Steve Jobs, CEO of Apple Computers, was ranked by *BusinessWeek* as one of the greatest innovators of the last 75 years in a 2004 article—written before Apple's introduction of the path-breaking iPhone and the recent iPad—because "More than anyone else, Apple's co-founder has brought digital technology to the masses."[1] Jobs is almost as famous for his self-confidence. According to the same article "He got his first job at 12 after calling Hewlett-Packard Co. … President Bill Hewlett and landing an internship." After achieving prodigious early success by co-founding Apple Computers, "Jobs' cocky attitude and the lack of management skills contributed to Apple's problems. He never bothered to develop budgets…." (Koontz and Weihrich 2007, p. 331). According to an article in *Fortune*, "Jobs likes to make his own rules, whether the topic is computers, stock options, or even pancreatic cancer. The same traits that make him a great CEO drive him to put his company, and his investors, at risk."[2]

Is this combination of visionary innovation and extraordinary overconfidence a coincidence? In this paper we examine a different possibility—that for CEOs, one goes hand in hand with the other.

A recent literature in corporate finance examines how the psychological biases or characteristics of managers affect firms' decisions (see, e.g., Bertrand and Schoar 2003, Baker, Xin, and Wurgler 2009). Our focus is on overconfidence, which is the tendency of individuals to think they are better than they really are on relevant characteristics, such as ability, judgment, or

[1] "So far, 49-year-old Jobs has done just that [changed the world] three times. Soon after he formed Apple in 1976 with high school friend Steve Wozniak, the Apple II became the first PC to hit it big. … A quarter-century later, he rocked the music business with Apple's iPod music player and iTunes online store. This created a blueprint for the music biz in the Net era. And his Pixar Animation Studios was the first to show that computer animation could be used to tell imaginative, touching stories." ("Steve Jobs: He Thinks Different," *BusinessWeek*, November 1, 2004).
[2] According to *Fortune*, "Jobs …oozes smug superiority, … No CEO is more willful, or more brazen, at making his own rules, in ways both good and bad. And no CEO is more personally identified with—and controlling of—the day-to-day affairs of his business." ("The trouble with Steve Jobs," *Fortune*, March 5, 2008).

prospects for successful life outcomes (the last item sometimes called 'optimism'). Theoretical research has analyzed why overconfidence exists (Benabou and Tirole 2002); psychological research indicates that people, including experts, tend to be overconfident along a variety of dimensions, but that there is substantial and persistent individual variation in the degree of confidence.[3]

Overconfident individuals will tend to overestimate the expected payoffs from uncertain endeavors, either because of the general tendency to expect good outcomes, or because they overestimate their own efficacy in bringing about success. Furthermore, people tend to be more overconfident about their performance on hard than easy tasks—the 'difficulty effect' (Griffin and Tversky 1992) or 'hard-easy effect.' So we expect overconfident CEOs (relative to other CEOs) to be especially enthusiastic about risky, challenging, and talent- and vision-sensitive enterprises.

Innovative projects—which apply new business methods, develop new technologies, or seek to provide new products or services—are risky and challenging. So innovation is the kind of undertaking for which we would expect managerial overconfidence to be potentially important. Two considerations reinforce this conclusion. First is the long time it takes to resolve whether an innovative project is successful; overconfidence tends to be more severe in settings with ambiguous and deferred feedback (Einhorn 1980). Second, the adoption of innovative projects may be perceived as indicative of managerial vision or ability. So, innovative projects are likely

[3] See, e.g., Oskamp (1965), Wagenaar and Keren (1986), Brenner et al. (1996), and Weinstein (1980). Puri and Robinson (2007) find that optimism is related to work/life choices, including financial risk-taking. Many experimental studies find substantial differences in the degree of overconfidence across individuals (see, e.g., Biais et al. 2005); such differences are strong and stable (Klayman and Burt 1998, Klayman et al. 1999). Overconfidence also varies with gender (Barber and Odean 2001, Biais et al. 2005), culture (Lee et al. 1995, Koellinger, Minniti and Schade 2007), and whether the individual is an expert in the decision domain (Wagenaar and Keren 1986).

to be consonant with the self-image of a manager who is strongly ego-driven or self-aggrandizing.[4]

We therefore hypothesize that firms with overconfident managers accept greater risk, invest more heavily in innovative projects, and achieve greater innovation, because they overestimate the gain to the firm from innovative projects. It is not crucial for our purposes whether CEOs are, on average, overconfident.[5] What our tests rely upon are substantial *differences* in the degree of confidence across managers. In addition to the general psychological evidence discussed in footnote 1, several corporate finance studies to be discussed find that this is indeed the case.

Whether overconfident CEOs will be better innovators after controlling for the level of spending on research and development (R&D) is less clear. On the one hand, overconfident managers who pursue innovation aggressively may undertake projects with low expected payoff. On the other hand, rational managers may, from the viewpoint of shareholders, excessively prefer the 'D' in R&D—fairly reliable projects rather than risky but more promising innovative ones.[6] Overconfident managers can potentially achieve higher average innovative productivity by accepting good but risky projects. So we do not hypothesize the direction of the effect of

[4] Furthermore, for reputational reasons managers have an incentive to avoid reporting low levels of earnings (Mergenthaler, Rajgopal, and Srinivasan 2009). Since research and development (R&D) expenditures, as expenses, reduce reported earnings, in the short run they increase the risk of a very low earnings outcome. Overconfident managers who expect good outcomes will underweight the possibility that increasing R&D will result in severe earnings shortfalls.

[5] Some studies fail to find evidence of overconfidence in certain contexts (see, e.g., Gigerenzer, Hoffrage, and Kleinbolting 1991, versus Griffin and Tversky 1992). Although there are exceptions, the preponderance of evidence supports a general tendency toward overconfidence in various manifestations. For example, according to DeBondt and Thaler (1995), overconfidence is "perhaps the most robust finding in the psychology of judgment." Similarly, Rabin (1998) states that "… there is a mass of psychological research that finds people are prone toward overconfidence in their judgments. The vast majority of researchers argue that such overconfidence is pervasive, and most of the research concerns possible explanations…"

[6] In the model of Goel and Thakor (2008), rational risk-averse CEOs underinvest in risky projects. Overconfident CEOs do not avoid these risky projects, so if overconfidence is not too severe it increases firm value. In the model of Gervais, Heaton, and Odean (2009), overconfidence encourages a risk-averse manager to take riskier projects, which reduces the cost of providing compensation incentives to do so.

overconfidence on the effectiveness of the CEO in generating innovation for given R&D expenditure.

The biggest puzzle raised by existing research on managerial beliefs and corporate policy is that firms often employ overconfident managers, and give them leeway to follow their beliefs in making major investment and financing decisions. Malmendier and Tate (2005a, 2005b, 2008) find this using options-based and media-based overconfidence measures; Ben-David, Graham, and Harvey (2007) show this for CFOs using an overconfidence measure based on stock market forecasts. This finding is counterintuitive, since we would normally view rationality as a desirable quality for a decisionmaker.

Furthermore, Graham, Harvey, and Puri (2009) provide evidence of a matching of growth firms with taller managers, and reference studies suggesting that height is a proxy for overconfidence. Such a matching puts the most confident managers into exactly those firms where overconfidence can radically influence strategy, investment choices, and firm survival. By measuring ex post success, we suggest a possible solution to this overconfident manager puzzle: that overconfident managers are better innovators.

To test our hypotheses, we use alternative proxies for managerial overconfidence based upon options exercise behavior or press coverage. The options exercise measure (Malmendier and Tate 2005a) is based on the idea that a manager who chooses to be exposed to the firm's idiosyncratic risk is likely to be confident about the firm's prospects. Under this approach, a CEO who voluntarily retains stock options after the vesting period in which exercise becomes permissible is viewed as overconfident.[7]

[7] Malmendier and Tate (2005a, 2008) develop measures of CEO overconfidence based on their options exercising behavior and insider net stock purchases. Billet and Qian (2008), Liu and Taffler (2008), and Campbell et al. (2009) also adopt this measurement approach. Overconfident CEOs may underestimate the variance of project payoffs rather than just overestimating the mean. As discussed by Malmendier, Tate, and Yan (2010), underestimation of

Our second measure of overconfidence is based upon the portrayal of the CEO in the news media, as developed by Malmendier and Tate (2005b, 2008). This is based on counts of words relating to overconfidence or its opposite in proximity to the company name and the keyword 'CEO.'[8]

We measure the firm's innovation-related investment by the level of R&D expenditure. At the end of a firm's R&D activities, firms may apply to the US Patents and Trademarks Office for a patent. Therefore, our first measure of innovative output and R&D success is the number of patents applied for during the year.

Since patents differ greatly in their importance, following Trajtenberg (1990), we use as our second measure of innovative output total citation count. This measure counts the total forward citations received by all the patents applied for during the year, where citations are made by subsequent patents. Hall, Jaffe, and Trajtenberg (2005) show that patent citations are positively correlated with firm value. We measure the patent count at the time of patent application; citations are specific to a patent rather than to a firm. Therefore, these innovation measures are not subject to survivorship bias.

We find that over the 1993-2003 period, firms with overconfident CEOs have higher stock return volatility, consistent with their undertaking riskier projects. Overconfident CEOs invest more heavily in R&D, and achieve a greater total quantity of innovation as measured by

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payoff volatility implies an underestimation of optionality, which tends to favor advancing rather than delaying exercise. However, it also reduces the perceived benefits of diversification, so overall the effect of underestimation of variance on the timing of CEO option exercise is theoretically ambiguous. However, as discussed in Section 5.2.1, evidence on relation between realized volatility and exercise decisions (e.g., Carpenter, Stanton, and Wallace 2009) suggests that underestimation of variance should contribute to later option exercise, so that this form of overconfidence is also captured by the options-based overconfidence measure.

[8]Hribar and Yang (2010) also use this press-based measure of CEO overconfidence. Other approaches have also been applied to measure executive overconfidence. Ben-David, Graham, and Harvey (2007) and Graham, Harvey, and Puri (2009) use surveys and psychometric tests administered to the executives themselves. Schrand and Zechman (2010) develop an overconfidence score that is a function of the CEO's prevalence in photographs in the annual report and the CEO's cash and non-cash pay relative to that of the second highest paid executive.

patent count and citation count. Greater innovative output is not just a result of greater resource input; overconfident CEOs achieve greater innovative success even after controlling for the level of R&D expenditure. Patenting may be less relevant for certain industries, either because they are less innovative, or because in these industries innovation does not result in patents. We find that overconfident managers only achieve greater total patents and citations than non-overconfident managers in industries where patents are important (defined as those with above median patent citation counts). We also find no sign that overconfidence is associated with inferior performance as measured by sales, return on assets (ROA), or Tobin's Q.

