Learning About CEO Ability and Stock Return Volatility

Yihui Pan
David Eccles School of Business, University of Utah

Tracy Yue Wang
Carlson School of Management, University of Minnesota

Michael S. Weisbach
Fisher College of Business, Ohio State University, NBER

Consistent with predictions from a stylized Bayesian learning model stock return volatility declines with CEO tenure in a convex manner, even for CEOs whose appointments occur for exogenous reasons. The decline is faster when there is higher uncertainty about the CEO's ability when there is more transparency about the firm's prospects, and when CEO ability is more important in value creation. We quantify the importance of uncertainty about CEO ability relative to the firm's fundamental cash flow uncertainty in contributing to stock return volatility, highlighting the importance of management in creating value. (*JEL* G32, G34, M12, M51)

Any manager's ability to do a new job is, to some extent, unknown. The uncertainty about his ability occurs because of his underlying talent as well as the quality of the match between the job and his personality, skills, or strategic vision. Over time, especially when the manager is a highly visible one like a CEO, his ability to create value at a particular firm will be revealed to the market. For example, JC Penney hired Ron Johnson, a former Apple executive, to be its CEO in 2011. When Johnson's strategy of adopting policies similar to those used by Apple turned out to decrease rather than increase profits, Johnson was fired; his style did not work well at an old-fashioned retailing company like JC Penney as at a technology company like Apple (see *Business Week*, October 22, 2013).

We thank Hengjie Ai, Frederico Belo, Hank Bessembinder, Miguel Ferreira, Shan Ge, Erasmo Giambona, Jarrad Harford, Dirk Jenter, Cami Kuhnen, Katharina Lewellen, Antoinette Schoar, Berk Sensoy, Miriam Schwartz-Ziv, Amit Seru, Kelly Shue, Jerome Taillard, Luke Taylor, Yingdi Wang, Jun Yang, Jianfeng Yu, two anonymous referees, Dave Denis (editor), as well as seminar participants at Brigham Young University, Catŏlica-Lisbon University, the European Finance Association Annual Meeting 2013, FMA Annual Meeting 2013, 2014 Financial Intermediation Research Society Annual Meeting, WFA 2014, the University of Lausanne, Miami University, University of Minnesota, NBER Summer Institute 2013, Ohio State University, 2014 Red Rock Conference, University of Utah, and University of Washington for helpful suggestions. We also thank Jongsik Park for excellent research assistance. Send correspondence to Yihui Pan, Department of Finance, David Eccles School of Business, University of Utah. E-mail: yihui.pan@business.utah.edu.

doi:10.1093/rfs/hhv014 Advance Access publication February 11, 2015

The process through which the market learns about the CEO's ability will affect the way in which it responds to news about the firm, and consequently will impact the firm's stock return volatility. To see why, suppose there is new information about the firm's profits. This news will cause the firm's price to change for two reasons: first, there is a direct effect of the news on the firm's expected cash flows, and second, the news will change the market's expectation of the manager's quality, which will impact expected future cash flows.

We present a stylized Bayesian learning model formalizing this idea in which the latter effect varies over time and across CEOs and firms in predictable ways. When a new CEO takes office, uncertainty about the quality of the new leadership is likely to be high, so any news about the firm will contain information about the CEO's unknown ability, magnifying stock return movements and increasing volatility. Over time, as the CEO's ability becomes more of a "known quantity," the market's update from a particular signal of his quality becomes smaller, leading volatility to decline with CEO tenure. Thus, changes in stock return volatility over a CEO's tenure and variation in the volatility–tenure relation across firm-CEO pairs allow us to draw inferences about the market's learning process (e.g., the factors that affect the speed of learning and the shape of the learning curve) and to quantify the extent to which CEO ability affects a firm's value.

In a sample of 1,873 CEOs in 1,582 U.S. publicly traded firms between 1992 and 2009, we confirm that volatility is indeed unusually high around the time of CEO turnover, and does decrease with tenure. During the first three years following the turnover, idiosyncratic return volatility declines by 14% and total return volatility declines by 10%. We use both polynomial and spline specifications to estimate the volatility–tenure sensitivity, which represents the way in which the market learns about the CEO. Our estimates indicate that this learning curve is convex, with learning being much faster in the first year of the CEO's tenure than in the second and third years. This pattern is consistent with the Bayesian learning model, because a given signal affects rational assessments of ability the most at the beginning of a CEO's tenure, when uncertainty about his ability is highest.

The interpretation we make throughout the paper is that the decline in volatility over CEO tenure occurs because learning reduces the uncertainty about management over time. However, an alternative interpretation to learning is that CEO turnovers tend to occur at times of high fundamental uncertainty. To identify the extent to which the patterns in volatility over CEO tenure reflect learning or endogenous timing of turnovers, we identify three subsamples of turnovers that are unlikely to be performance driven: first, turnovers occurring because of deaths, health issues, or normal retirements of outgoing CEOs; second, turnovers that are not followed by changes of any other top management positions; and third, turnovers following above-average stock and accounting performance and low stock return volatility. In each subsample, we observe a convex decline in volatility following the turnover, consistent with the idea that the post-turnover declines in stock return volatility occur because of learning about management ability rather than the tendency of turnovers to happen at times of high volatility.

Another reason why firms' volatilities could change subsequent to CEO turnovers is that CEO turnovers are often followed by substantial real changes to the firm, such as expansions, divestitures, or new product developments, which could affect the fundamental volatility of the firm. If these real changes tend to cluster in the early periods of CEO tenure and decrease in intensity over time, then we could observe declining volatility over CEO tenure even without any uncertainty about the CEO. In addition, CEO turnovers can also facilitate revelation of (negative) information about the firm's fundamentals that has been withheld by the previous management (e.g., accounting write-off, earnings restatement, and fraud investigation). We evaluate the extent to which both anticipated and implemented post-turnover corporate real actions and disclosures could lead to a spurious relation between tenure and volatility. Our results suggest that controlling for these actions has little impact on the estimated volatility–tenure sensitivity.

Our model allows us to quantify the magnitude of uncertainty about CEO ability relative to the firm's fundamental cash flow uncertainty. Bayesian updating implies that the speed of learning at a given point of time equals the ratio of these two types of uncertainty at that time. Our estimates indicate that at CEO turnover, uncertainty about management quality accounts for about one-quarter of the total stock return volatility. These results provide initial estimates of the extent to which uncertainty about management quality can contribute to the overall firm uncertainty and stock return volatility.

We perform a series of tests designed to understand the way in which the market learns about management ability. We first examine the way that the market reacts to salient corporate news that could potentially be used to draw inferences about CEO ability. The learning model suggests that corporate news early in a CEO's career should be more informative about the CEO's ability than news arriving later, so it should lead to larger market updates and stock price movements. We evaluate this prediction using data on four types of news: expansions/downsizing, new products, dividend changes, and earnings surprises. For each type, our results suggest that the absolute value of stock price reactions to news declines at a decreasing rate with CEO tenure.

In addition, Bayesian updating implies that the market reaction to news depends on whether the news confirms or contradicts the market's belief about CEO ability at that time. Our estimates suggest that as a CEO's tenure lengthens, presumably reflecting favorable updates about his ability, market reaction to good earnings news, which are more likely to be confirming news, becomes increasingly smaller relative to reaction to bad earnings news, which are more likely to contradict the updated posterior.

Third, our estimates suggest that actions that are more informative about CEO ability, such as new product and acquisition announcements, speed up market learning more than routine capital expenditures announcements that do not require as much discretion from the CEO. The results are consistent with the idea that a component of stock price reaction to news is related to learning about the CEO's ability, and that this component depends on the timing, nature, and quality of news.

We also examine the cross-sectional determinants of the learning speed at the industry and the firm-CEO levels. The learning model suggests that learning should be faster when initial uncertainty about the CEO's ability is higher and when firm disclosure is more informative. To test these predictions, we estimate the sensitivity of volatility to tenure for each firm-CEO pair in our sample and then measure the extent to which it is related to the initial uncertainty about the CEO and the informativeness of potential signals. Our estimates suggest that learning about CEO ability is significantly faster in more transparent firms, and for CEOs with higher prior uncertainty (e.g., outsider CEOs, younger CEOs, and less experienced CEOs). Across industries, learning appears to be fastest in the technology industry and slowest in the utilities industry.

Finally, since learning speeds provide a novel way of measuring the fraction of volatility explained by uncertainty of management, the cross-sectional differences in learning speeds also shed new light on differences of the importance of CEO ability to firm value across industries. Our results suggest that learning is faster in more competitive industries and in industries in which firms do more R&D and introduce new products more frequently. Therefore, CEOs appear to matter more in more competitive, dynamic industries.

The existing literature has used two approaches to assess the value of a CEO. First, it has studied the way that firm strategies vary with heterogeneous CEO "styles" (Bertrand and Schoar 2003). This approach identifies the impact of the CEO by relating observable CEO attributes or CEO fixed effects to firm policies. The second approach is to draw inferences about the value of CEO based on changes in stock prices and cash flows following rare events such as CEO death (Johnson et al. 1985; Bennedsen, Pérez-González, Nielsen, et al. 2007) or hospitalization (Bennedsen, Pérez-González, and Wolfenzon 2013). Our study contributes to this literature by estimating the fraction of stock price movements that occur because of uncertainty about management. Our estimates of the importance of CEO based on the second moment of stock returns for a large sample of CEOs also complement existing estimates based on the first moment of stock prices in small samples.

A literature in asset pricing started by Timmermann (1993) and Pastor and Veronesi (2003) argues that the market's learning about firms' cash flow–generating process contributes to firms' stock return volatility. Our study contributes to this literature by isolating the process of learning about an important source of value, the quality of the firm's management.

Our study also draws on a literature inspired by Holmström (1999) that explains aspects of management incentives and governance using the learning process about management ability as one key ingredient (see Gibbons and

Murphy 1992; Hermalin and Weisbach 1998, 2012; Milbourn 2003; Hermalin 2005; and Taylor 2010).[1] Our results suggest that the process by which the market learns about the manager's ability can be well characterized by a Bayesian learning model.

Two particularly related papers are Clayton, Hartzell, and Rosenberg (2005) and Taylor (2013). Clayton, Hartzell, and Rosenberg (2005) document an increase in stock return volatility around CEO turnovers, especially after forced turnovers and outsider successions. Our analysis builds on Clayton, Hartzell, and Rosenberg (2005), and pins down the way in which learning about CEO ability affects volatility. In contrast to Clayton et al., we focus on the dynamics of post-turnover volatility in our empirical work, as the learning model implies that market learning about ability is naturally measured by the decline of volatility over the CEO's tenure. In addition, we consider alternative explanations to learning for why volatility tends to be high following CEO turnovers; this identification issue is particularly pronounced for forced turnovers and outsider successions. By isolating the impact of uncertainty about CEO ability on stock price movement, we are able to quantify the substantial valuation effect of management uncertainty.