Recent work has identified other important effects of managerial overconfidence. Malmendier and Tate (2005a) find that overconfident managers are more prone to financing projects internally (as predicted by the hypothesis that they think that their company's stocks are undervalued), and to investing more when internal cash is plentiful. Malmendier and Tate (2008) find that CEO overconfidence is associated with making acquisitions, and with more negative market reactions to acquisition announcement. Ben-David, Graham, and Harvey (2007) document that firms with overconfident CFOs engage in more aggressive financing and other managerial policies. Hribar and Yang (2010) find that overconfident managers are more likely to issue optimistically biased forecasts. Schrand and Zechman (2010) find that overconfidence is associated with a greater likelihood of earnings management and financial fraud. Graham, Harvey, and Puri (2009) document the relation of managerial traits, including confidence, to a variety of corporate policies. Malmendier, Tate, and Yan (2010) find that overconfident managers are less likely to use external finance, and issue less equity. Most of these findings add to the puzzle of why firms are willing to hire overconfident managers.[9]

[9] After developing this paper, we became aware of a recent paper that examines the relation between managerial overconfidence and innovation (Galasso and Simcoe 2010). Our papers differ in several ways. We examine how

2 Data and Descriptive Statistics

2.1 The Data

We use several databases to construct our sample. The Standard and Poor's Execucomp database provides information on the CEOs and their compensation, and we use the data on option compensation to construct one of our two measures of CEO overconfidence. The second overconfidence measure relies on keyword searches of the text of press articles in *Factiva*. All accounting data are from Compustat and stock returns are from CRSP. Patent-related data are from the 2006 edition of the NBER patent database.

The sample consists of firms in the intersection of Execucomp, Compustat, CRSP, and the patent database. All Execucomp firms that operate in the same 4-digit SIC industries as the firms in the patent database are included; the sample is therefore not limited to firms with patents. Firm-years with missing data on control variables and dependent variables are deleted. We further require that there be information on at least one of the CEO overconfidence measure. Since our overconfidence measures are lagged by one year, we require that the CEO be the same one in the prior year to ensure that we are measuring the characteristics of the CEO who is in place at the time that innovation is being measured. Financial firms and utilities are also excluded from the study. The final sample consists of 2,880 CEOs from 11,652 firm-year observations between 1993 and 2003. 10,297 firm-years have information on the options-based

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overconfidence affects risk-taking as well as innovation, and we show that the effects of managerial overconfidence come solely from innovative industries. We also examine the effects of overconfidence on firm performance. To ensure the robustness of our conclusions, we use the press-based measure of overconfidence as well as the options-based measure. Finally, our time period and sample size differ substantially. Our time period, 1993-2003, encompasses the millennial high-tech boom, and overlaps little with their 1980-94 sample. Our sample is also much larger, as it is drawn from the top 1500 firms covered by Execucomp. It consists of 1,913 firms and 11,652 firm-year observations whereas their sample covers 290 firms and 3,648 firm-years.

measure of overconfidence while 9,246 firm-years have information on the press-based measure of overconfidence.

To test our hypothesis that overconfident CEOs undertake riskier projects, as dependent variable we use the standard deviation of daily stock returns during the fiscal year. We measure innovation using R&D expenditures and patenting activities which we describe in detail in the next subsection. The measurement of CEO overconfidence and the associated control variables are also discussed below. A detailed summary of variable definitions is provided in Appendix A.

2.1.1 Measuring Innovation

We measure resource input into innovation by R&D scaled by book assets. Firms with missing R&D information are assigned a zero R&D value and kept in the sample.[10] Our output-oriented measures of innovation are based upon patent counts and patent citations.

Data for patent counts and patent citations are constructed using the 2006 edition of the NBER patent database (Hall, Jaffe, and Trajtenberg 2001). The database covers over 3.2 million patent grants and 23.6 million patent citations from 1976 to 2006 and contains information about patent assignee names and their Compustat-matched identifiers, the number of citations received by each patent, the technology class of the patent, and similar details. Our second measure of innovation is the number of patent applications by a firm during the year.

Patents are included in the database only if they are eventually granted. Furthermore, 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 2004 and 2005 may not appear in the database. As suggested by Hall, Jaffe, and Trajtenberg (2001), we restrict our sample period to end in 2003

[10] The non-reporting of R&D as a separate line item indicates that the amount of R&D does not cross the threshold for materiality under GAAP. Our results are robust to deleting firms with missing R&D instead.

and include year fixed effects in our regressions to take into account potential truncation issues discussed below.

Simple patent counts capture innovation success imperfectly (see e.g., Griliches, Pakes, and Hall 1987) since patent innovations vary widely in their technological and economic significance. One measure of the importance of a patent is its citation count. Patents continue to receive citations from other patents for many years subsequent to the innovation. Trajtenberg (1990) concludes that citations are related to the social value created by the innovation; Hall, Jaffe, and Trajtenberg (2005) show that forward citations are related to firm value as measured by Tobin's *Q*. Therefore, our third measure of innovative activity is based on citation count. This is the total number of citations ultimately received by the patents applied for during the given year; as such it takes into account both the number of patents and the number of forward citations per patent.[11]

Survivorship bias is minimal to non-existent in the patent database. An ultimately successful patent application is counted and attributed to the applying firm at the time of application even if the firm is later acquired or goes bankrupt.[12] Furthermore, citations are specific to a patent and not a firm. Therefore, a patent that belongs to a bankrupt firm can continue to receive citations in the database for many years after the firm goes out of existence.

However, owing to the finite length of the sample, citations suffer from a truncation bias. Since 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, we

[11] Citation count includes self-citations. Hall, Jaffe, and Trajtenberg (2005) find that self-citations are more valuable than external citations. They suggest that this is because self-citations (which require generating further related patents) are indicative of the firm's competitive advantage in the relevant technology.

[12] One issue that remains is when a firm goes bankrupt prior to the granting of the patent. It is unclear whether the patent would be assigned to the bankrupt firm in the database. However, the average time between patent application and grant date is only about 2 years, so a firm would need to apply for a patent and go bankrupt almost immediately for this circumstance to arise.

adjust the patent citation count of each patent using the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005), also found 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. *Citation count* is the sum of the adjusted patent citations across all patents applied during each firm-year.

2.1.2 Options-based Measure of CEO Overconfidence

To identify overconfidence, Malmendier and Tate (2005a, 2008) exploit the overexposure of CEOs to the idiosyncratic risk of their firms through their holdings of stock options. Following Malmendier and Tate, we define a CEO as overconfident once she postpones the exercise of vested options that are at least 67% in the money.[13] The *Confident CEO (Options)* variable takes on the value one when she is identified as overconfident, and is zero otherwise. Once a CEO is identified as overconfident under the options-based measure, she remains so for the rest of the sample period. This treatment is consistent with the notion that overconfidence is a persistent trait. In our regression tests, the CEO overconfidence measures are lagged by one period with respect to the dependent variable.

As we do not have detailed data on the CEO's options holdings and exercise prices for each option grant, we follow Campbell et al. (2009) 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

[13] Malmendier and Tate (2005a) further require that the CEO exhibit the late exercise behavior twice, which leads to the use of forward-looking information. Malmendier and Tate (2008) refine their measure and require that the CEO exhibits late exercise behavior only once. In our robustness checks, we require that the CEO holds a 67% in the money option at least twice and define the CEO as overconfident after the first time she exhibits such a behavior. Results are generally similar using this alternative measure.

the average realizable value. The average moneyness of the options is then calculated as the stock price divided by the estimated strike price minus 1. As we are only interested in options that the CEO can exercise, we include only the vested options held by the CEO.

2.1.3 Press-based Measure of CEO Overconfidence

Following Malmendier and Tate (2005b, 2008), we also use a press-based measure of CEO overconfidence. We search Factiva for articles referring to the CEO in the *New York Times*, *BusinessWeek*, *Financial Times*, the *Wall Street Journal*, *The Economist*, *Fortune*, and *Forbes*. Specifically, we retrieve all articles using the available unique company code in Factiva and the search keyword 'CEO.' For each CEO and year, we record (1) the total number of articles, (2) the number of articles containing the words 'confident,' 'confidence,' or variants such as overconfidence and over-confident, (3) the number of articles containing the words 'optimistic,' 'optimism,' or variants such as overoptimistic, over-optimism, (4) the number of articles using 'pessimistic,' 'pessimism' or variants such as over-pessimistic, and (5) the number of articles using 'reliable,' 'steady,' 'practical,' 'conservative,' 'frugal,' 'cautious,' or 'gloomy.' Category 5 also contains articles in which 'confident' and 'optimistic' are negated.

For each year, we compare the number of articles that use the 'Confident' terms, i.e., categories 2 and 3, and articles that use the 'Cautious' terms, i.e., categories 4 and 5. We measure of CEO overconfidence for each CEO *i* in year *t* as

$$\textit{Confident CEO (Press)}_{it} = \begin{cases} 1 \text{ if } \sum_{s=1}^{t} a_{is} > \sum_{s=1}^{t} b_{is} \\ 0 \text{ otherwise,} \end{cases}$$

where a_{is} is the number of articles using the 'Confident' terms and b_{is} is the number of articles using the 'Cautious' terms. We cumulate articles starting from the first year the CEO is in office (for CEOs who assumed office after 1992) or 1992 when we begin our article search and is also the first year of Execucomp data.

Following Malmendier and Tate (2008), we also control for the total number of press mentions over the same period (*TotalMention*). The press may be biased toward positive stories and this would imply a higher number of mentions as 'confident' or 'optimistic' when there is more attention in the press. In our regression tests, the CEO overconfidence measures are lagged by one period with respect to the dependent variable. Thus, only past articles are used to predict innovation. In one of our robustness checks, we define our press-based confidence measure using only news articles in the past one year; the results are quantitatively and qualitatively similar.

2.1.4 Other explanatory variables

When explaining patenting activities, we follow Hall and Ziedonis (2001) in including controls for firm size and capital intensity. We measure firm size using the natural logarithm of sales, measured in 2006 millions of dollars. Similar results are obtained if we use book assets or number of employees as alternative size controls. Capital intensity is proxied by the natural logarithm of the ratio of net Property, Plant, and Equipment in 2006 dollars to the number of employees. When explaining stock return volatility and R&D expenditures, we further include as control variables sales growth, profitability measured by return on assets (ROA), book leverage, and cash holdings. All the regressions include year and industry fixed effects, where the industry is defined at the 2-digit SIC level.