Taylor (2013) uses a Bayesian learning model to examine the sharing of surplus from learning between the firm and its CEO. As part of his analysis, Taylor (2013) derives and graphs the relation between stock return volatility and CEO tenure. He then uses the average yearly firm-level return volatility for ten years following CEO turnover as part of the moments to estimate a learning and bargaining model structurally. However, the research questions in our papers are very different: Taylor focuses on the way learning affects the bargaining power between firms and CEOs, while we aim to understand the market learning process itself, how corporate disclosure and real actions affect this process, the cross-sectional differences in the speed of learning, and the way that these estimates can be used to understand the overall importance of the CEO choice to the firm.

1. Uncertainty About CEO Ability and Stock Return Volatility: A Simple Model

In this section, we develop a stylized model based on Pastor and Veronesi (2003, 2009) to formalize the link between uncertainty about CEO ability and stock return volatility. This model provides clear predictions about the factors that determine the speed of learning and guides the quantitative volatility decomposition in Section 4.

In the model, managers have an unknown "ability" that affects their firms' profits. Over time, market participants draw inferences about this ability when

[1] In addition, several studies apply the learning framework to understand managerial incentives in the money management industry (e.g., Berk and Green 2004; Chung et al. 2012; and Lim, Sensoy, and Weisbach 2015).

news about a firm arrives. When there is uncertainty about CEO ability, news about a firm has two effects on that firm's expected future prospects. First, the news can lead the market to update its expectation about the firm's future profits directly. Second, the news can also lead the market to update its assessment of the manager's ability, and thus indirectly change the expected future profits from the change in the assessment of ability. This indirect effect through learning about managerial quality will augment the direct effect of news on expected profitability, leading to higher stock return volatility.

We assume that stock prices are formed based on an efficient market with a representative agent:

$$P_t = \frac{1}{1+r} E(P_{t+1} + D_{t+1} | I_t), \tag{1}$$

where P_t is the stock price at time t; D_{t+1} is the dividend (or equity earnings) at time $t+1$; r is the constant expected rate of return; I_t denotes the information set of investors at the end of t. We assume that the firm's dividend process follows the geometric Brownian motion with a drift that depends on CEO ability:

$$\frac{dD_t}{D_t} = \alpha dt + \sigma dW_t, \tag{2}$$

where α is the (true) CEO ability that determines the average dividend growth rate, σ reflects the volatility of the firm's dividend or earnings growth, and dW_t is a Wiener process. We refer to σ as "fundamental volatility" because it represents the volatility that the firm would have absent uncertainty about the CEO's ability. We assume that α follows a truncated normal distribution with prior mean θ_0 and variance δ_0^2, and $\alpha < r$ with probability one as we only consider nonexplosive solutions. While investors cannot directly observe α, they continually update their belief about it according to Bayes' rule. At any time t, we have

$$\alpha_t \sim N(\theta_t, \delta_t^2), \alpha_t < r \tag{3}$$

$$d\theta_t \approx m_t \left[\frac{dD_t}{D_t} - \theta_t dt \right], \quad \text{with} \quad m_t = \frac{\delta_t^2}{\sigma^2} \tag{4}$$

$$\delta_t^2 = \frac{\sigma^2 \delta_0^2}{\sigma^2 + \delta_0^2 t} \tag{5}$$

Equations (4) and (5) represent Bayesian updates of θ and δ^2 (see, e.g., Pastor and Veronesi 2009). Equation (4) is an approximation because α follows a truncated normal distribution, and holds exactly only when α is nontruncated normal. Intuitively, if the term in the bracket is positive, the agent observes a better than expected signal, so he revises the expectation upward. Conditional on the surprise, the magnitude of the revision depends on the multiplier m_t, which we refer to as the "speed of learning" about managerial ability and equals the ratio of uncertainty about the CEO's ability δ_t^2 to the firm's fundamental cash flow uncertainty σ^2. Equation (5) implies that uncertainty about the CEO's ability, δ_t^2, decreases over time due to learning, and δ_t^2 is convex in t. Consequently, the above equations imply that there should be a decreasing and convex learning curve about CEO ability, because of faster updating about CEO ability in earlier periods. We mainly focus on the second moment in this paper, because unlike θ, the evolution of δ over time does not depend on the realizations of the signals.

In this setup, we obtain the following equation about stock return volatility:

$$vol\left(\frac{dP_t}{P_t}\right) \approx \sigma \times \left[1+\left(\frac{\partial \log(P/D)_t}{\partial \theta_t}\right) m_t\right] \tag{6}$$

Equation (6) characterizes the way in which market learning about CEO ability influences the firm's stock return volatility. It implies that a firm's stock return volatility contains two components: the fundamental volatility and the volatility due to the market learning of the CEO's ability (see Appendix A for proof).[2]

The expression $\partial \log(P/D)_t / \partial \theta_t$ represents the marginal return to expected CEO ability: when it is positive, a shock to the perceived ability translates to greater movements in stock prices, and when it equals zero, uncertainty about CEO ability will affect neither firm value nor return volatility. Therefore, the first empirical implication of Equation (6) is that if CEO ability matters for firm value, then the firm's stock return volatility should increase with the speed of learning m_t and thus the amount of uncertainty about the CEO's ability (δ_t^2). Second, over time, as the market learns about α, m_t and therefore δ_t^2 should decline, leading stock return volatility to decline as well and eventually converge to the level of fundamental volatility ($vol\left(\frac{dP_t}{P_t}\right) \rightarrow \sigma \ as \ \delta_t \rightarrow 0$).[3] Third, since the decline of δ_t^2 in t is convex, stock return volatility should also be decreasing in t in a convex manner.[4]

Equations (4), (5), and (6) suggest that, holding other factors constant, a more negative volatility–tenure relation over a CEO's tenure reflects a faster learning speed (m_t). The model establishes a link between the empirically estimable volatility–tenure relation and the concept of learning speed formalized by this model. Thus, the model provides a roadmap for inferring the nature of market

[2] We can also obtain a result similar to Equation (6) in a two-state continuous time Bayesian learning model, in which CEO ability is assumed to be high with probability π_t and low with probability $(1-\pi_t)$. With this distributional assumption, an equation comparable to Equation (6) holds exactly. We focus on the case in which ability is distributed normally because the posterior variance is characterized by the formula presented in Equation (5) and is a monotonic function of time, which provides cleaner guidance for the empirical analysis.

[3] The model presented here assumes that CEO ability α is constant over time so that the uncertainty about it δ_t^2 converges to zero. If CEO ability changes over time, then the uncertainty about it converges to a stationary level above zero (e.g., Holmström 1999). In this case, the stock return volatility will always be above the level of fundamental volatility.

[4] The model in Pastor and Veronesi (2003) endogenizes the discount rate. In that model, learning affects the firm's idiosyncratic risk, but not its systematic risk and the expected rate of return. Our simpler model with constant discount rate cannot speak to this point. However, we do provide empirical evidence suggesting that systematic risk does not change with CEO tenure in a similar way to idiosyncratic risk.

learning about CEO ability based on the dynamics of stock return volatility, as well as cross-sectional variation in learning speeds.

2. Empirical Design and Specification

2.1 CEO tenure and stock return volatility

The model presented above suggests that the market will update its assessments about CEO ability the most when uncertainty about ability is highest, presumably when a new CEO takes office. At the time of turnover, the market will have relatively diffuse priors about the CEO's ability and strategy for managing the firm. Any news will lead to relatively large updates of the market's assessment of the CEO's ability α and consequently large stock price movements. As α becomes known more precisely, the impact of new information on the market's estimate of α declines, lowering stock price movements and return volatility. For this reason, we consider a sample of CEO turnovers and draw inferences about the process by which the market subsequently learns about the new CEOs' abilities.

The underlying assumption in this argument is that the fundamental uncertainty of the firm unrelated to the CEO change remains relatively stable over the learning period. There are at least three reasons why fundamental volatility could in fact be correlated with turnovers in the data. First, CEO turnovers could tend to occur at times of high uncertainty about the firm's fundamentals. To evaluate this possibility and to isolate the effect of learning, we examine the pattern around "exogenous" turnovers that are likely to be unrelated to other sources of uncertainty about the firm's value.

Second, CEO turnovers are often followed by substantial real changes in the firm that could directly affect the firm's fundamental uncertainty. If these real changes tend to cluster in the early periods of CEO tenure and decrease in intensity over time, then we could observe declining volatility over CEO tenure even without any uncertainty about the CEO. For this reason, we control for both anticipated and implemented post-turnover corporate real actions when estimating the volatility–tenure relation.

Third, CEO turnover could increase the likelihood of the revelation of (negative) information about the firm's fundamentals that had been withheld by the previous management. The new information could accelerate the market's update about the firm's expected profitability and contribute to the increase in return volatility around CEO turnover. To address this possibility, we also control for information disclosure immediately after CEO turnover through announcements of accounting write-offs, earnings restatements, securities fraud investigation, divestitures, and termination of investment.

Because a firm's fundamental uncertainty is more likely to change over a relatively long horizon, we focus our analysis throughout the paper on the first thirty-six months of a CEO's tenure, and control for other factors that could affect volatility econometrically. In addition, we use relatively high-frequency data (monthly and in some analysis even daily) so that it is unlikely that an average firm's fundamentals change substantially within one time unit.

2.2 Sample construction

We start with 24,780 firm-year observations from 1992 to 2006 for which we can identify the CEOs from the ExecuComp database. We use information on job title, the date becoming CEO, and the CEO annual flag provided by ExecuComp to identify CEOs at the firm-year level. For each CEO, the calendar year-month in which the CEO takes office is designated as event month 0. We exclude turnover events involving transitory CEOs such as turnaround specialists and interim CEOs (with tenure shorter than three years), although we do include the short-term CEOs in a robustness check. This process leads to a sample of 1,873

Table 1
Summary statistics

Panel A: Turnover year distribution

Became CEO year	Freq.	Percent
1992	125	6.67
1993	125	6.67
1994	129	6.89
1995	115	6.14
1996	109	5.82
1997	126	6.73
1998	129	6.89
1999	140	7.47
2000	146	7.79
2001	154	8.22
2002	110	5.87
2003	120	6.41
2004	113	6.03
2005	129	6.89
2006	103	5.50
Total	1,873	100

This table reports the distribution of turnover years. The sample contains all CEO turnover events in S&P 1500 firms from 1992 to 2006 identified in ExecuComp for CEOs that have tenure of three years or longer. We use the information on job title, the year becoming CEO, and the CEO annual flag provided by ExecuComp to identify CEOs at the firm-year level. The turnover year is identified as the year of "becameceo" in ExecuComp.

Panel B: Volatility and risk factor measures

Variable	Obs.	Mean	25th percentile	Median	75th percentile
Option-implied volatility	35,614	16.665	10.911	14.718	20.325
Realized return volatility	68,150	11.884	6.636	9.700	14.649
Idiosyncratic volatility	64,899	9.907	5.378	8.011	12.275
Market beta	68,150	1.060	0.378	0.979	1.662
SMB beta	68,150	0.620	−0.357	0.459	1.449
HML beta	68,150	0.268	−0.801	0.296	1.397

This table reports the summary statistics for the three monthly volatility measures (in percentage) and firm-level monthly estimated loadings on the three Fama-French risk factors during the thirty-six months after a new CEO takes office. The calendar year-month in which the CEO takes office is identified with the variable *becameceo* in ExecuComp. Data on option-implied volatility are obtained from Option Metrics and available starting from 1996. Other volatility measures and factor loadings are estimated using CRSP data, as well as monthly factor data from Kenneth French's data library. All variable definitions are in Appendix B.

(*continued*)

Table 1
Continued

Panel C: Likely exogenous vs. forced turnovers

	Obs.	Sample median cum. industry-adj. return in month [–12,–1]	Sample median industry-adj. monthly IVOL in month [–12,–1]
(1): Turnovers due to death or illness	65	3.1	7.1
(2): Death/illness/retirement at good performance	192	6.5	7.1
(3): No management shakeup	291	−0.8	7.9
(4): Pre-turnover ind-adj. IVOL ≤ 0 and stock return ≥ 0 and ROA ≥ 0	450	7.6	6.5
(5): (2) or (3) or (4)	623	5.2	6.8
(6): Not classified as likely exogenous or forced	978	0.0	7.6
(7): outright forced	101	−8.3	9.8

This table reports the number of observations, the median pre-turnover twelve-month cumulative industry-adjusted stock return (in percentage) and the pre-turnover median industry-adjusted monthly idiosyncratic volatility (in percentage) for each type of CEO turnover. Month 0 is the new CEO's inauguration month. We distinguish between turnovers that are unlikely to be performance motivated and those that are likely to be. The likely non-performance-motivated turnovers include (1) turnovers due to death/illness of the departing CEOs, (2) turnovers due to death/illness/retirement at good firm performance (the firm's pre-turnover ind-adj. stock return ≥ 0), (3) turnovers not accompanied by subsequent management shakeup, (4) turnovers that satisfy three conditions: pre-turnover ind-adj. idiosyncratic volatility ≤ 0, pre-turnover ind-adj. stock return ≥ 0, pre-turnover ind-adj. ROA ≥ 0, (5) the union of (2), (3), and (4). Turnovers that are likely related to poor performance include the outright forced turnovers based on news search in row (7). Row (6) contains turnovers that are not in other categories so are not classified as "likely exogenous" or "forced." All relevant definitions are provided in Appendix B.

Panel D: Firm attributes

Variable	Obs.	Mean	25th percentile	Median	75th percentile
Div. payer	5,095	0.550	0	1	1
Leverage	5,077	0.195	0.030	0.161	0.306
M/B	5,095	2.540	1.424	2.129	3.524
Log(Assets)	5,095	7.212	5.931	7.138	8.407
VOLP	4,878	0.569	0.253	0.287	0.436
ROE	4,878	0.079	0.041	0.119	0.186

This table reports the summary statistics of firm attributes that we use as control variables. The observations are at the firm-year level for the first three years after each CEO turnover in our sample. Variables definitions are provided in Appendix B. Data on company attributes are provided in Compustat. Our sample includes S&P 1500 firms over the period 1992–2009 with identifiable CEO turnovers from 1992 to 2006.

CEO turnovers at 1,582 firms. Panel A of Table 1 describes the distribution of turnovers over time.

We classify CEOs based on their succession origin. Using information on the time of a CEO "joining company" from ExecuComp, supplemented by the data on "starting job" from Boardex, we classify CEOs who have been with the firm for less than three years when becoming CEO as outsider CEOs, and those who have been with the firm for at least three years as insider CEOs. Based on this classification, about 33% of new CEOs in our sample are considered as outsider CEOs.[5]

[5] This fraction is consistent with those reported in other studies such as Parrino (1997), Murphy and Zabojnik (2007), and Cremers and Grinstein (Forthcoming).

2.3 Stock-return volatility

We calculate the firm's volatility during the first thirty-six months of new CEOs' tenures. We rely on three measures of monthly firm-level equity volatility: *Option-implied volatility, Realized return volatility,* and *Idiosyncratic return volatility. Option-implied volatility* is the monthly average of the implied volatility calculated based on the daily prices of the thirty-day at-the-money call options written on the firm's common stock. This measure reflects the market's forward-looking assessment of the firm's risk. *Realized return volatility* is the standard deviation of daily stock returns within a month, based on data from CRSP. To estimate *Idiosyncratic return volatility*, we follow Ang et al. (2006) and calculate the monthly volatility of the residual stock return of the Fama-French three-factor model:

$$r_t^i = \alpha^i + \beta_{MKT}^i MKT_t + \beta_{SMB}^i SMB_t + \beta_{HML}^i HML_t + \varepsilon_t^i. \quad (7)$$

Idiosyncratic return volatility is defined as $\sqrt{Var(\varepsilon_t^i)}$ from the above equation. All three volatility measures are calculated for each firm-month in the three years after each CEO turnover in our sample and are converted to the monthly level by multiplying them with $\sqrt{21}$, the square root of the average number of trading days in a month.

Panel B of Table 1 reports statistics on the volatility measures. Data for *Realized return volatility* and *Idiosyncratic return volatility* are from 1992 to 2009, and data for *Implied volatility* are from 1996 to 2009, as OptionMetrics data are available only since 1996. The average monthly option implied volatility is 17%, the average realized monthly volatility is 12%, and the average monthly idiosyncratic volatility is 10%. We also report the summary statistics of the monthly betas on the three Fama-French factors, which measure the firm's systematic risks. The average market beta in our sample is 1.06, the average small minus big (SMB) beta is 0.62, and the average high minus low (HML) beta is 0.27.

2.4 Reasons for turnovers

Firms are generally secretive about the true reasons for CEO changes and usually offer bland, uninformative reasons when announcing CEO departures (e.g., he wants to "spend more time with his family").[6] One can, however, classify some subsamples of turnovers as, with high probability, either exogenously occurring, or outright forced. One group of turnovers that are likely to be exogenously occurring are turnovers caused by illness, death, or retirement of the departing CEOs. We use Factiva news search to identify such exogenous turnovers.[7] To mitigate the incidence of "suspicious" retirement

[6] See Warner, Watts, and Wruck (1988) or Weisbach (1988) for more detail. Schwartz-Ziv and Weisbach (2013) use private data on board meetings to document details of specific cases in which CEOs are forced out of their jobs, but for which one could never tell so using publicly available information.

[7] We thank Edward Fee, Charles Hadlock, and Joshua Pierce for kindly providing us with the classification of illness, death related, and outright forced turnovers.

announcements, we additionally require that the firm's stock performance in the year prior to the turnover be above the industry-year median for the turnover to be classified as due to retirement.

A second group of turnovers that are likely to be exogenously occurring are those that are not accompanied by any shakeup in the top management team. Therefore, we consider the subsample for which the top four most highly paid non-CEO executives do not change in the first thirty-six months of the new CEO's tenure. Third, because forced turnovers tend to be preceded by high stock return volatility or poor firm performances, we consider the subsample of turnovers following both good performance (both stock return and return on assets [ROA] above industry-year median) as well as low idiosyncratic volatility (below industry-year median). Finally, we use the Factiva news search to identify 101 turnovers that appear to be overtly forced (e.g., Factiva reported that the CEO was forced to leave or left under pressure).

Panel C of Table 1 reports the number of observations and the pre-turnover performance of the different subsamples of turnovers. The sample contains 65 turnovers occurring because of death or health issues of outgoing CEOs, 192 because of death or health issues or retirements following good performance, 291 turnovers that are not accompanied by top management shakeups, and 450 turnovers preceded by good performance and low volatility. The union of these three categories accounts for 37% of the entire turnover sample (623 out of 1,702).[8] In contrast, outright forced turnovers represent only 6% of the turnover sample.[9] The turnovers that did not fall into one of the "likely exogenous" subsamples or the outright forced subsample compose the remaining 57% of the sample. In fact, these turnovers are similar to the turnovers identified as unlikely to be performance driven in terms of the pre-turnover stock performance and volatility. This finding suggests that the vast majority of CEO departures are unlikely to be performance-based firings.

2.5 Corporate news

The underlying mechanism in the learning model is that agents should update their priors about management based on available news about the firm. Therefore, we consider corporate announcements on (i) three types of actions that have real effects on the firm's asset portfolio: downsizing, expansion, and introduction of new products; and (ii) three types of actions that reveal negative information about the firm's fundamentals: accounting write-offs, earnings restatements, and securities fraud investigations.

For each type of action except the revelation of fraud, we obtain information about action announcement from the "Key Developments" database from

8 The total number of turnovers in our sample period is 1,873 (see Panel A of Table 1). However, there are 171 turnovers with insufficient pre-turnover performance or volatility data, and thus are excluded from the analysis.

9 The small number of outright forced turnovers is consistent with the institutional evidence that firings of CEOs are relatively rare events. Using an interview-based approach, Vancil 1987, 82–83) estimates that only 10% of CEOs during 1960 to 1984 left involuntarily.

Capital IQ, which starts in 2001, and SDC Platinum, which contains announcement dates for mergers and acquisitions (M&A) transactions. We classify announcements as "downsizing" if they contain announcements of "seeking to sell/divest" and "discontinued operation/downsizing." "Expansion" announcements are those containing "seeking acquisitions/investment," "business expansion," or acquisition announcements. "New product" announcements contain announcements that are related to new product releases. "Restatement/write-off/fraud" contains announcements of "restatement of operating profits," or "impairments/write-offs." We augment this category with announcements about securities fraud investigations from the Federal Securities Regulation (FSR) database (Karpoff et al. 2014), which contains all financial misrepresentation cases prosecuted by the SEC during our sample period. For each type of action, we create a dummy variable that equals one if there is related announcement in a particular month. About 5% of firm-month observations during the first thirty-six months after turnovers contain downsizing announcements, 12% contain expansion announcements, 13% contain new product announcements, and 1% contain restatement/write-off/fraud announcements.