We also include controls that take into account CEO tenure and compensation. We include CEO stock ownership and option ownership, defined as the number of options held by the CEO divided by the shares outstanding. We alternatively use measures of CEO incentives motivated by option pricing theory, CEO delta and CEO option holdings 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 stock price. Vega is the dollar change in a CEO's option holdings for a 1% change in stock return volatility; it measures the risk-taking incentives generated by the CEO's option holdings. We calculate delta and vega values using the one-year approximation method of Core and Guay (2002). All control variables are lagged by one period and winsorized at the 1% level in both tails.

2.2 Descriptive Statistics

Table 1 describes the frequency of overconfident CEOs in our sample.[14] The two measures generate very different average frequencies of overconfident CEOs: 61.35% with the options-based measure, and 7.70% with the press-based measure. However, a CEO-year is more likely to be classified as overconfident by the press-based measure when the CEO-year is overconfident using the options-based measure; out of the CEO-years with non-missing data on both measures, 5.37% of the CEO-years are classified as overconfident by both measures, while only 2.86% are classified as overconfident by the press-based measure when the options-based measure indicates otherwise. The relatively small number of overconfident CEOs by the press-based measure suggests that the press-based measure may be considerably more stringent. If so, those it identifies as overconfident may be more likely to actually be overconfident, but the non-

[14] Steve Jobs of Apple Computers turns out to be overconfident in our sample using both measures of overconfidence.

overconfident category may contain a relatively high number of misidentified overconfident CEOs.

A manager who is identified as overconfident in any year using the options-based measure remains so throughout the sample period. This mechanically tends to induce an increase in the fraction of overconfident managers through the sample period. This is evident in the earlier part of the sample period. However, owing to increased CEO turnover activity (see e.g., Kaplan and Minton 2008), during the second half of the sample period there is a slight decreasing trend in the fraction of overconfident CEOs. Nevertheless, using the options-based measure, the overall fraction of overconfident managers, 61.35%, is only somewhat higher than the fraction in the last year of the sample, 58.77%.

Under the press-based measure, a CEO can sometimes change from being confident to non-confident. This happens when there is an increase in the number of articles in the year that use the 'Cautious' terms relative to articles that use the 'Confident' terms, so that the cumulative number of 'Cautious' articles increases. However, overconfidence as measured by the press-based measure is highly persistent. In our sample, given that in period *t*, the CEO is classified as overconfident, she will still be overconfident 92.71% of the time in period $t + 1$, 86.96% of the time in period $t + 2$, and 82.90% of the time in period $t+3$.

Since we start cumulating articles only in 1992 or later, and classify CEOs with zero news mention as non-overconfident, the number of confident CEOs in the earlier years could be biased downwards. Therefore, in untabulated robustness checks, we perform tests involving the press-based measure only on firm-years from 2000 onward. The results and conclusions drawn are similar.

Table 2 provides descriptive statistics for the variables used in this study. Panel A classifies the sample according to the options-based confidence measure. Consistent with our hypotheses, more confident managers have significantly higher mean and median stock return volatility, R&D/Assets, and citation count.[15] Also consistent with our hypotheses, they have greater mean number of patents applied for and raw citation count, which does not take into account the truncation bias. An overconfident CEO has on average about 10 more patents than a non-overconfident CEO and has about 1.5 times as many citations.

Panel B provides statistics for the press-based measure. As with Panel A, overconfident managers have higher innovation measures; indeed the effects are consistently significant for medians as well as means. Furthermore, compared to Panel A, the effects of overconfident CEO on patenting activities is even larger, consistent with the press-based measure being a more stringent proxy for overconfidence. For example, an overconfident CEO has on average 77.75 patents, while a non-overconfident CEO has only 18.93. Furthermore, an overconfident CEO has about three times as many citations as the non-confident CEO. However, the effect of overconfident CEO becomes insignificant for return volatility.

With respect to the control variables, in Panel A for options-based overconfidence, overconfident CEOs manage firms with smaller firm size as measured by sales, greater sales growth, greater ROA, lower book leverage, lower capital intensity (PPE/emp), and greater cash. The association with greater sales growth is consistent with the finding of Graham, Harvey, and Puri (2009) that tall CEOs tend to be associated with growth firms if, as suggested by several authors, height is a proxy for overconfidence. The association with lower leverage differs from the evidence of Ben-David, Graham and Harvey (2007) that overconfident CFOs (as identified

[15] The citation count variable is significantly higher for overconfident managers in the Wilcoxon-Mann-Whitney test even though the medians in both categories are zero. This can occur because strictly speaking the test is a rank sum test rather than a test of medians (see, e.g., http://www.ats.ucla.edu/stat/mult_pkg/faq/general/mann-whitney.htm).

using their stock market forecasts) use more debt. However, the univariate relation in Panel A is not necessarily causal; there are also differences in sample owing to data restrictions.

Overconfident CEOs also tend to have longer tenure, higher share ownership, higher option holdings, and higher delta and vega values. The last four items make sense, as an overconfident manager who expects to perform well and to take risky projects should be more willing to accept compensation that is more positive sensitive to performance and risk. These findings are also consistent with the evidence of Ben-David, Graham and Harvey (2007) that firms with overconfident CFOs tilt their executive compensation more toward performance-based bonuses.

For Panel B using the press-based measure, some of these relations are different, probably because the press-based measure of overconfidence is much more strongly tilted toward large firms. For example, in contrast with Panel A, in Panel B the sales of firms with overconfident CEOs are on the order of 3-4 times greater than the sales of non-overconfident firms. Given this, it is not surprising that in contrast with Panel A, in Panel B the sales growth rate of overconfident firms is significantly smaller than the growth rate of non-overconfident firms. We do not view this as indicating that low-growth firms try to hire overconfident managers; this is probably just a consequence of the fact that small firms tend to grow more rapidly than large firms. Also in contrast with Panel A but consistent with the CFO evidence of Ben-David, Graham and Harvey (2007), in Panel B firms with overconfident CFOs have higher leverage. Panel B also shows that firms with overconfident managers have greater capital intensity, again possibly driven by their greater size.

3 Overconfidence and Risk-Taking

We hypothesize that overconfident managers are more willing to undertake risky projects because they expect to succeed in such undertakings. Therefore, we examine the relation between CEO overconfidence and overall firm volatility.

In the tests, for each of the options- and press-based overconfidence measures, we use three specifications. Our base specification includes only firm characteristics. In the second specification, we include manager-related controls in some specifications. Our manager-related controls are the natural logarithm of one plus CEO tenure, Log(1+tenure), CEO share ownership, and CEO option holdings. Finally, in the third specification, we replace share ownership and option holdings with the natural logarithm of one plus CEO delta, Log(1+delta), and the natural logarithm of one plus CEO vega, Log(1+vega), which measures the CEO's incentive to increase stock price and firm risk respectively. The regression tests include year and industry fixed effects, defined based on 2-digit SIC codes. Standard errors are clustered at the firm level.

Table 3 provides evidence that CEO overconfidence is associated with greater subsequent realized stock return volatility. We measure stock return volatility as the standard deviation of daily stock returns, expressed in percentage terms. Models (1)-(3) use the options-based measure of overconfidence, and models (4)-(6) use the press-based measure. Following Malmendier and Tate (2008), in all the press-based tests, we additionally control for *TotalMention*, which measures the frequency with which the manager is referred to in the press.

In all the tests, CEO overconfidence is associated with higher subsequent realized stock return volatility. The coefficient in the base model (1) shows that having an overconfident CEO increases daily return volatility by 0.104% ($p < 0.01$). Multiplying this by the square root of about 252 trading days in a year implies that overconfidence increases volatility by about 1.65%

per year. Taking the ratio of 0.104 to the median level of volatility of non-overconfident managers of 2.294 from Table 1 shows that overconfidence increases volatility by about 4.53% above its base level. The coefficients and statistical significance in models (2) and (3) are similar.

As a benchmark for comparison, the coefficient on Log(sales) in model (1) is –0.232, which indicates that a doubling of firm size, as measured by sales, increases volatility by Log(2) * (–0.232) = –0.161% per day, or –0.161% * sqrt(252) = –2.55% per year. So the absolute value of the effect of overconfidence on volatility is smaller than, but of the same order of magnitude as, the effect of doubling firm size.

Using the press-based measure of overconfidence, the effect on volatility is larger. In Models (4)-(6), the coefficients on *Confident CEO (Press)* range from 0.201 to 0.228, all significant at the 1% level. The coefficient in the base model (4) shows that having an overconfident CEO increases daily return volatility by 0.201%. Multiplying this by the square root of about 252 trading days in a year implies that overconfidence increases volatility by about 3.19% per year. Taking the ratio of 0.201 to the median level of volatility of non-overconfident managers of 2.698 from Table 1 shows that overconfidence increases volatility from its base level by about 7.45%.

Consistent with prior literature, Table 1 shows that small, high growth, and high leverage firms tend to have higher stock return volatility. Poorly performing firms and firms with high cash levels also tend to have higher risk (Opler et al. 1999). Perhaps surprisingly, firms in which CEOs have higher vega values have lower stock return volatility.[16]

[16] This could be due to the endogeneity of vega, see e.g., see Coles, Daniel, and Naveen (2006) and Low (2009).

4 Overconfidence and Innovative Activity

We have hypothesized that overconfidence increases innovative investment, as measured by R&D expenditures, and innovative output, as measured by patents and patent citations.

4.1 R&D Expenditures

To test whether overconfidence causes CEOs to increase spending on innovation as measured by R&D expenditures, we use as R&D scaled by assets as dependent variable in the regressions of Table 4. The first two rows show that using either the options- or press-based overconfidence measures, overconfident CEOs spend more on R&D.

The models in columns (1)–(3) using the options-based measure of overconfidence all show a positive and significant effect of overconfidence on R&D at a significance level of 1% to 5%. The coefficient in model (1) shows that having an overconfident CEO increases R&D/Assets by 0.006. Taking the ratio of this to the mean level of R&D/Assets of non-overconfident CEOs of 0.028 from Table 1 (the median is zero) shows that overconfidence increases the amount of R&D by 21.35%, a substantial effect.

In model (2), which includes additional controls that capture managerial characteristics that could affect the incentives to engage in spending on innovation, the coefficient on *Confident CEO (Options)* declines only slightly from the base model, and remains significant at the 5% level. In model (3) the coefficient on *Confident CEO (Options)* becomes a bit higher (0.008), and is significant at the 1% level.