2.6 Other variables

We control for observable firm attributes that could capture differences in average dividend growth rates across firms (profitability measured by return on equity [ROE], dividend dummy, leverage, market equity to book equity [M/B], and log(Assets)) or differences in the fundamental volatility in the dividend growth rate (volatility of profitability, monthly betas on three Fama-French factors). Panel D of Table 1 contains summary statistics of these control variables for three firm-years after each turnover. The firms in our sample are covered by ExecuComp and thus are S&P 1500 firms. About 55% of them pay common dividends. The average firm in our sample has existed for twenty-two years since its initial public offering (IPO), has book assets of about $1.3 billion, 20% leverage (long-term debt to total assets), M/B ratio 2.5, and ROE (net income divided by book equity) 8%. Following Pastor and Veronesi (2003), the volatility in profitability (VOLP) is estimated as the annual residual volatility from an AR(1) model of ROE, and has an average value of 57%. Appendix B provides details of the way in which the variables are constructed.

3. Measuring the Relation Between CEO Tenure and Stock Return Volatility

Figure 1 portrays a graphical depiction of the relation between monthly average stock return volatility and CEO tenure from twelve months before CEO turnover to sixty months following it. Panel A uses option implied volatility, Panel B uses realized volatility, and Panel C uses idiosyncratic volatility. For each measure, Figure 1 indicates that volatility increases substantially around the time of the

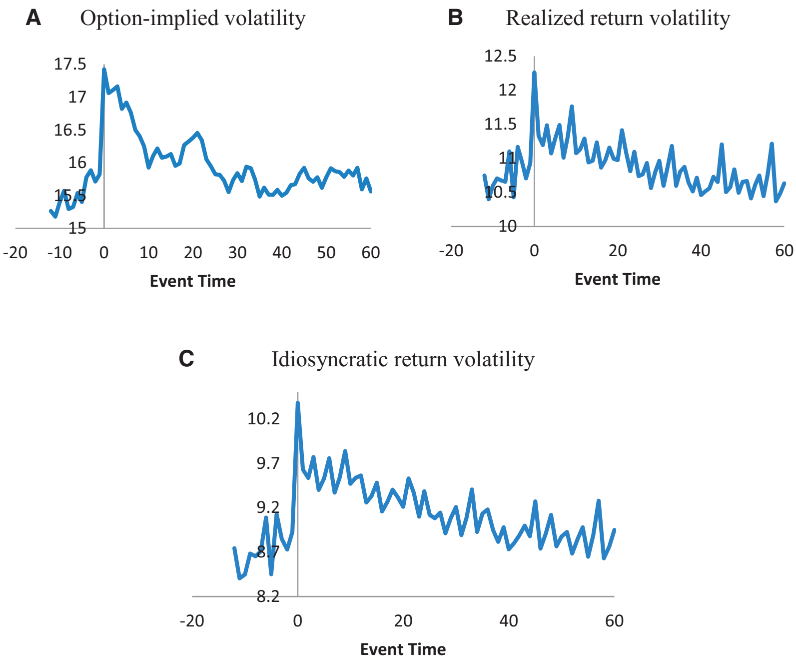

Figure 1
Stock return volatility around CEO turnover
The figures graph the average monthly stock return volatility from twelve months before the CEO takes office to sixty months after that. For each CEO, the calendar year-month in which the CEO takes office is designated as event month 0. To construct the sample for this figure, we require CEOs to have at least sixty months of tenure and that the pre-turnover sample period (−12, 0) of the successor CEO does not overlap with the post-turnover sample period (0, 60) of the departing CEO. We also drop the crisis period (years 2008 and 2009) to avoid a biased upward trending in volatility due to the uncertainty from the crisis. *Event time* is the event month count from −12 to 60. *Option-implied volatility* is the monthly average of implied volatility from daily prices of thirty-day at-the-money call options written on the firm's common stock. *Realized return volatility* is the monthly standard deviation of daily stock returns. *Idiosyncratic return volatility* is the monthly volatility of the residual return from the Fama-French three-factor model. All volatility variables are measured in percentage.

turnover, and decreases subsequently. The decrease is particularly pronounced during the first three years of the CEO's tenure.

Figure 2 illustrates firms' systematic risks and the aggregate volume of (non-turnover-related) corporate news announcements over the same period. Panel A shows how market betas vary, while Panels B and C use the SMB betas and HML betas, respectively. These figures indicate that, unlike idiosyncratic risk, firms' exposures to systematic risks do not have a clear relation with CEO tenure. This pattern suggests that changes in stock return volatility over CEO tenure are unlikely to be driven by changes in the firm's systematic risk and expected rate of return. This result also supports the prediction of Pastor and Veronesi (2003) that learning affects the firm's idiosyncratic volatility, but not systematic risk.

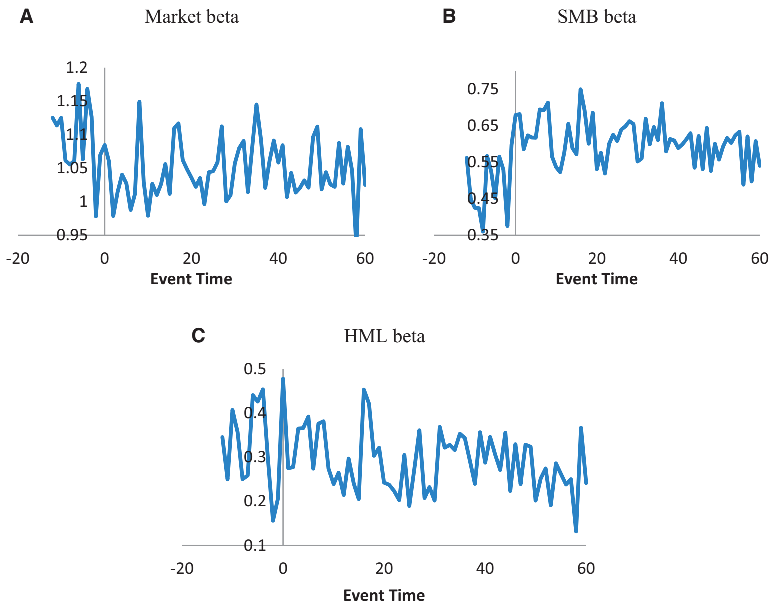

Figure 2
Firm-level exposure to systematic risks and volume of information around CEO turnover
The figures graph the average firm monthly loadings on the three systematic factors in the Fama-French three-factor model, from twelve months before the CEO takes office to sixty months after that. *Event time* is the event month count from −12 to 60. For each CEO, the calendar year-month in which the CEO takes office is designated as event month 0. The data sample description is the same as in Figure 1.

Figure 3 graphs the pre-turnover pattern in the option-implied volatility.[10] Forty-two percent of the appointment announcements occurred in the inauguration month (month 0), leading to the spike of volatility at month 0, as observed in Figure 1. For 490 turnovers for which the appointment announcements and inauguration occurred in different months, Panel A of Figure 3 plots the average of the option-implied volatility from the month of the first appointment announcement for the new CEO until twelve months after his inauguration. In Panel B, we focus on the subsample of 151 turnovers for which the departure announcements of the outgoing CEO, the appointment announcements of the incoming CEO, and the inauguration of the incoming CEO all occurred in different months.

Comparing the decline in volatility during various periods in Figure 3, the majority of the uncertainty about CEO ability appears to be resolved only after the new CEO takes office. We focus on the post-turnover part in our main analysis, since our goal is to understand the market's learning about the

[10] We use both the information from Capital IQ and news searches to identify the key announcement dates for the 875 CEO turnovers since 2001 in our sample. These sources provide 700 departure announcements and 851 appointment announcements. In a number of cases, the incoming CEO is the earliest CEO that we can identify in the firm's history, which is why there are fewer departure announcements than appointment announcements.

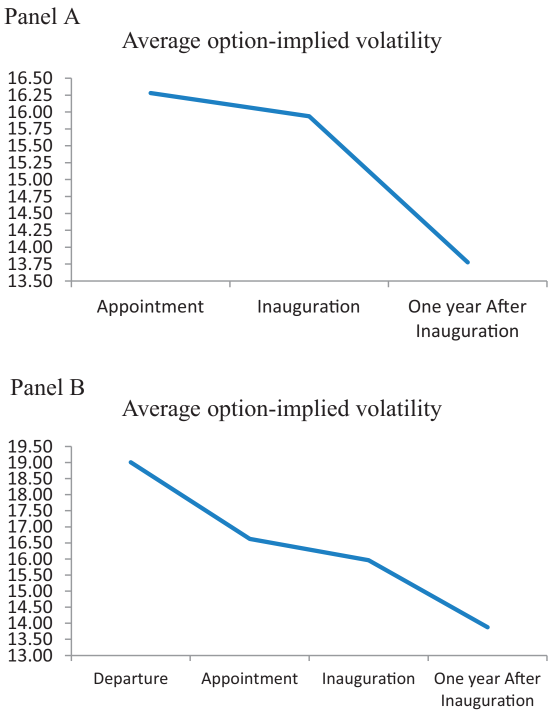

Figure 3
Option-implied volatility around CEO turnover for a longer horizon
The figures plot the average option-implied volatility (measured in percentage) in each event month. In Panel A, the sequence of events starts from the appointment announcement month of the new CEO, to the inauguration month of the new CEO, and then twelve months after inauguration. The turnover sample includes 490 CEO turnovers since 2001, for which the appointment announcement and the inauguration occurred in different month. In Panel B, the sequence of events starts from the announcement month of the old CEO's departure to the appointment announcement month of the new CEO, to the inauguration month, and then twelve months after the inauguration. The turnover sample includes 151 CEO turnovers since 2001, for which the departure announcement, the appointment announcement, and the inauguration all occurred in different months.

CEO's ability rather than about his identity. However, the pre-turnover pattern in stock return volatility is consistent with our argument that volatility reflects uncertainty about the new leadership, and is hard to explain by only uncertainty about the firm's fundamentals.

3.1 Estimating the volatility–tenure relation

Next, we estimate multivariate models predicting a stock's volatility as a function of CEO tenure, as well as other relevant factors. We would like to capture the volatility pattern over time while imposing as little structure as possible. For this reason, we allow volatility to be a function of the event month count *Tenure*, and use a number of alternative specifications to characterize this relation, which can be summarized by the following equation:

$$Vol_t^{ij} = f(Tenure) + \alpha^{ij} + \lambda_t + Controls_t^i + \varepsilon_t^{ij}, \tag{8}$$

where Vol_t^{ij} is one of the three volatility measures. The variable *Tenure* is the number of months since the CEO took office, scaled by twelve, so that the variable takes discrete values between zero and three. We focus on the three years following the turnover, since Figure 1 suggests that the decrease in volatility occurs primarily in this period. Since the theory predicts that volatility should be a decreasing, convex function of CEO tenure, we use either a piecewise-linear (spline) function or a polynomial function to estimate the degree of convexity in the learning curve.

The variable α^{ij} is the firm-CEO fixed effect for firm i and CEO j; its inclusion implies that we identify learning about CEO ability from the time-series variation in volatility within a firm-CEO pair. This approach, therefore, controls for any time-invariant differences across firm-CEO pairs. The variable λ_t is the calendar year-month fixed effect, which controls for market-wide factors that affect firm-level volatility. The controls include firm attributes intended to capture differences in firms' fundamental volatilities.

In Panel A of Table 2, we present results using a spline specification (Friedman 1991) with cutoff points at *Tenure* = 1 (first year), 2 (second year). This specification allows us to estimate the learning slope separately in each of the first three years of the CEO's tenure. Convexity of the learning speed m_t in t implies that stock return volatility should decline faster in earlier periods of the CEO tenure than in later periods. In each of the spline models, we find that the slope estimate is significantly more negative in year 1 than in year 2. The absolute value of the estimated slope coefficient in year 2 is less than half of its value in year 1. The estimate of the slope in year 3 is less negative than that in year 2, although the difference across these two years is not always statistically significant. In Model (4), we include the first five years of tenure in the spline regression for CEOs with at least seven years in office as a robustness check. The slope estimates for the first three years are still negative and significant, and those for the periods after year 3 are also negative, although not statistically significant. This pattern is consistent with the idea that the impact of learning about CEO ability on volatility is largest when uncertainty about that ability is highest.

Panel B of Table 2 reports estimates of the relation between volatility and tenure based on a polynomial specification. Models (1) to (3) estimate this relation using linear and quadratic terms of *Tenure*. In this specification, convexity implies that the coefficient on the linear term should be negative and on the quadratic term should be positive. Our estimates follow exactly this pattern, and the results are statistically significant and robust across different volatility measures.[11] In Models (4) to (6), we add a cubic term of *Tenure* to

[11] All the CEOs in our sample have at least three years of tenure. Thus, the decrease in stock volatility is not driven by CEOs in high-volatility firms being fired quickly. We have also estimated these equations including CEOs with tenure shorter than thirty-six months, and the results are similar to those reported in Table 2. For example, the coefficient estimate on *Tenure* is -0.593 (p-value <0.001) and that on *Tenure*^{2} is 0.137 (p-value <0.001) using the specification of Model (3) of Table 2, Panel B.

Table 2
CEO's time in office and volatility

Panel A: Spline specification

	(1) Option-implied volatility	(2) Realized return volatility	(3) Idiosyncratic return volatility	(4) Idiosyncratic return volatility
Tenure (year1)	−0.602***	−0.992***	−0.927***	−0.227***
	(−3.067)	(−.003)	(−.226)	(−5.249)
Tenure (year2)	−0.257*	−0.349***	−0.410***	−0.073**
	(−1.409)	(−2.862)	(−3.431)	(−2.146)
Tenure (year3)	0.121	−0.289**	−0.385***	−0.052*
	(0.813)	(−2.326)	(−3.157)	(−1.726)
Tenure (year4)				−0.047
				(−1.440)
Tenure (year5)				−0.066
				(−1.536)
Market beta	0.204***	0.605***		
	(7.105)	(8.208)		
SMB beta	0.055***	0.141***		
	(2.687)	(2.594)		
HML beta	−0.037*	−0.181***		
	(−1.853)	(−4.366)		
Dividend dummy	−1.709***	−0.879**	−0.754*	−0.137
	(−2.785)	(−2.304)	(−1.860)	(−1.539)
Leverage	2.291***	1.454**	1.347**	0.120
	(2.848)	(1.985)	(1.973)	(0.677)
M/B	−0.001	0.001	0.001	0.002
	(−0.329)	(0.548)	(0.367)	(1.474)
Log(Assets)	−0.896**	−0.807***	−1.082***	−0.178***
	(−2.233)	(−3.090)	(−4.091)	(−2.812)
VOLP	0.190	0.291**	0.308***	0.093***
	(1.208)	(2.316)	(2.739)	(3.256)
ROE	−0.275	−0.696***	−0.593***	−0.087**
	(−1.526)	(−3.615)	(−3.738)	(−2.277)
Calendar year-month fixed effects	x	x	x	x
Firm-CEO fixed effects	x	x	x	x
Obs.	33,336	64,142	61,011	52,159
Adj. R^2.	0.839	0.622	0.570	0.570

This table reports the nonlinear trend in various volatility measures from the time when the CEO took office to five years after that, using (piecewise linear) spline regressions. Tenure (year i) is the spline for the twelve months in the i-th year after turnover. For example, for the 1st to 12th month since the new CEO takes office, *Tenure (year1)* takes the value of 1/12 to 1, while the other two splines take the value of 0. For the 13th to 24th month, *Tenure (year1)* takes the value of 1, *Tenure (year2)* takes the value of 1/12 to 1, and *Tenure (year3)* takes the value of 0. In Models (1)–(3), we include all turnovers followed by CEOs with at least three years of tenure. In Model (4), we focus on the subsample with long-tenured CEOs (at least seven years). The Huber–White robust standard errors are clustered by firm-CEO. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

the equation. In each of the three models, the coefficient on the cubic term itself is not statistically significantly different from zero, and its sign varies across specifications. However, the linear term and the quadratic term still have the signs observed in Models (1) to (3) and are statistically significant. These results suggest that the linear and quadratic terms of *Tenure* are sufficient to characterize the convex shape of the volatility–tenure relation.[12]

[12] In the polynomial specification with option-implied volatility or idiosyncratic volatility as the dependent variable, the fitted value of volatility (ignoring the controls) is not necessarily monotonically declining with tenure in the

Table 2
Continued

Panel B: Polynomial specification

	(1) Option-implied volatility	(2) Realized return volatility	(3) Idiosyncratic return volatility	(4) Option-implied volatility	(5) Realized return volatility	(6) Idiosyncratic return volatility
Tenure	−0.786***	−1.030***	−0.725***	−0.741*	−1.531***	−1.056***
	(−3.728)	(−6.837)	(−3.893)	(−1.951)	(−4.999)	(−3.543)
$Tenure^2$	0.179***	0.173***	0.162***	0.141	0.606***	0.448**
	(3.076)	(3.964)	(4.193)	(0.502)	(2.623)	(2.140)
$Tenure^3$				0.008	−0.096	−0.063
				(0.138)	(−1.554)	(−1.417)
Market beta	0.204***	0.605***		0.204***	0.605***	
	(7.195)	(8.208)		(7.194)	(8.206)	
SMB beta	0.055***	0.141***		0.055***	0.141***	
	(2.698)	(2.595)		(2.698)	(2.595)	
HML beta	−0.037*	−0.181***		−0.037*	−0.181***	
	(−1.876)	(−4.367)		(−1.876)	(−4.365)	
Div. payer	−1.710***	−0.873**	−0.499	−1.709***	−0.880**	−0.503
	(−2.810)	(−2.288)	(−1.456)	(−2.808)	(−2.305)	(−1.470)
Leverage	2.290***	1.458**	1.385**	2.291***	1.451**	1.382**
	(2.837)	(1.990)	(1.991)	(2.838)	(1.981)	(1.988)
M/B	−0.001	0.001	0.001	−0.001	0.001	0.001
	(−0.330)	(0.531)	(0.663)	(−0.331)	(0.547)	(0.676)
Log(Assets)	−0.895**	−0.804***	−0.981***	−0.895**	−0.808***	−0.984***
	(−2.231)	(−3.076)	(−3.738)	(−2.230)	(−3.092)	(−3.747)
VOLP	0.191	0.289**	0.286**	0.190	0.292**	0.288**
	(1.210)	(2.302)	(2.466)	(1.210)	(2.321)	(2.478)
ROE	−0.275	−0.696***	−0.624***	−0.275	−0.696***	−0.624***
	(−1.555)	(−3.611)	(−3.666)	(−1.553)	(−3.616)	(−3.669)
Constant	22.895***	15.656***	17.503***	22.879***	15.792***	17.594***
	(7.471)	(8.643)	(8.554)	(7.432)	(8.685)	(8.559)
Calendar year-month fixed effects	x	x	x	x	x	x
Firm-CEO fixed effects	x	x	x	x	x	x
Obs.	33,336	64,142	61,011	33,336	64,142	61,011
Adj. R^2	0.839	0.622	0.580	0.839	0.622	0.580

This table reports the nonlinear trend in various volatility measures from the time when the CEO took office to thirty-six months after that, using polynomial specifications. The definitions of all variables are in Appendix B. The Huber–White robust standard errors are clustered by firm-CEO. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

In summary, the results in Table 2 are consistent with the stylized Bayesian learning model in Section 3. Market learning about the CEO's ability leads to decreasing uncertainty about the CEO, which in turn leads to decreasing stock return volatility (particularly idiosyncratic volatility) over the CEO's tenure. The learning curve appears to be convex, with faster learning in periods immediately after turnover.

third year. This is likely due to the noise from an imperfect measurement process. The spline specification reported in Panel A of Table 2 yields a convex and monotonic decline of volatility over a CEO's first three years in office. Therefore, in an unreported robustness check, we put restrictions on the coefficient estimation in the polynomial specification, so that volatility monotonically changes with *Tenure* throughout the first three years. The estimates from the constrained polynomial specification confirm that there is a convex and monotonic decline of volatility over CEO tenure.

3.2 The volatility–tenure relation for turnovers unlikely to be performance driven

It is possible that CEO turnovers tend to occur at times of high fundamental uncertainty. A long literature beginning with Warner, Watts, and Wruck (1988) and Weisbach (1988) documents that CEO turnovers, particularly forced turnovers, are more likely to occur subsequent to poor firm performance, which also tend to be times of unusually high stock return volatility (see Bushman, Dai, and Wang 2010). However, this literature also documents that turnovers due to exogenous events such as illness, death, and normal retirements of the departing CEOs do not occur subsequent to unusual performance (e.g., Weisbach 1988; Fee et al. 2013). Consistent with these findings, each of the subsamples that we have identified as unlikely to be performance driven does not appear to have unusual stock returns or volatility prior to the turnover (Table 1, Panel C). Therefore, to evaluate whether learning about ability rather than endogenous timing explains the decline in volatility following turnovers, we reestimate the relation between volatility and tenure for each of these subsamples of likely exogenous turnovers, and compare the estimates with those for the outright forced subsample and the subsample of turnovers for which the likely cause could not be identified.

The first five columns of Table 3 present estimates of polynomial specification used in Table 2, Panel B, Column 3, for subsamples of turnovers that are likely to have occurred for exogenous reasons. For each of these subsamples, there appears to be a negative, convex relation between stock return volatility and CEO tenure. Further, the estimated volatility–tenure relation is very similar between the union of arguably exogenous turnovers (Column 5) and the turnovers that could not be classified (Column 6). Panel C of Table 1 also shows that neither of the two subsamples is preceded by unusual stock performance or volatility. Since the two subsamples together account for 94% of the all the turnovers, our results suggest that for most firms, the post-turnover decline in stock return volatility is not driven by turnovers occurring at periods of unusually high volatility. Instead, these declines appear to come from the reduction in uncertainty about CEO quality over time because of market learning.