Models (4)-(6) use the press-based measure of overconfidence. The qualitative conclusions are identical to those using the options-based measure, with the economic significance somewhat larger. In model (4), which uses the basic set of firm controls, the

coefficient on overconfidence is 0.009 ($p < 0.05$). The inclusion of managerial controls in model (5) increases the coefficient on overconfidence to 0.012 ($p < 0.01$), and the results are similar when share and option holdings are replaced with Log(1+delta) and Log(1+vega) with the coefficient on overconfidence being 0.011 ($p < 0.01$).

The coefficient in model (4) shows that having an overconfident CEO, as defined using the press-based measure, increases R&D/Assets by 0.009. Taking the ratio of this to the mean level of R&D/Assets of 0.037 from Panel B of Table 1 (the median level is 0.001) shows that overconfidence increases the amount of R&D/Assets by 24.32%, which is again a substantial effect.

We find that higher R&D expenditures are associated with smaller firms and firms with poor profitability, low leverage, higher capital intensity, and higher cash holdings. Furthermore, as in Coles, Daniel, and Naveen (2006), we find that lower delta values and higher vega values are associated with increased spending on R&D.

4.2 Overconfidence and Patenting Activity

We now examine the effect of overconfidence on the fruits of innovative activity as proxied by the number of patents the firm applies for in a given year (and eventually receives). The dependent variable is the natural logarithm of one plus patent count. The control variables in the base model are based on the tests of Hall and Ziedonis (2001) and Aghion, Van Reenen, and Zingales (2009). Table 5 indicates that overconfident CEOs have higher patent counts.

The base model (1) shows that with the options-based measure, overconfident managers are associated with significantly higher patent count ($p < 0.05$). The coefficient in model (1) shows that having an overconfident CEO increases Log(1 + patent) by 0.111. From Table 1

Panel A, the mean number of patents for non-overconfident managers is 21.886, implying Log(1 + Patent) of 3.13. So overconfidence increases this variable by 0.111, to 3.24. This implies an increase in the number of patents to exp(3.24) – 1 = 24.53. This represents an increase in the number of patents by (24.53/21.89) – 1 = 12.06%.

In model (2), the addition of the managerial controls leaves the coefficient unchanged, and the effect remains significant at the 5% level. In model (3), the replacement of the stock and option holding variables with the delta and vega variables causes a modest drop in the size of the coefficient (from 0.111 to 0.086), and the effect becomes marginally insignificant (p = 10.1%). It is not surprising that there would be some loss of significance in model (3), since Log(1+delta) has a fairly high correlation, 0.32, with *Confident CEO (Options)*. Furthermore, the vega control may capture part of the effect of overconfidence that we seek to measure, because an overconfident manager who is prone to risky projects may be more willing to accept compensation schemes that reward risk-taking.

Strongly reinforcing evidence about the effect of overconfidence on patents is provided by the tests that use the press-based overconfidence measure. The coefficients on overconfidence are significant at the 1% to 5% levels, and the coefficients are even more substantial economically (ranging from 0.271 to 0.291). Relative to the mean number of patents for non-confident managers (18.926), model 4 implies 33.32% more patents for firms led by overconfident CEOs. The larger economic significance with the press-based measure is also consistent with the press-based measure being a more stringent measure of overconfidence. Together, the evidence from the options- and press-based measures indicates that overconfidence is associated with a substantially greater number of patent applications.

4.3 Patent Citations

Patents differ greatly in their importance. One measure of their importance is the number of citations that they receive from subsequent patents. To assess whether overconfidence increases the total extent of successful innovative activity, we test for the relation of overconfidence to the number of citations the firm's patents receive. We do not control here for firm-level R&D, so the effect of overconfidence on citations could come from either greater investment in innovation or from higher productivity. We later examine specifically the effect of overconfidence on the firm's innovation controlling for R&D.

Table 6 indicates that firms with overconfident CEOs obtain a greater number of patent citations. The dependent variable is Log(1 + citation count). As discussed in Section 2, to address truncation bias we adjust the raw citation count number for each patent using the weighting index of Hall, Jaffe, and Trajtenberg (2001, 2005) before aggregating across all patents for the firm-year.

The base model (1) uses the same controls as in the tests for patent counts to capture firm scale and capital intensity. Model (1) shows that using the options-based measure, overconfidence increases Log(1 + citation count) by 0.201 ($p < 0.01$). Using calculations similar to those performed with the patent count and comparing with the mean citation count (290.681) for the non-confident CEOs in Table 1 Panel A, this represents an increase in the citation count by 22.38%, an economically substantial effect.

In model (2), the addition of the managerial controls decreases the coefficient slightly to 0.188, significant at the 5% level. In model (3), the replacement of the stock and option holding variables with the delta and vega variables causes a moderate drop in the size of the coefficient to 0.156, but the effect remains significant at the 10% level.

The tests that use the press-based overconfidence measure confirm that overconfidence results in greater citation count. The coefficients on overconfidence are significant at the 1% to 5% levels, and the coefficients are even more substantial, ranging from 0.388 to 0.436, which translates to even greater economic significance. For example, from Table 1 Panel B, the mean citation count for non-overconfident managers is 319.422, and the coefficient on confident CEO in the base model (4) is 0.388, so overconfidence is associated with a 47.55% increase in the citation count.

As in Aghion, Van Reenen, and Zingales (2009), we find that larger and more capital intensive firms have more patent citations. Overall, the evidence from the options- and press-based overconfidence measures indicates that overconfidence is associated with a substantially greater number of patent citations.

4.4 Industry Innovativeness

We expect the effect of overconfidence on innovative outcomes to be much larger in industries in which good opportunities for innovation are available. We therefore split the sample to perform separate tests of the effect of overconfidence in more- versus less- innovative industries. In addition to providing a test of whether industry is important, we expect the test that is limited to innovative industries to be a more powerful way to identify the effects of overconfidence on innovation. We focus on citation count as the dependent variable, but the results using patent count are similar.

We define an industry as innovative if the average citations (adjusted for truncation bias) per patent for the industry during the preceding year is greater than the median average citation across all industries. The percentage of overconfident CEOs in the innovative industry is

somewhat higher than the percentage in the non-innovative industries for both overconfidence measures. Using the options-based measure, the percentage of overconfident CEOs is 63.61% in innovative industries and 56.53% in non-innovative industries. The corresponding figures using the press-based measure are 8.10% and 6.88% for innovative and non-innovative industries respectively.

Table 7 shows that overconfidence increases patent citations only in innovative industries. Within innovative industries, the effect of overconfidence is stronger and has higher statistical significance than the previous tests in Table 6 that pool across all industries. The base model (1) shows that using the options-based measure, overconfidence increases citation count with significance at the 1% level. The coefficient on overconfidence of 0.279 is larger than the corresponding coefficient in Table 6 which pools across all industries, 0.201. This shows that having an overconfident CEO has a greater effect on citations within innovative industries.

In model (2), the addition of the managerial controls leaves the coefficient almost unchanged at 0.281, still significant at the 1% level. In model (3), the replacement of the stock and option holding variables with the delta and vega variables causes a slight drop in the size of the coefficient to 0.260, significant at the 5% level.

The tests that use press-based overconfidence measure show even more strongly that within innovative industries overconfidence results in greater citation count. The coefficients on overconfidence are all significant at the 1% level, with coefficients ranging from 0.549 to 0.613.

Overall, the evidence from the options- and press-based overconfidence measures indicates that within innovative industries, overconfidence is associated with a substantially greater number of patent citations. In sharp contrast, within non-innovative industries, for all of models (1)–(6), the coefficients on overconfidence are close to zero and statistically insignificant.

This suggests that overconfidence encourages patent citations only within industries where there are substantial opportunities for innovation of this type.

5 Robustness Checks and Alternative Hypotheses

In this section, we examine several further robustness checks, and consider alternative hypotheses that can potentially explain our results.

5.1 Robustness Checks

Since focusing on innovative industries provide the most powerful tests of the effects of overconfidence on innovation, it is useful at this point to discuss several robustness checks for the tests that use only firms in innovative industries. The first is to use an alternative method to adjust citation count for truncation bias. We divide the citation count for each patent by the average citations per patent for all patents applied in the same year. The results (not reported) are similar to those in Table 7.

As mentioned earlier, the control variables we use are similar to those in other studies of the determinants of patent citations. If we also include the additional variables used in our tests of the determinants of R&D (sales growth, ROA, book leverage, and cash), the results are similar to those shown in Table 7. The results in Table 6, which pool across innovative versus non-innovative industries, are also generally similar but not all the tests using the options-based overconfidence measure are statistically significant. As discussed earlier, we view tests within innovative industries to be a more powerful way of evaluating the effects of overconfidence.

The independent variables are lagged by one year in our tests. However overconfidence and other variables could have a longer lagged effect on innovation, so we examine the effect of

adding a two year lag on the overconfidence variable and the controls. The results are similar to those in Tables 5-7.

We also consider a Negative Binomial model for the prediction of citation count instead of an OLS regression specification.[17] Since this requires a discrete count variable, for this test we did not perform the truncation bias adjustment (which causes adjusted citations to become continuous). The results are similar to that in Table 7. We also test for the effect of overconfidence on patent counts with a Negative Binomial model. Again, overconfidence increases patent count only among firms in innovative industries.

Since innovation is important in high-tech industries, and the technology boom of 1998-2000 was an exceptional period for these industries, we examine the effects of excluding this period from our sample in the patent count and citation count tests for the overall sample and for firms in innovative industries. The results are generally similar.

As shown in Table 1 Panel B, the average number of articles mentioning the CEO is much smaller for the sample of non-confident CEOs. This is due to the fact that we classify CEOs with zero press coverage as non-overconfident. 5,978 firm-years have zero press coverage. For the press-based confidence measure, when we restrict the sample to the subsample of CEOs for which we have at least one news article, results are similar.

5.2 Alternative Hypotheses

We consider here several alternative interpretations of our findings associated with alternative interpretations of the overconfidence proxies (private information, differences in risk

[17] A Negative Binomial model is preferable to the Poisson model because the likelihood ratio test of no over-dispersion is rejected for all the models.

tolerance, and CEO underestimation of risk), and endogenous matching between CEO and firm characteristics.

5.2.1 Alternative Interpretations of the Overconfidence Proxies

Private Information

A possible concern about the options-based measure of overconfidence is that it may be correlated with private information on the part of the manager, since a manager with favorable information may be inclined to hold the option rather than exercise and sell the stock.[18] Such favorable information could then explain strong subsequent performance in patents and citations.