In contrast, the coefficients for the subsample of “outright forced” turnovers are substantially (and statistically significantly) larger in absolute value than those in the “likely exogenous” subsamples and the non-classified subsample. This difference likely occurs because the identified forced turnovers tend to happen at times of bad performance and high volatility (Panel C of Table 1).

3.3 Corporate real actions, information revelation, and the volatility–tenure relation

CEO turnovers are often followed by substantial policy changes in the firm. These real actions could change the firm’s asset portfolio or business policies, thus the firm’s fundamental volatility as well. There is evidence that firms’

Table 3
Estimates of the volatility–tenure relation across subsamples of turnovers

	Non-performance-motivated turnovers						Performance-motivated turnovers
	(1) Turnovers due to death or illness	(2) Death/illness/ retirement at good performance	(3) No management shakeup	(4) Pre-turnover ind-adj. IVOL ≤ 0 and stock return ≥ 0 and ROA ≥ 0	(5) (2) or (3) or (4)	(6) Not classified as likely exogenous or forced	(7) Outright forced
Tenure	−0.535	−0.648**	−0.439*	−0.588*	−0.624***	−0.659***	−1.615***
	(−1.680)	(−2.106)	(−1.917)	(−1.786)	(−3.998)	(−4.920)	(−3.153)
$Tenure^2$	0.091	0.104*	0.139**	0.094*	0.093**	0.125***	0.344**
	(0.500)	(1.873)	(1.996)	(1.913)	(2.114)	(3.358)	(2.084)
Controls	x	x	x	x	x	x	x
Calendar year-month fixed effects	x	x	x	x	x	x	x
Firm-CEO fixed effects	x	x	x	x	x	x	x
Obs.	2,045	6,969	9,423	15,172	21,096	32,827	3,494
Adj. R^2	0.548	0.561	0.564	0.564	0.57	0.578	0.512

This table reports the learning patterns for various turnover subsamples, with the idiosyncratic return volatility as the dependent variable, using polynomial specifications. The definitions of the turnover subsamples and *Tenure* are provided in Appendix B. The summary statistics for pre-turnover performance of each subsample are provided in Table 1, Panel C. The control variables including *Div. payer, Leverage, M/B, Log(Assets), VOLP, ROE,* and a constant term are included in all regressions but omitted for brevity. The Huber–White robust standard errors are clustered by firm-CEO. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

assets do change systematically over CEO tenure as there tends to be more disinvestment early in a CEO's career and more investment later on (see Pan, Wang, and Weisbach 2014). However, these changes occur throughout the CEO's tenure, but the volatility changes mostly occur in the first three years. We nonetheless examine the extent to which investment patterns during the first three years of CEO tenure influence our estimates of the volatility induced by uncertainty about CEO ability.

It is also possible that CEO turnover could lead to an increase of information about the firm's fundamentals if incumbent management withholds negative information about the firm's profitability because of career concerns. When a new CEO takes over, he has incentives to let the market know about such negative information quickly to avoid being held responsible for the poor decisions of his predecessor. For this reason, CEO turnovers can facilitate information revelation and investment re-optimization (Kanodia, Bushman, and Dickhaut 1989; Boot 1992). Consistent with this argument, empirical studies have shown that substantial accounting write-offs and divestitures are more likely to occur following CEO turnover (e.g., see Murphy and Zimmerman [1993] on "accounting baths," and Weisbach [1995] and Pan, Wang, and Weisbach [2014] on disinvestment). The additional information revelation and the corresponding "corrective" actions could potentially contribute to the increase in return volatility around CEO turnover.

To address these possibilities, we examine three types of actions that have real effects on the firm's asset portfolio: downsizing, expansion, and introduction of new products; and also three types of actions that reveal negative information about the firm's fundamentals: accounting write-offs, earnings restatements, and securities fraud investigations. In Figure 4 we graph the likelihood of these actions being announced during the first three years of CEO tenure. These graphs suggest that the downsizing intensity declines while the expansion and new product release intensity increases during the first three years. Negative information revelation is rare, and its intensity is flat over this period. The total volume of these announcements actually slightly increases over time. Thus, the change in the intensity of corporate actions does not appear to be the reason for the observed declining stock return volatility during the first three years of a CEO's tenure.

Next, we explicitly control for the realized as well as expected real actions and information revelation. In Column (1) of Table 4, we reestimate our baseline specification, controlling for the announcements of these actions. In Column (2), we reestimate the same equation for the subsample of turnovers due to death, illness, or retirement of the departing CEOs. In Column (3), we focus on the subsample without any announced events. In each of these specifications, idiosyncratic volatility has a convex decline over CEO tenure, as in our baseline specifications in Table 2. A further concern is that volatility could depend on the anticipation of the above events rather than their realization. To address this concern, in Columns (4) and (5), we control for the hazard rate of each

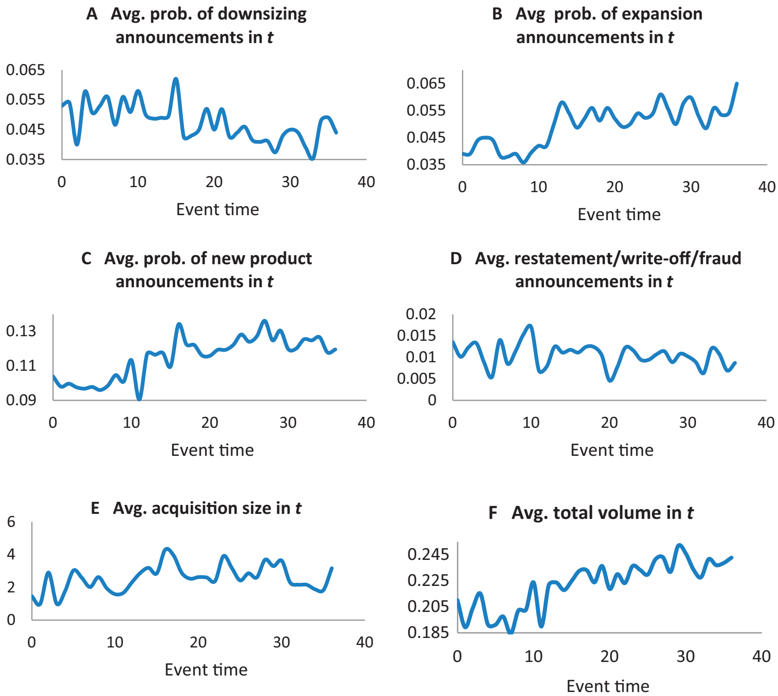

Figure 4
Intensity of various corporate announcements over CEO tenure
The figures graph the average monthly probability of having a certain type of corporate announcement during the first thirty-six months of a CEO's tenure. *Event time* is the event month count from 0 to 36. For each CEO, the calendar year-month in which the CEO takes office is designated as event month 0. The CEO turnover sample includes all long-term CEOs (who stayed in office for at least three years) who took office in S&P 1500 firms during 1992–2006. Panel A for corporate downsizing (from Capital IQ); Panel B for business expansion (from Capital IQ) and acquisitions (from SDC Platinum); Panel C for new product announcements (from Capital IQ); Panel D for earnings restatement, write-offs, and financial frauds (from Capital IQ and FSR database). Panel E reports the average amount of acquisition transaction values (in millions) each month over tenure. Panel F reports the average volume of all the above types of corporate announcements (downsizing, expansion, new product announcement, M&A, restatement/fraud/write-off) in each month over tenure. The sample period for data from Capital IQ is 2001–2007, and is 1992–2007 for data from SDC. We stop the sample at 2007 for the figures to avoid potential effects from the financial crisis in the plot of raw data without control variables.

event. The event hazard rates over CEO tenure are predicted using the COX proportional hazard model (Cox 1972), controlling for firm fixed effects and calendar year-month fixed effects. Controlling for the event hazard rates does not affect the estimated convex decline in idiosyncratic volatility over CEO tenure either.

4. The Magnitude of Ability-Induced Volatility

Equation (6) shows how the firm's stock return volatility can be decomposed into uncertainty about the firm's fundamental cash flow (σ) and uncertainty about management quality (δ). While under the model's assumptions, both

Table 4
Post-turnover announced and expected real changes and idiosyncratic volatility

Dependent variable: Idiosyncratic return volatility	(1) Full Sample Sample	(2) Death/health/ retirement at good performance	(3) No real actions announced	(4) Whole sample	(5) Death/health/ retirement at good performance
Tenure	−1.558***	−1.387***	−1.325***	−0.697**	−0.532*
	(−4.637)	(−3.385)	(−2.787)	(−2.001)	(−1.824)
Tenure^2	0.210***	0.156*	0.192***	0.237***	0.123*
	(3.702)	−1.782	(3.039)	(3.764)	(−1.753)
Downsizing announced	1.098***	0.297			
	(5.450)	(0.736)			
Restatement/write-off/ fraud announced	0.324***	−0.022			
	(3.179)	(−0.097)			
New product announced	−0.063	−0.033			
	(−0.586)	(−0.178)			
Expansion announced	1.402***	0.120			
	(4.690)	(0.283)			
Downsizing hazard rate				0.957*	0.739
				(1.911)	(1.510)
Restatement/write-off/ fraud hazard rate				2.345***	2.288**
				(3.922)	(2.508)
New product announcement hazard rate				1.079	−0.172
				(1.170)	(−0.189)
Expansion announcement hazard rate				2.978**	5.203***
				(2.281)	(3.021)
Obs.	30,128	3,301	22,154	24,561	3,084
Adj. R^2	0.571	0.563	0.571	0.557	0.547

This table reports the results of regressing the idiosyncratic return volatility on tenure and tenure squared, controlling for announced or expected corporate events. The hazard rates over CEO tenure are predicted using the COX proportional hazard model, controlling for firm fixed effects and calendar year-month fixed effects. All equations include control variables (not reported): *Div. payer, Leverage, M/B, Log(Assets), VOLP, ROE*, as well as calendar year-month and firm-CEO fixed effects. Variable definitions are provided in Appendix B. The Huber–White robust standard errors are clustered by firm-CEO. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

factors should contribute to volatility, it is unclear how quantitatively important the uncertainty about management quality is relative to the firm's fundamental uncertainty. Conveniently, the learning speed parameter in the model, $m_t = \delta_t^2/\sigma^2$, equals the square of the ratio of the two components of volatility. Thus, estimates of this parameter allow us to gauge the relative importance of these two components.

The learning model is useful for this quantitative exercise for two reasons. First, stock return volatility is not just a simple summation of managerial uncertainty and fundamental uncertainty; in our model, the learning speed (m_t) depends on the ratio of these two sources of uncertainty at a given point in time. The learning model provides a structured way to think about how these two sources of uncertainty contribute to the total return volatility. Second, even though learning is fastest in the first three years, neither the learning model nor our empirical results suggest that uncertainty about management decreases to zero by the end of year 3 or by any fixed time period.

Since both the theory and the empirical work suggest that learning speeds decline as a CEO becomes more established, any measurement of a learning speed requires specifying a particular time. The learning speed at time 0 when the new CEO takes office is particularly meaningful, because $m_0 = \delta_0^2/\sigma^2$ reveals how large the prior uncertainty about the CEO is relative to the fundamental uncertainty.

We present two approaches to estimate m_0. The first approach is based on a first difference version of Equation (6). Using *Vol* to denote stock return volatility, we define $Vol' = (Vol/\sigma) - 1$, which represents the percentage excess volatility. Let $K_t = \frac{\partial \log(P/D)_t}{\partial \theta_t}$, a measure of the marginal return to CEO ability. Equation (6) implies that $Vol'_t = K_t m_t$. The percentage change in Vol' from 0 to t is: $\frac{\Delta Vol'}{Vol'_0} = \frac{\Delta m}{m_0} + \frac{\Delta K}{K_0} \times \left(1 + \frac{\Delta m}{m_0}\right)$, where Δ is the first difference operator. We do not have a closed form for K as a function of t. Numerical simulation suggests that K is increasing in t for reasonable parameter values, but the sensitivity of K to t is very small ($\frac{\Delta K}{K_0}$ <1% over a three-year period). This implies that $\frac{\Delta m}{m_0} \approx \frac{\Delta Vol'}{Vol'_0}$, the percentage change in the learning speed approximately equals the percentage change in the excess volatility Vol'. Then we have $\frac{\Delta m}{m_0} = \frac{1}{1+m_0 t} - 1 \approx \frac{\Delta Vol'}{Vol'_0} = \frac{\Delta Vol}{Vol_0} \times \frac{Vol_0}{Vol_0 - \sigma}$.

In the data, the average percentage change in the realized return volatility in the first three years of CEO tenure is $\frac{\Delta Vol}{Vol_0} = -10\%$, the average (annualized) return volatility at month 0 (Vol_0) is about 45%, and the average annual firm-level volatility of dividend growth rate (σ) for the dividend-paying firms in our sample is 28%.[13] Thus, $\frac{\Delta Vol'}{Vol'_0} = -26.5\%$. With t=3, we have $m_0 = \frac{1}{3}\left[\frac{1}{1-26.5\%} - 1\right] \approx 12\%$, which implies that at time 0 the ratio of uncertainty about the management quality (δ_0) to fundamental volatility (σ) is approximately 35% (= $\sqrt{12\%}$). With this estimate of the volatility ratio, the contribution of uncertainty about management to total volatility is: $\frac{\delta_0}{Vol_0} = \frac{\delta_0}{\sigma} \times \frac{\sigma}{Vol_0} = 0.35 \times \frac{0.28}{0.45} = 22\%$.

The second approach we propose to estimate m_0 is to consider a Taylor expansion of m_t at $t=0$ in Equation (6). For simplicity, we assume that K is constant over time. Then Equation (6) can be written as:

$$vol\left(\frac{dP_t}{P_t}\right) \approx \sigma + \sigma K m_t = \sigma + \sigma K \frac{1}{1/m_0 + t} = \sigma + \sigma K\{m_0 - [m_0^2]t + [m_0^3]t^2 - \ldots\}$$

$$\approx \sigma(1 + K m_0) + [-\sigma K (m_0)^2]t + [\sigma K (m_0)^3]t^2 + \varepsilon_t^i$$

$$= \alpha^i + \beta^i t + \gamma^i t^2 + \varepsilon_t^i, \quad (9)$$

where ε_t represents the sum of all the higher order terms. Note that $m_0 = -\gamma/\beta$ in Equation (9). Thus, we can estimate m_0 using the coefficient estimates from

[13] The estimated volatility of dividend growth rate ranges from 0.23 to 0.28, depending on the definition of dividend-paying firm and the time period that we use for the estimation of σ.

the polynomial specification in Table 2. The benefit of this regression approach is that we can control for other factors that may affect volatility, including the systematic risks, and the estimation of m_0 does not rely on any specific estimates of the fundamental volatility (σ). Panel B of Table 2 suggests that m_0 is about 17% (= −0.173/−1.030) using the realized return volatility. The estimated learning speed implies that the volatility ratio is approximately 41% ($=\sqrt{17\%}$). Thus, the second approach estimates that the contribution of uncertainty about management to total volatility is $\frac{\delta_0}{Vol_0} = \frac{\delta_0}{\sigma} \times \frac{\sigma}{Vol_0} = 0.41 \times \frac{0.28}{0.45} = 26\%$.

This calculation potentially overestimates the contribution of uncertainty about CEO ability to stock return volatility because of the endogenous nature of CEO turnover. Column (2) in Table 3 suggests that m_0 is 16% (=−0.104/−0.648) using only turnovers due to death, health issues, or retirement of the departing CEOs. We also estimate m_0 using a "further cleaned" subsample of turnovers that are (i) due to death, illness, or retirement of the departing CEO, (ii) with no disclosure of negative information through the announcements of restatements, write-offs, fraud investigations, or downsizing in the three years after turnover, and (iii) in mature firms that were publicly traded for at least twenty-two years at the time of turnover (the median of the sample distribution). Estimation using this subsample is likely to reflect the impact of a new draw of CEO on equity volatility rather than other factors. Using this relatively small subsample of 84 turnovers, the estimate of m_0 is about 17% based on the second approach discussed above. The fact that estimates using the exogenous turnover subsamples are comparable to those based on the full sample suggests that nonrandom timing of turnovers and information releases following them are not the primary determinant of our estimates of m_0.

In Table 5, we present alternative estimates of the volatility ratio as well as the contribution of management uncertainty to volatility, using two different approaches, various volatility measures and subsamples. Regardless of the approach used, about one-quarter of total stock-return volatility (or about one-third of the idiosyncratic volatility) at the time of turnover is due to uncertainty about CEO ability.[14]

5. How Does the Market Learn About CEO Ability?

We have documented that there is an increase followed by a convex decline in volatility around the time of CEO turnovers. This pattern is consistent with the predictions of the learning model, in which a new CEO creates uncertainty about the firm's valuation that is resolved over time as the market learns more about the CEO's talents and plans for the firm. The model contains specific predictions about the way this process works: learning should be faster when

14 The estimated high importance of the CEO is consistent with Bennedsen, Pérez-González, and Wolfenzon (2013), who find that a ten-day hospital stay of the CEO reduces firm profitability by 4%.

Table 5
Decomposing volatility

Approach	Sample	Volatility measure	Controls	Volatility ratio $\delta_0/\sigma=\sqrt{m_0}$	Contribution of uncertainty about mgmt. δ_0/Vol_0
First difference	Full	Realized return vol.	No	0.35	0.22
Taylor expansion	Full	Realized return vol.	Yes	0.41	0.26
Taylor expansion	Turnovers due to death, health issues, or retirement	Idiosyncratic vol.	Yes	0.40	0.29
Taylor expansion	Turnovers due to death, health issues, or retirement of departing CEOs in old and mature firms with no disclosure of negative information	Idiosyncratic vol.	Yes	0.41	0.30

This table reports the ratio of uncertainty about management (δ_0) to the firm's fundamental uncertainty (σ), as well as the contribution of δ_0 to the total return volatility Vol_0, using the two approaches outlined in Section 4, for various samples and various volatility measures. The volatility ratio is the square root of the learning speed at time 0 (m_0). The contribution of uncertainty about management to total volatility is calculated as: $\frac{\delta_0}{Vol_0}=\frac{\delta_0}{\sigma}\times\frac{\sigma}{Vol_0}$, with Vol_0 being either the average (annualized) total return volatility or idiosyncratic volatility at the time of turnovers. In our calculation, we set $\sigma=28\%$, Vol_0 = 45% for total return volatility, and Vol_0 = 38% for idiosyncratic volatility, which are computed directly from data. We also indicate whether the usual set of firm level control variables are included in each approach.

news about the firm contains more information about the CEO's ability, and when the prior belief about the ability is more diffuse.

5.1 News about the firm and learning about CEO ability

5.1.1 The effect of CEO tenure on the market reaction to news. In the learning model, when uncertainty about the CEO's ability is larger, news related to expected profitability leads to larger updates in the market's assessment of the firm's future prospects. As the CEO's ability becomes known more precisely over time, the magnitude of stock price reactions to news should decline over the CEO's tenure, holding constant the nature of the news. Consistent with this argument, Clayton, Hartzell, and Rosenberg (2005) document that market reactions to earnings announcement surprises decrease over a CEO's tenure.

We replicate Clayton et al.'s analysis on earnings surprises using data from the I/B/E/S database and extend their analysis using other kinds of news announcements related to the firm's future profitability, which could reflect the CEO's ability: expansion/downsizing, product-related announcements, and dividend changes. We define an earnings announcement to be a "surprise" if the actual earnings per share deviates from the median analyst forecast by at least 10% (the median of the sample distribution). For each news announcement, we calculate the announcement-day market-adjusted stock return ("AR") and estimate the following specification:

$$\left|AR_t^{ij}\right|=\beta_0+\beta_1\times Tenure+\beta_2\times Tenure^2+\gamma\times MktVol_t+\alpha^{ij}+\varepsilon_t^{ij}, \quad (10)$$

Table 6
Corporate news and learning

Panel A: Market reactions to news

	(1) Expansion or downsizing	(2) New product	(3) Dividend change	(4) Earnings surprise |AR|	(5) Earnings growth	(6) Sales growth	(7) Dividend growth
Tenure	−0.046**	−0.023***	−0.021*	−0.025*	−0.020***	−0.010**	−0.007***
	(−2.425)	(−2.584)	(−1.743)	(−1.784)	(−4.578)	(−2.188)	(2.846)
Tenure^2	0.001**	0.0004*	0.0004**	0.001**			
	(2.257)	(1.870)	(2.503)	(2.219)			
Tenure × (growth rate)					−0.007*	−0.011*	−0.024*
					(−1.893)	(−1.836)	(−1.821)
Growth rate					0.102	0.275	0.687
					(1.270)	(1.495)	(1.341)
Market volatility	0.394***	0.470***	0.274***	0.508***	1.245***	0.870***	0.281***
	(5.908)	(4.678)	(4.971)	(6.731)	(17.580)	(10.912)	(8.780)
|Change/surprise|			1.268	0.025*			
			(1.269)	(1.703)			
Firm-CEO fixed effects	x	x	x	x	x	x	x
Obs.	7,370	12,859	1,342	10,873	19,329	22,411	5,134
Adj. R^2	0.241	0.209	0.260	0.181	0.356	0.335	0.202

This table reports the pattern of market reactions to various types of corporate news over CEO tenure. We first examine four types of news announcements: (1) expansion/downsizing, (2) new product announcements, (3) dividend changes (increase or decrease), (4) earnings surprise (quarterly actual earnings deviate from median analyst forecast by at least 10%). The dependent variable in all regressions, $|AR|$, is the absolute value of market-adjusted announcement-day return, where market return is the "value-weighted market return" from CRSP. Both market and firm returns are ex-dividend. *Tenure* is the event month count scaled by 12 (month 0 is the inauguration month). $|Change/surprise|$ measures the absolute magnitude of the dividend per share change and earnings surprise per share in columns (3) and (4), respectively. Then, we interact *Tenure* with the EPS growth rate (column 5), the sales growth rate (column 6), compared to the same quarter last year and the dividend growth rate (column 7) compared with the last quarter. Observations with growth rates equal to zero are included in columns (5) to (7). Variable definitions are provided in Appendix B. The Huber–White robust standard errors are clustered by firm-CEO. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

where *Tenure* is defined as before, α^{ij} is the firm-CEO fixed effect for the pair of firm i and CEO j, and $MktVol_t$ is the cross-sectional standard deviation of all CRSP firm returns on date t.