However, private information should be fairly short-lived, whereas our overconfidence measures are persistent. As in Malmendier and Tate (2005), we view overconfidence as a fairly persistent personality trait. Malmendier and Tate find that overconfident CEOs are late exercisers persistently over time, and do not earn abnormal returns through their decision not to exercise. Furthermore, Carpenter and Remmers (2001) report that there is almost no evidence that managers exercise based upon inside information under the current regulatory regime (in place since May 1991) that allows insiders to sell shares immediately after exercise. So it is unlikely that the effects of overconfidence identified here derive from inside information. Also, the press-based measure of overconfidence is based upon publicly available and widely disseminated information and hence is not a proxy for inside information.

Furthermore, the private information argument suggests that non-exercising CEOs will make better investments. The evidence of Malmendier and Tate (2008) is exactly the opposite;

[18] A special case of this argument is that managers refrain from exercising their options in order to signal favorable information. Malmendier and Tate (2005a) argue that option non-exercise is an implausible vehicle for signaling firm value, and that the financial press and financial advisory firms do not focus on exercise as a value indicator. However, what we emphasize here is that signaling motives do not present any special problem for the options-based measure above and beyond the issue of private information discussed in the main text.

acquisitions made by overconfident CEOs, defined using the options-based measure, perform less well.

Risk-Tolerance

A possible alternative explanation for our findings is that managers who refrain from option exercise are more risk tolerant rather than more overconfident. This willingness to bear risk could then result in greater risk-taking and greater innovation. Furthermore, some of the words used to identify overconfidence using the press-based measure may also be indicators of risk tolerance.

Even if this interpretation were true, it would not overturn one of the key insights of this paper, that there are managerial traits that are systematically associated with greater innovation. Furthermore, as pointed out by Malmendier and Tate (2005a), their evidence that their options-based overconfidence measure is associated with lower investment-cash flow sensitivity is inconsistent with it being a proxy for higher risk-tolerance. Less-risk-averse managers should be more willing to leverage up the firm if necessary to finance investment projects. Malmendier and Tate (2005b) find similar results with the press-based measure of overconfidence.

Underestimation of Risk

A possible concern about the options-based measure is that instead of just overestimating the expected profitability of undertaking new projects, an overconfident CEO may overestimate the precision of their beliefs about the future, and therefore may underestimate risk. This raises a possible concern about the options-based measure, since a manager who underestimates risk will underestimate the value of the option feature. This seems to suggest that overconfident managers

will tend to exercise options early instead of late. In other words, this suggests that the options-based measure is a proxy for *under*confidence rather than overconfidence.

This would be quite surprising, given evidence from several papers (including the current one) that the options-based measure is associated with behaviors predicted by (overestimation-of-mean) overconfidence, and yields results very similar to the press-based option measure (Malmendier and Tate 2005a, 2005b, 2008, 2010). As Campbell et al. (2009) discuss, it is invalid to value a CEO option using no-arbitrage option pricing theory, since CEOs cannot perform the required costless riskfree dynamic hedging strategy. When CEO options are instead valued using expected utility theory, there is an opposing effect: higher volatility makes the option riskier, which encourages exercise in order to sell the stock and diversify. Therefore, underestimation of risk can lead to late exercise.

Overall, theoretical analysis indicates that the effect of higher variance on option value is nonmonotonic (Carpenter, Stanton, and Wallace 2010), and empirically high realized variance is associated with earlier exercise of executive options (Bettis, Bizjak, and Lemmon 2005, Carpenter, Stanton, and Wallace 2009). This suggests that underestimating variance should favor later exercise—consistent with the options-based measure being a proxy for overconfidence, both in the sense of overestimating the mean and underestimating the variance.

5.2.2 Matching between CEO Overconfidence and Firm Characteristics

There are two causally distinct interpretations of the results we have presented so far. One is that overconfidence causes managers to overestimate their prospects for success in risky endeavors and therefore to undertake more innovative activity. The other is that firms that are risky and have strong opportunities for innovative projects appoint overconfident CEOs. Several

authors propose that height is an overconfidence proxy; Graham, Harvey, and Puri (2009) interpret their evidence that growth firms tend to have tall CEOs as consistent with a matching between manager and firm.

One reason to believe that our findings are not driven solely by matching is that all our tests control for industry fixed effects (using 2-digit SIC codes), and several of the tests control for firm characteristics such as sales growth and leverage. To further address matching, we now restrict our sample to focus on a subset of firm-years for which matching is likely to be less important.

CEO overconfidence in our tests is a persistent trait (and with the options-based measure is fully persistent by definition). In contrast, a firm's growth opportunities vary over time as its strategic resources and competitive environment shift. So any matching effects between CEO overconfidence and firm characteristics should be strongest when the manager is first appointed. Therefore, to evaluate whether the effects we identify derive solely from matching, in Table 8 we reexamine the effects of overconfidence after eliminating from the sample all firm-years in which the manager's tenure with the firm was 5 years or less. Table 8 only shows the coefficients on the confidence measures. The control variables and model specifications are the same as in the corresponding earlier tables that use the corresponding dependent variables.

Panel A shows that for both options- and press-based overconfidence measures, overconfidence continues to be positively related to stock return volatility, with significance at the 5% in all models. Panel B shows that for both overconfidence measures, overconfidence positively and significantly predicts the ratio of R&D to assets (with 5% or 1% significance). The coefficients in Panel B are larger than the corresponding coefficients in Table 4, consistent with a causal effect of overconfidence rather than a pure matching effect. Similarly, Panel C

shows that for both overconfidence measures, overconfidence positively and significantly predicts Log(1+ patent) with 5% or 1% significance, and the coefficients are larger than the corresponding coefficients in Table 5. Finally, Panel D shows that for both overconfidence measures, overconfidence positively and significantly predicts Log(1 + citation count) with 5% or 10% significance, and again the coefficients are larger than the corresponding coefficients in Table 6. In summary, while we do not rule out matching effects, these tests are consistent with causality from CEO overconfidence to greater innovation.

6 Overconfidence and Efficiency in Generating Innovation

We have found that managerial overconfidence increases patent applications and patent citations. But since we have also found that managerial overconfidence increases R&D investment, the question remains open of whether managerial overconfidence increases or decreases the effectiveness of the manager in generating innovation for any given level of R&D expenditure. To test whether managerial overconfidence improves the effectiveness of the firm in generating innovation, we regress Log(1+citation count) on the overconfidence measures and add lagged R&D scaled by book assets to the set of controls.[19]

In Table 9, as in the earlier tables, models (1)-(3) use the options-based measure of overconfidence, and models (4)-(6) use the press-based measure. The coefficients on the overconfidence variables among the firms in innovative industries are all positive and significant, and are smaller than the corresponding coefficients in Table 7, indicating that overconfidence increases the effectiveness of innovation for given level of R&D. For the options-based measure

[19] The innovation process normally has considerable lags. However, as discussed by Hall and Ziedonis (2001), much of the earlier patent literature has concluded that it is hard to identify the lag structure for the production of patents from past R&D spending due to high autocorrelation in R&D spending. Therefore, we include R&D spending lagged by only one period. In untabulated results, we follow Hall and Ziedonis (2001) and control for the contemporaneous R&D spending instead. Results are similar to those shown in Table 9.

the coefficients are surprisingly close to those of Table 7, suggesting that the major source of the total increase in innovative output from having an overconfident CEO is the increase in innovation effectiveness. However, for the press-based measure, the coefficients are substantially lower than the corresponding coefficients in Table 7, indicating that both the increase in R&D and increased effectiveness contribute to the overall innovative productivity. When we focus on the firms in the non-innovative industries, none of the coefficients on the overconfidence measures are significant.

Within innovative industries, the base model (1) shows that using the options-based measure, overconfidence increases the citation count ($p < 0.01$).The coefficient on overconfidence of 0.254 is a bit smaller than the corresponding coefficient in Table 7 which does not control for R&D, 0.279, suggesting that a major part of the effect of overconfidence on citation count operates through its effect on increasing the effectiveness of innovation for given R&D.

The findings using the press-based overconfidence measure are similar. The coefficients on press-based overconfidence are all significant at the 5% level, with coefficients ranging from 0.358 to 0.382 among firms in the innovative industries. Overall, the evidence from both the options- and press-based overconfidence measures shows that within innovative industries, overconfident CEOs are associated with greater patent citations after controlling for the amount of innovative investment.

This is surprising, since we would typically expect biased perceptions to lead to error and inefficiency. A possible explanation is that these projects generate patents and citations but not market value. However, evidence from Hall, Jaffe, and Trajtenberg (2005) indicates that patent citations are on average positively related to firm value. Another possible explanation is that

rational risk-averse managers may be too reluctant to take risky but high-expected-return projects. If so, managerial overconfidence can be beneficial for stockholders as a means of encouraging desirable risk-taking. Indeed, this may help explain the puzzle of why overconfident managers are permitted to rise to the CEO position in many firms.[20]

7 Does Overconfidence Affect Firm Value and Performance?

Our proposed solution to the overconfident manager puzzle, that overconfident managers improve innovation, suggests that overconfident CEOs do not necessarily harm firm value or profitability. We therefore examine the effect of overconfidence on future Q, ROA, and Log(Sales). We found earlier that overconfidence increases R&D, which is expensed and therefore mechanically reduces the book value of assets in the short run. Since Q and ROA contain assets in the denominator, it is important to control for lagged R&D in tests with these dependent variables. All the independent variables are lagged by one period with respect to the dependent variables. The conclusions drawn are similar if we lag the independent variables by two or three periods.

The results are reported in Table 10. For brevity, we show results where we control for firm characteristics only. The results are similar if we also include manager-related characteristics, such as tenure, share and option ownership, or CEO delta and vega values. Overall, we find no evidence that overconfidence reduces Q, ROA, or Log(sales). The evidence

[20] It could alternatively be argued that the propensity of overconfident managers to increase risk is desirable for shareholders because it helps them expropriate debtholders. However, if potential debtholders foresee this agency problem prior to issuance, it is equity rather than debt that bears the cost of inefficient risky projects. Furthermore, this argument does not explain why shareholders would hire overconfident managers who make acquisitions that reduce equity value, as found by Malmendier and Tate (2008).

is not entirely consistent across specifications, but there is some indication that these dependent variables are positively related to CEO overconfidence.

For tests where Log(sales) is the dependent variable, we run regressions with and without the ratio of R&D to assets as a control. For both specifications, we find that there is a significant positive relation between CEO overconfidence and subsequent Log(sales). Therefore, controlling for current sales, overconfident CEOs are associated with higher future sales. However, the results are weaker and less consistent if we use Log(assets) as a control instead of Log(sales).

The tests for ROA and Q (in which we control for R&D) are somewhat more mixed. The effect of overconfidence on both ROA and Q is positive and significant using the options-based overconfidence measure but not the press-based overconfidence measure. Overall, it is not clear whether overconfidence increases performance, but there is no sign whatsoever that it reduces performance. This is consistent with the idea that there are advantages as well as disadvantages to CEO overconfidence.

8 Concluding Remarks

Using proxies for CEO overconfidence based upon options exercise and press coverage, we find that over the 1993-2003 period, overconfident CEOs undertake riskier projects, invest more heavily in innovation, achieve a greater total quantity of innovation as measured by patent applications and patent citations, and are more effective innovators in the sense that they achieve greater innovation controlling for the amount of R&D expenditure. Greater innovative output of overconfident managers is achieved only in innovative industries. We find no sign that overconfident CEOs achieve inferior firm performance as measured by sales, ROA, or Tobin's Q.

Our main findings could derive from overconfidence causing innovation, or from innovative firms matching with overconfident CEOs. However, the characteristics of firms evolve over time, so we expect recently-appointed CEOs to be best-matched to the characteristics of the hiring firms. We find that overconfidence remains a strong and significant predictor of innovation even when we remove managers with short tenures at their firms. Intuitively, it would be surprising if innovative firms continued to seek overconfident CEOs if overconfidence were not useful for business needs.

The results of this study have a bearing on the usual presumption that overconfidence is undesirable. Business commentators often point to examples of headstrong, overconfident CEOs who made disastrous decisions. However, the chance of a big defeat may be a corollary to the chance of great victory, so the lesson to draw from examples is unclear. A more serious charge is provided by the evidence of Malmendier and Tate (2008) that the market reacts more negatively to acquisitions made by overconfident CEOs. This dark side to CEO overconfidence might seem to suggest that the CEO selection process should be designed to filter out CEOs with oversized egos, or that compensation and governance should be designed to constrain such CEOs more severely.

On the other hand, a few authors have suggested positive roles for overconfidence, such as improving decision implementation (Russo and Schoemaker 1992), encouraging agents to take sufficient risk on behalf of principals (Goel and Thakor 2008, Gervais, Odean, and Heaton 2009), or countering information externality problems by stimulating entrepreneurship and experimentation (Bernardo and Welch 2001).

Our tests identify empirically a positive side to CEO overconfidence. Within innovative industries, greater confidence results in greater innovation, both on the input side (R&D) and on

the output side (patents and citations). Furthermore, for a given expenditure on R&D, overconfident managers achieve greater innovative success.

Why would overconfidence adversely affect acquisition decisions, yet favorably affect innovation decisions? This may be a natural consequence of the bright sides and the dark sides of CEO overconfidence. We have argued, consistent with Goel and Thakor (2008) and Gervais, Heaton, and Odean (2009), that if managers are risk averse, the willingness to take audacious risks can be valuable to the firm. However, overconfidence may have more adverse effects for external acquisition than for internally-driven innovation. Self-aggrandizing CEOs may engage in excessive empire-building through acquisition because they overestimate their ability to exert effective control over a wider domain.

Our findings therefore suggest a possible solution to the puzzle of why so many firms hire overconfident CEOs and CFOs (Malmendier and Tate 2005a, 2008, Ben-David, Graham and Harvey 2007, Graham, Harvey and Puri 2008), and why such CEOs seem to be placed at the helm of growth firms (Graham, Harvey and Puri 2008)—exactly the kind of firm in which overconfidence will have the greatest effect. The hiring of such managers, and their matching with growth firms, may be efficient if overconfident CEOs are better innovators.

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Appendix A

This appendix defines the variables used in the study. Accounting data is from Compustat, stock return data from CRSP, patent data is from the NBER patent dataset, and compensation data from Execucomp.

Variables	Description
Dependent variables	
Stock return volatility	Standard deviation of daily stock returns over the year, in percentage
R&D / Assets	Research and development expenditures scaled by book assets. Missing values are coded with zero
Patent	No. of patents applied for during the year
Citation (raw) count	Total number of citations summed across all patents applied for during the year
Citation count	Total number of citations summed across all patents applied for during the year. Each patent's no. of citations is multiplied by the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005)
Variables relating to CEO overconfidence, lagged values	
Confident CEO (Options)	Options-based measure of CEO overconfidence. Indicator variable equals to one for all years after a CEO holds options that are at least 67% in-the-money, and zero otherwise
Confident CEO (Press)	Press-based measure of CEO overconfidence. Indicator variable equals one when the no. of "confident" articles for a CEO in Factiva is greater than the no. of "cautious" articles, and zero otherwise
TotalMention	No. of articles mentioning the CEO
Other independent variables, lagged values	
Sales	Firm sales in millions of 2006 dollars
Sales growth	Log transformation of sales divided by prior year sales
ROA	Return on assets, ratio of operating income before depreciation to book assets
Book leverage	Ratio of sum of long-term debt and short-term debt to book assets
PPE / Emp	Ratio of net property, plant, and equipment in 2006 dollars to no. of employees
Cash	Ratio of cash to book assets
CEO tenure	CEO tenure in months
CEO share ownership (%)	% of common stocks held by CEO
CEO option holdings (%)	Total no. of options held by CEO scaled by shares outstanding (%)
CEO delta	Dollar change in CEO stock and option portfolio for 1% change in stock price, in thousands of 2006 dollars
CEO vega	Dollar change in CEO option holdings for a 1% change in stock return volatility, in thousands of 2006 dollars

Table 1. Frequency of overconfident CEOs

The table gives the yearly breakdown of the number of CEOs, number of overconfident CEOs, and percentage of overconfident CEOs in our sample. Sample of CEOs is from Execucomp from 1993 to 2003. Financial and utility firms are deleted. We require that firms have accounting data from Compustat, stock returns data from CRSP, and patent data from the NBER patent dataset. The options-based measure of CEO overconfidence defines a CEO as being overconfident after he holds options that are at least 67% in-the-money. The press-based measure of CEO overconfidence defines a CEO as being overconfident when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. For brevity, overconfident CEOs are labeled as 'confident' in the tables.

	Options-based measure			Press-based measure		
Year	No. of CEOs	Confident CEOs (#)	Confident CEOs (%)	No. of CEOs	Confident CEOs (#)	Confident CEOs (%)
1993	533	228	42.78	564	8	1.42
1994	798	414	51.88	695	22	3.17
1995	857	440	51.34	720	31	4.31
1996	915	524	57.27	781	35	4.48
1997	982	622	63.34	850	59	6.94
1998	1038	715	68.88	931	58	6.23
1999	1059	730	68.93	953	84	8.81
2000	1006	688	68.39	917	97	10.58
2001	980	660	67.35	894	100	11.19
2002	1052	663	63.02	968	103	10.64
2003	1077	633	58.77	973	115	11.82
Total	10297	6317	61.35	9246	712	7.70

Table 2. Summary statistics

The table gives the means and medians of the variables used in this study. The sample consists of all non-financial and non-utility firms in Execucomp from 1993 to 2003. To be included in the sample, firms are required to have accounting data from Compustat, patent data from the NBER patent dataset, and stock returns data from CRSP. Panel A divides the firms based on the options-based measure of CEO overconfidence. Panel B divides the firms based on the press-based measure of CEO overconfidence. The options-based measure of CEO overconfidence defines a CEO as being overconfident after he holds options that are at least 67% in-the-money. The press-based measure of CEO overconfidence defines a CEO as being overconfident when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. For brevity, overconfident CEOs are labeled as 'confident' in the tables. Definitions of the variables are described in Appendix A. *T*-tests (Wilcoxon-Mann-Whitney tests) are conducted to test for differences between the means (medians) for the firms with overconfident CEOs and firms with non-overconfident CEOs. *, **, and *** measure significance at the 10%, 5%, and 1% level, respectively.

Panel A. Options-based measure of confidence

	Non-confident CEO (N = 3980)		Confident CEO (N = 6317)	
Variable	Mean	Median	Mean	Median
Dependent variables				
Stock return volatility	2.689	2.294	3.217 ***	2.879 ***
R&D / Assets	0.028	0.000	0.046 ***	0.008 ***
No. of patents	21.886	0.000	30.302 ***	0.000
Citation (raw) count	139.067	0.000	204.110 ***	0.000
Citation count	290.681	0.000	522.877 ***	0.000 *
Control variables				
Sales	4637.250	1404.500	3592.530 ***	938.469 ***
Sales growth	0.054	0.048	0.171 ***	0.131 ***
ROA	0.134	0.136	0.152 ***	0.158 ***
Book leverage	0.252	0.254	0.208 ***	0.194 ***
PPE / Emp	181264.780	54129.230	132500.420 ***	43920.010 ***
Cash	0.096	0.037	0.158 ***	0.072 ***
CEO tenure	69.435	39.000	104.971 ***	83.000 ***
CEO share ownership (%)	2.297	0.240	2.961 ***	0.645 ***
CEO option holdings (%)	1.193	0.751	1.721 ***	1.237 ***
CEO delta	357.604	127.101	959.904 ***	309.866 ***
CEO vega	100.264	44.936	122.978 ***	45.572

Panel B. Press-based measure of confidence

Variable	Non-confident CEO (*N* = 8534) Mean	Median	Confident CEO (*N* = 712) Mean	Median
Dependent variables				
Stock return volatility	3.048	2.698	3.135	2.735
R&D / Assets	0.037	0.001	0.044 ***	0.013 ***
No. of patents	18.926	0.000	77.750 ***	4.000 ***
Citation (raw) count	137.887	0.000	310.782 ***	4.000 ***
Citation count	319.422	0.000	956.037 ***	19.571 ***
Control variables				
TotalMention	1.267	0.000	10.208 ***	4.000 ***
Sales	2927.830	909.288	8834.060 ***	3910.760 ***
Sales growth	0.133	0.100	0.106 ***	0.073 ***
ROA	0.149	0.152	0.146	0.144 *
Book leverage	0.210	0.197	0.242 ***	0.226 ***
PPE / Emp	128711.110	42917.040	144189.970	58613.660 ***
Cash	0.143	0.060	0.142	0.066
CEO tenure	98.832	70.000	99.166	69.000
CEO share ownership (%)	3.892	0.600	4.128	0.271 ***
CEO option holdings (%)	1.389	0.929	1.122 ***	0.692 ***
CEO delta	755.166	217.181	2440.300 ***	527.040 ***
CEO vega	84.781	34.170	251.902 ***	119.346 ***

Table 3. Overconfident CEOs and stock return volatility

The table presents results of regressions of stock return volatility on CEO overconfidence. Stock return volatility is the standard deviation of daily stock returns over the fiscal year, in percentage. Confident CEO (Options) is an indicator variable equals to one for all years after the CEO holds options that are at least 67% in-the-money. Confident CEO (Press) is an indicator variable equals to one when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. All independent variables are lagged by one year. Definitions of the variables are described in Appendix A. All regressions include year and industry fixed effects, defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors, clustered at the firm level, are reported in parentheses. *, **, and *** measure significance at the 10%, 5%, and 1% level, respectively.