Panel A of Table 6 reports estimates of this equation. Model (1) reports the results for the sample of expansion/downsizing announcements, Model (2) for new product releases, Model (3) for dividend changes, and Model (4) for earnings surprises. We control for the magnitudes of dividend changes and earnings surprises in Models (3) and (4). The estimates in Table 6 indicate that the absolute value of the stock price reaction has a convex decline over CEO tenure, regardless of the types or magnitudes of the news. This result is consistent with the notion that over time, the indirect effect of the news on stock prices through the learning channel decreases.

5.1.2 Confirming versus non-confirming news. The learning model implies that the market's learning about managers should also depend on the nature of the news that it has access to. At any point of time, information that confirms the market's belief about a CEO's ability should be less of a surprise and lead to a smaller update in his perceived ability, while news that contradicts

Table 6
Continued

Panel B: Information content of corporate news

	(1)	(2) Idiosyncratic return volatility
Tenure	−0.854***	−0.829***
	(−3.283)	(−3.180)
CAPX announced	0.463	
	(1.592)	
(CAPX announced) × Tenure	−0.161	
	(−1.035)	
New product announced	0.510**	
	(2.202)	
(New product announced) × Tenure	−0.329***	
	(−2.668)	
M&A announced		1.914**
		(2.334)
(M&A announced) × Tenure		−0.765*
		(−1.923)
Controls	x	x
Calendar year-month fixed effects	x	x
Firm-CEO fixed effects	x	x
Obs.	30,128	30,128
Adj. R^2	0.569	0.569

In this table, the dependent variable is idiosyncratic return volatility. *(Action announced)* × *tenure* is the interaction of the action announcement indicator variable and *Tenure*. All equations include control variables (not reported): *Div. payer, Leverage, M/B, Log(Assets), VOLP, ROE,* as well as a constant term. Variable definitions are provided in Appendix B. The Huber–White robust standard errors are clustered by firm-CEO. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

the market's belief should be more of a surprise and lead to a larger update. As a CEO's tenure lengthens, presumably reflecting favorable updates about his ability over time, good outcomes become more anticipated, while bad outcomes become more of a surprise. Therefore, as CEO tenure increases, the absolute values of the stock price reaction to good earnings news and to bad earnings news should become more and more asymmetric, with the reaction to good outcomes becoming increasingly smaller relative to the reaction to bad outcomes.

To test this prediction, we compute firms' growth rates in earnings per share (EPS) and sales over the same quarters in consecutive years, and firms' quarterly dividend growth rates. We estimate an equation relating the absolute value of the market reaction to the reported financial outcome as a function of CEO tenure and its interaction with the financial outcome, and report these estimates in Columns (5), (6), and (7) of Table 6, Panel A. In each equation, the estimated direct effect of *Tenure* on the absolute value of stock reactions is negative and statistically significant, suggesting that there is learning going on independent of the reported financial outcomes. The estimated interaction effect of *Tenure* with the financial outcome variables is negative and statistically significant, although only at the 10% confidence level. Nevertheless, this finding suggests that over time, good outcomes lead to increasingly smaller market reactions than do bad outcomes.

5.1.3 Information content of post-turnover corporate actions. Not all disclosed corporate actions are equally informative about the CEO's ability. When an action requires more discretion from a CEO, it is more likely to be informative about his ability. Since learning is reflected in the volatility–tenure sensitivity, we expect that actions the CEO takes, especially ones that are relatively informative about his ability, should increase the volatility–tenure sensitivity.[15]

In this subsection, we compare the effects of three types of corporate expansion news on the volatility–tenure sensitivity: capital expenditures, new product releases, and mergers and acquisitions. Among the three, introducing a new product to the market tells the market about the new CEO's vision and strategic direction for the firm, which should be informative about the CEO's ability. In addition, mergers and acquisitions are related to expanding the boundary of the firm, and usually require substantial CEO judgment and discretion. Thus, they should be particularly informative about the CEO's ability as well. In contrast, routine capital expenditures are likely to require the least CEO judgment and discretion. Therefore, if the estimated volatility–tenure slope reflects the market's learning about managerial ability, we expect new product releases and acquisition announcements to have a larger impact on the volatility–tenure slope than do capital expenditures.

To test this prediction, we separate the news about expansions into M&A-related news and capital expenditures–related news.[16] Panel B of Table 6 reports estimates of the impact of different kinds of expansion announcements on the volatility–tenure slope. The results suggest that routine expansion announcements have no statistically significant effect on the volatility–tenure slope, as reflected in the insignificant interaction effect between the capital expenditures announcement dummy and CEO tenure. In contrast, the interaction between the new product announcement dummy and *Tenure* has a significant and negative effect on firm volatility, implying that uncertainty declines faster over CEO tenure when the firm announces new products (Column 1). M&A announcements have the largest impact on the speed of learning, as reflected in the negative, significant, and economically large interaction effect with tenure (Column 2).

The differences in the types of news announcements on the volatility–tenure slope suggests that the more informative the news is about a CEO's ability, the more the market uses it to draw inferences about the CEO's ability, and consequently the firm's volatility declines faster.

[15] Note that this exercise is different from that in Section 4.3 (Table 4) where we control for the direct impact of post-turnover actions on the level of volatility rather than the impact of the information content of these actions on the volatility–tenure slope.

[16] News related to capital expenditures mainly come from the category "Business Expansion" in Capital IQ (e.g., opening a new store or a new office). The M&A announcements come from SDC Platinum.

5.2 Cross-sectional determinants of the learning speed

In the model presented in Section 2, market participants continually update their assessment of the CEO's ability using Bayes' rule. The learning speed (m_t) depends on the amount of uncertainty about CEO ability (δ_t) relative to the precision of information the market has access to (σ). We examine these predictions empirically by estimating the factors that affect the learning speeds for firm-CEO pairs.

5.2.1 Estimating CEO-/firm-specific learning speeds. The volatility–tenure slope for a particular CEO measures the speed at which the market updates its assessment of his ability, and a steeper volatility–tenure slope corresponds to a faster learning speed. We estimate the volatility–tenure slope separately for each firm-CEO pair in the sample, using data from the CEO's first thirty-six months in office and the following specification:

$$Vol_t^{ij} = \eta + \beta^{ij} \times Tenure + \varepsilon_t^{ij}, \tag{11}$$

where Vol^{ij} refers to idiosyncratic volatility under CEO i's tenure in firm j, and *Tenure* is the month in office count scaled by 12 (0, 1/12, …3). The coefficient β^{ij} captures the average rate of decline in volatility during the tenure of CEO i in firm j. For our purpose here, we refer to $(-\beta)$ as the learning slope, which should be positively related to the average learning speed over the first thirty-six months. To reduce the impact of noise in the estimated slope, we normalize estimated slopes using their empirical cumulative distribution function, so that slopes are ranked between zero and one, reflecting the relative rankings of learning speeds across firms, with a learning slope of one corresponding to the fastest speed.

Panel A in Table 7 summarizes the estimates of learning slopes for each industry based on the Fama-French 10-industry classification.[17] The two industries with the highest estimated learning speeds are the technology industry (computers, software, and electronic equipment) and the health care industry (health care, medical equipment, drugs), while the industries with the lowest learning speeds are the energy, nondurables, and utilities industries. The difference between the estimated learning slopes between the top and the bottom industries are statistically significant.

5.2.2 Firm transparency and prior uncertainty about CEO ability. We next relate the estimated learning slope to its determinants according to the model, such as firm transparency and prior uncertainty about CEO ability. To examine the determinants of the learning slope, we estimate a cross-sectional specification:

$$LearningSlope_{ij} = X_{ij}^{'}\gamma + u_{ij}. \tag{12}$$

[17] A detailed definition is at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

Table 7
Determinants of the learning speed

Panel A: Summary statistics of the estimated learning speed by industry

Industry	Obs.	Std. dev.	Mean	Median
Hi-Tech	277	0.301	0.531	0.534
Health	137	0.299	0.525	0.549
Other	515	0.271	0.501	0.522
Wholesale	195	0.272	0.495	0.482
Manufacturing	279	0.246	0.493	0.489
Durables	57	0.258	0.490	0.453
Telecom	29	0.252	0.489	0.489
Energy	62	0.274	0.486	0.482
Nondurables	111	0.260	0.485	0.480
Utilities	121	0.196	0.438	0.431
Total	1,783	0.269	0.499	0.499
Wilcoxon Z-statistic for the difference between the top and bottom industries		2.621***		

This table reports the summary statistics of the estimated firm-CEO specific learning speed for Fama-French 10 industries. We estimate firm-CEO specific regressions of idiosyncratic volatility on *Tenure* and a constant term. Then for each firm-CEO pair, the learning slope is the estimated coefficient on *Tenure* multiplied by -1 and then normalized with its empirical cumulative distribution function so it is between zero and one The Wilcoxon Z statistics for the difference between the top and bottom industries, along with the significance levels, are reported as well. *** indicates significance at the 1% level.

Panel B: Summary statistics of the determinants

	Obs.	Std. dev.	Mean	Median
Learning speed	1,873	0.269	0.500	0.500
Number of analyst	1,669	9.627	11.813	9.000
Analysts forecast error	1,669	0.439	0.179	0.040
Log(MV)	1,678	1.749	6.886	6.843
Firm age	1,743	16.051	22.124	18.000
Outsider CEO	1,873	0.464	0.312	0.000
Heir apparent	1,873	0.372	0.165	0.000
CEO age	1,439	7.216	53.575	53.000
Number of previous positions	678	2.561	3.155	3.000
Industry HHI	1,873	0.044	0.042	0.033
Industry R&D	1,873	0.099	0.105	0.071
Industry new products	729	0.872	0.585	0.172
Industry sales growth	1,873	0