	Dependent variable = Stock return volatility					
	(1)	(2)	(3)	(4)	(5)	(6)
Confident CEO (Options)	0.104***	0.107***	0.098***			
	(0.033)	(0.035)	(0.037)			
Confident CEO (Press)				0.201***	0.226***	0.228***
				(0.065)	(0.069)	(0.069)
TotalMention				0.004	0.003	0.004
				(0.003)	(0.003)	(0.003)
Log(sales)	-0.232***	-0.213***	-0.198***	-0.275***	-0.257***	-0.257***
	(0.013)	(0.014)	(0.017)	(0.016)	(0.018)	(0.020)
Sales growth	0.527***	0.497***	0.497***	0.665***	0.638***	0.633***
	(0.061)	(0.063)	(0.061)	(0.068)	(0.074)	(0.075)
ROA	-3.472***	-3.511***	-3.554***	-3.473***	-3.529***	-3.568***
	(0.195)	(0.204)	(0.203)	(0.207)	(0.224)	(0.224)
Book leverage	0.250**	0.184	0.199	0.292**	0.236*	0.262*
	(0.125)	(0.131)	(0.130)	(0.130)	(0.140)	(0.141)
Log(PPE / Emp)	0.000	0.009	0.010	0.024	0.036	0.034
	(0.022)	(0.022)	(0.022)	(0.025)	(0.027)	(0.027)
Cash	1.502***	1.525***	1.590***	1.166***	1.187***	1.196***
	(0.141)	(0.141)	(0.142)	(0.162)	(0.174)	(0.177)
Log(1+tenure)		-0.030*	-0.021		-0.037*	-0.036*
		(0.018)	(0.019)		(0.019)	(0.021)
Share ownership (%)		0.005			0.000	
		(0.003)			(0.003)	
Option holdings (%)		0.025**			0.034***	
		(0.011)			(0.013)	
Log(1+delta)			0.019			0.003
			(0.017)			(0.018)
Log(1+vega)			-0.062***			-0.027*
			(0.017)			(0.016)
No. of firm-years	10297	9180	9131	9246	8034	7985
No. of firms	1826	1728	1727	1378	1306	1305
Adj *R*-square	0.541	0.546	0.548	0.533	0.532	0.533
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Table 4. Overconfident CEOs and R&D expenditures

The table presents results of regressions of research and development expenditures (R&D) on CEO overconfidence. The dependent variable is the ratio of R&D to book assets. Missing values of R&D are coded with zero. Confident CEO (Options) is an indicator variable equals to one for all years after the CEO holds options that are at least 67% in-the-money. Confident CEO (Press) is an indicator variable equals to one when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. All independent variables are lagged by one year. Definitions of the variables are described in Appendix A. All regressions include year and industry fixed effects, defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors, clustered at the firm level, are reported in parentheses. *, **, and *** measure significance at the 10%, 5%, and 1% level, respectively.

	Dependent variable = R&D / Assets					
	(1)	(2)	(3)	(4)	(5)	(6)
Confident CEO (Options)	0.006**	0.005**	0.008***			
	(0.002)	(0.002)	(0.002)			
Confident CEO (Press)				0.009**	0.012***	0.011***
				(0.004)	(0.004)	(0.004)
TotalMention				0.000***	0.000***	0.000**
				(0.000)	(0.000)	(0.000)
Log(sales)	-0.002**	-0.003**	-0.005***	-0.005***	-0.005***	-0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Sales growth	0.000	0.004	0.005	-0.005	0.001	0.002
	(0.007)	(0.007)	(0.007)	(0.006)	(0.007)	(0.007)
ROA	-0.182***	-0.176***	-0.174***	-0.173***	-0.165***	-0.168***
	(0.030)	(0.030)	(0.030)	(0.031)	(0.032)	(0.032)
Book leverage	-0.035***	-0.037***	-0.038***	-0.026***	-0.030***	-0.032***
	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)
Log(PPE / Emp)	0.003**	0.004***	0.003**	0.005***	0.005***	0.005***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Cash	0.146***	0.141***	0.136***	0.124***	0.118***	0.114***
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Log(1+tenure)		-0.001	-0.002		0.000	-0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Share ownership (%)		-0.001***			-0.001***	
		(0.000)			(0.000)	
Option holdings (%)		0.000			0.001	
		(0.001)			(0.001)	
Log(1+delta)			-0.003***			-0.002*
			(0.001)			(0.001)
Log(1+vega)			0.007***			0.005***
			(0.001)			(0.001)
No. of firm-years	10297	9180	9131	9246	8034	7985
No. of firms	1826	1728	1727	1378	1306	1305
Adj *R*-square	0.430	0.449	0.453	0.409	0.438	0.439
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Table 5. Overconfident CEOs and patent counts

The table presents results of regressions of patent counts on CEO overconfidence. Patent is the number of patents applied for during the year. Confident CEO (Options) is an indicator variable equals to one for all years after the CEO holds options that are at least 67% in-the-money. Confident CEO (Press) is an indicator variable equals to one when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. All independent variables are lagged by one year. Definitions of the variables are described in Appendix A. All regressions include year and industry fixed effects, defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors, clustered at the firm level, are reported in parentheses. *, **, and *** measure significance at the 10%, 5%, and 1% level, respectively. $^{+}$ indicates *p*-value of 10.1%.

	Dependent variable = Log (1 + patent)					
	(1)	(2)	(3)	(4)	(5)	(6)
Confident CEO (Options)	0.111**	0.111**	0.086^{+}			
	(0.046)	(0.050)	(0.052)			
Confident CEO (Press)				0.275***	0.291***	0.271**
				(0.106)	(0.110)	(0.110)
TotalMention				0.026***	0.026***	0.024***
				(0.005)	(0.005)	(0.005)
Log(sales)	0.446***	0.431***	0.368***	0.367***	0.349***	0.326***
	(0.026)	(0.028)	(0.030)	(0.027)	(0.030)	(0.030)
Log(PPE / Emp)	0.192***	0.202***	0.176***	0.213***	0.216***	0.203***
	(0.040)	(0.042)	(0.042)	(0.044)	(0.048)	(0.049)
Log(1+tenure)		-0.015	-0.059**		0.002	-0.030
		(0.025)	(0.025)		(0.025)	(0.025)
Share ownership (%)		-0.010**			-0.013***	
		(0.004)			(0.004)	
Option holdings (%)		-0.014			-0.014	
		(0.013)			(0.014)	
Log(1+delta)			0.034			0.011
			(0.025)			(0.021)
Log(1+vega)			0.132***			0.083***
			(0.027)			(0.022)
No. of firm-years	10297	9180	9131	9246	8034	7985
No. of firms	1826	1728	1727	1378	1306	1305
Adj *R*-square	0.480	0.493	0.501	0.512	0.530	0.532
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Table 6. Overconfident CEOs and patent citations

The table presents results of regressions of patent citations on CEO overconfidence. Citation count is the total number of citations to all the patents applied for during the year. To take into account truncation bias, the raw citation count number for each patent is multiplied with the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Then the adjusted citation count of each patent belonging to a firm-year is aggregated up to the firm-year level. Confident CEO (Options) is an indicator variable equals to one for all years after the CEO holds options that are at least 67% in-the-money. Confident CEO (Press) is an indicator variable equals to one when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. All independent variables are lagged by one year. Definitions of the variables are described in Appendix A. All regressions include year and industry fixed effects, defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors, clustered at the firm level, are reported in parentheses. *, **, and *** measure significance at the 10%, 5%, and 1% level, respectively.

	Dependent variable = Log (1 + citation count)					
	(1)	(2)	(3)	(4)	(5)	(6)
Confident CEO (Options)	0.201***	0.188**	0.156*			
	(0.075)	(0.080)	(0.085)			
Confident CEO (Press)				0.388**	0.436***	0.405**
				(0.159)	(0.161)	(0.161)
TotalMention				0.034***	0.034***	0.030***
				(0.007)	(0.007)	(0.007)
Log(sales)	0.601***	0.572***	0.469***	0.496***	0.461***	0.425***
	(0.038)	(0.041)	(0.045)	(0.042)	(0.046)	(0.047)
Log(PPE / Emp)	0.294***	0.317***	0.275***	0.317***	0.335***	0.313***
	(0.064)	(0.066)	(0.066)	(0.072)	(0.077)	(0.079)
Log(1+tenure)		-0.015	-0.084**		0.013	-0.044
		(0.040)	(0.041)		(0.040)	(0.042)
Share ownership (%)		-0.019***			-0.022***	
		(0.007)			(0.007)	
Option holdings (%)		-0.014			-0.015	
		(0.023)			(0.024)	
Log(1+delta)			0.044			0.024
			(0.041)			(0.035)
Log(1+vega)			0.221***			0.130***
			(0.045)			(0.036)
No. of firm-years	10297	9180	9131	9246	8034	7985
No. of firms	1826	1728	1727	1378	1306	1305
Adj *R*-square	0.457	0.470	0.478	0.484	0.502	0.504
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Table 7. Effect of industry innovativeness

The table presents results from regressions of patent citations on CEO overconfidence, where firms are classified based on whether they belong to an innovative industry or not. An innovative industry is one where the average citation (adjusted for truncation bias) per patent for the industry is greater than the median average citation across all industries. Innovative industry is lagged by one year. Citation count is the total number of citations to all the patents applied for during the year. To take into account truncation bias, the raw citation count number for each patent is multiplied with the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Then the adjusted citation count of each patent belonging to a firm-year is aggregated up to the firm-year level. Confident CEO (Options) is an indicator variable equals to one for all years after the CEO holds options that are at least 67% in-the-money. Confident CEO (Press) is an indicator variable equals to one when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. All independent variables are lagged by one year. Definitions of the variables are described in Appendix A. All regressions include year and industry fixed effects, defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors, clustered at the firm level, are reported in parentheses. *, **, and *** measure significance at the 10%, 5%, and 1% level, respectively.

	Dependent variable = Log (1 + citation count)											
	Innovative industry						Non-innovative industry					
	(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
Confident CEO (Options)	0.279***	0.281***	0.260**				0.019	-0.006	-0.039			
	(0.089)	(0.097)	(0.104)				(0.113)	(0.119)	(0.123)			
Confident CEO (Press)				0.549***	0.613***	0.592***				-0.046	-0.021	-0.053
				(0.199)	(0.200)	(0.199)				(0.211)	(0.226)	(0.223)
TotalMention				0.029***	0.030***	0.025***				0.050***	0.047***	0.045***
				(0.008)	(0.007)	(0.008)				(0.011)	(0.011)	(0.010)
Log(sales)	0.667***	0.628***	0.502***	0.548***	0.502***	0.452***	0.472***	0.467***	0.406***	0.394***	0.383***	0.375***
	(0.046)	(0.049)	(0.054)	(0.050)	(0.056)	(0.058)	(0.053)	(0.055)	(0.062)	(0.057)	(0.060)	(0.063)
Log(PPE / Emp)	0.361***	0.385***	0.319***	0.388***	0.412***	0.372***	0.133*	0.162**	0.154*	0.153*	0.155*	0.156*
	(0.082)	(0.085)	(0.086)	(0.094)	(0.103)	(0.105)	(0.079)	(0.080)	(0.080)	(0.078)	(0.082)	(0.083)
Log(1+tenure)		-0.034	-0.123**		-0.006	-0.083		0.002	-0.037		0.024	0.001
		(0.049)	(0.049)		(0.051)	(0.052)		(0.061)	(0.063)		(0.055)	(0.058)
Share ownership (%)		-0.022**			-0.027***			-0.014*			-0.012*	
		(0.009)			(0.009)			(0.008)			(0.007)	
Option holdings (%)		-0.015			-0.010			-0.004			-0.026	
		(0.029)			(0.032)			(0.025)			(0.027)	
Log(1+delta)			0.064			0.044			0.015			-0.006
			(0.051)			(0.044)			(0.058)			(0.045)
Log(1+vega)			0.258***			0.152***			0.140**			0.074*
			(0.054)			(0.044)			(0.064)			(0.044)
No. of firm-years	7010	6228	6191	6210	5363	5327	3287	2952	2940	3036	2671	2658
No. of firms	1616	1511	1507	1233	1159	1156	813	760	759	663	611	611
Adj *R*-square	0.455	0.467	0.476	0.472	0.495	0.497	0.411	0.429	0.434	0.446	0.468	0.470
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 8. Deleting firms with short-tenured CEOs

The sample consists of all firms where the CEO has tenure of more than 60 months. The table shows the results from regressions of various dependent variables on measures of CEO overconfidence and other control variables. Only the coefficients and standard errors associated with the confidence variables are shown. The control variables and model specifications for regressions involving stock return volatility and research and development expenditures scaled by assets are similar to the ones used in Tables 3 and 4, respectively. The control variables and model specifications involving patent count and citation count are similar to the ones used in Tables 5 and 6, respectively. Confident CEO (Options) is an indicator variable equals to one for all years after the CEO holds options that are at least 67% in-the-money. Confident CEO (Press) is an indicator variable equals to one when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. All regressions include year and industry fixed effects, defined based on 2-digit SIC codes. Standard errors, clustered at the firm level, are reported in parentheses. *, **, and *** measure significance at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Dependent variable = Stock return volatility						
Confident CEO (Options)	0.106**	0.125**	0.105**			
	(0.051)	(0.052)	(0.053)			
Confident CEO (Press)				0.201**	0.207**	0.208**
				(0.085)	(0.087)	(0.087)
Panel B: Dependent variable = R&D / Assets						
Confident CEO (Options)	0.009***	0.008**	0.010***			
	(0.003)	(0.003)	(0.003)			
Confident CEO (Press)				0.013**	0.014**	0.013**
				(0.006)	(0.006)	(0.006)
Panel C: Dependent variable =Log (1+ patent)						
Confident CEO (Options)	0.158**	0.145**	0.142**			
	(0.069)	(0.067)	(0.070)			
Confident CEO (Press)				0.386***	0.373***	0.340**
				(0.142)	(0.142)	(0.142)
Panel D: Dependent variable = Log (1 + citation count)						
Confident CEO (Options)	0.249**	0.213*	0.219*			
	(0.114)	(0.112)	(0.118)			
Confident CEO (Press)				0.546**	0.527**	0.483**
				(0.212)	(0.209)	(0.210)

Table 9. Effectiveness of Innovative Activity

The table presents results from regressions that test the effect of overconfident CEOs on the effectiveness of innovation for given research and development (R&D) expenditure. Firms are classified based on whether they belong to an innovative industry or not. An innovative industry is one where the average citation (adjusted for truncation bias) per patent for the industry is greater than the median average citation across all industries. Innovative industry is lagged by one year. Citation count is the total number of citations to all the patents applied for during the year. To take into account truncation bias, the raw citation count number for each patent is multiplied with the weighting index from Hall, Jaffe, and Trajtenberg (2001, 2005). Then the adjusted citation count of each patent belonging to a firm-year is aggregated up to the firm-year level. Confident CEO (Options) is an indicator variable equals to one for all years after the CEO holds options that are at least 67% in-the-money. Confident CEO (Press) is an indicator variable equals to one when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. All independent variables are lagged by one year. Definitions of the variables are described in Appendix A. All regressions include year and industry fixed effects, defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors, clustered at the firm level, are reported in parentheses. *, **, and *** measure significance at the 10%, 5%, and 1% level, respectively.

	Dependent variable = Log (1 + citation count)											
	Innovative industry						Non-innovative industry					
	(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
Confident CEO (Options)	0.254***	0.242***	0.204**				-0.073	-0.097	-0.120			
	(0.083)	(0.091)	(0.098)				(0.107)	(0.114)	(0.121)			
Confident CEO (Press)				0.358**	0.382**	0.371**				-0.081	-0.041	-0.063
				(0.173)	(0.176)	(0.176)				(0.217)	(0.234)	(0.230)
TotalMention				0.020***	0.021***	0.017**				0.035***	0.035***	0.034***
				(0.007)	(0.007)	(0.007)				(0.009)	(0.009)	(0.009)
Log(sales)	0.775***	0.735***	0.645***	0.688***	0.641***	0.608***	0.602***	0.594***	0.569***	0.534***	0.510***	0.523***
	(0.045)	(0.048)	(0.054)	(0.049)	(0.056)	(0.057)	(0.051)	(0.054)	(0.061)	(0.054)	(0.058)	(0.059)
Log(PPE / Emp)	0.277***	0.297***	0.256***	0.286***	0.318***	0.292***	0.159**	0.191**	0.186**	0.162**	0.168**	0.169**
	(0.075)	(0.078)	(0.079)	(0.085)	(0.095)	(0.096)	(0.077)	(0.079)	(0.079)	(0.076)	(0.082)	(0.082)
R&D/Assets	12.907***	12.998***	12.459***	12.812***	12.230***	12.105***	8.850***	8.191***	7.991***	8.526***	7.536***	7.463***
	(1.003)	(1.022)	(1.008)	(1.087)	(1.142)	(1.131)	(1.402)	(1.396)	(1.402)	(1.671)	(1.738)	(1.733)
Log(1+tenure)		-0.027	-0.095**		0.008	-0.056		0.015	-0.007		0.020	0.011
		(0.046)	(0.046)		(0.048)	(0.049)		(0.059)	(0.060)		(0.053)	(0.056)
Share ownership (%)		-0.010			-0.015*			-0.005			-0.006	
		(0.009)			(0.008)			(0.007)			(0.006)	
Option holdings (%)		-0.029			-0.025			-0.015			-0.042	
		(0.027)			(0.031)			(0.024)			(0.027)	
Log(1+delta)			0.077			0.062			0.014			-0.018
			(0.047)			(0.042)			(0.056)			(0.043)
Log(1+vega)			0.162***			0.086**			0.057			0.033
			(0.051)			(0.041)			(0.064)			(0.042)
No. of firm-years	7010	6228	6191	6210	5363	5327	3287	2952	2940	3036	2671	2658
No. of firms	1616	1511	1507	1233	1159	1156	813	760	759	663	611	611
Adj *R*-square	0.506	0.518	0.522	0.525	0.541	0.542	0.446	0.458	0.461	0.475	0.489	0.490
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 10. Overconfident CEOs and Performance

The table presents results from regressions that test the effect of CEO overconfidence on firm performance as measured by sales, Tobin's *Q*, and return on assets (ROA). All the independent variables are lagged one period with respect to the timing of the dependent variables. Sales is measured in 2006 million dollars. Tobin's *Q* is the ratio of market value of assets to book value of assets, where the market value of assets is equals to the sum of book value of assets and market value of equity less the sum of book value of equity and deferred taxes. ROA is defined as the ratio of operating income before depreciation to book value of assets. Confident CEO (Options) is an indicator variable equals to one for all years after the CEO holds options that are at least 67% in-the-money. Confident CEO (Press) is an indicator variable equals to one when the number of 'confident' articles for a CEO in Factiva exceeds the number of 'cautious' articles. Definitions of the other variables are described in Appendix A. All regressions include year and industry fixed effects, defined based on 2-digit SIC codes. Intercepts are not reported. Standard errors, clustered at the firm level, are reported in parentheses. *, **, and *** measure significance at the 10%, 5%, and 1% level, respectively.

	Dependent variable =							
	Log(sales)		Log(sales)		Tobin's *Q*		ROA	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Confident CEO (Options)	0.076***		0.076***		0.483***		0.017***	
	(0.006)		(0.006)		(0.042)		(0.003)	
Confident CEO (Press)		0.029**		0.032***		0.128		-0.001
		(0.012)		(0.012)		(0.130)		(0.006)
TotalMention		0.002***		0.003***		0.034***		0.001***
		(0.000)		(0.000)		(0.006)		(0.000)
Log(sales)	0.965***	0.956***	0.964***	0.953***	-0.062***	-0.167***		
	(0.002)	(0.003)	(0.002)	(0.003)	(0.023)	(0.028)		
Log(PPE / Emp)	0.007	0.004	0.007*	0.005	-0.004	-0.013	0.005**	0.003
	(0.004)	(0.004)	(0.004)	(0.004)	(0.033)	(0.035)	(0.002)	(0.003)
R&D/Assets			-0.080	-0.215***	8.022***	6.788***	-0.575***	-0.587***
			(0.071)	(0.081)	(0.814)	(0.885)	(0.063)	(0.073)
No. of firm-years	10295	9244	10295	9244	10291	9241	10293	9242
No. of firms	1826	1378	1826	1378	1826	1378	1826	1378
Adj *R*-square	0.978	0.975	0.978	0.975	0.232	0.216	0.172	0.176
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes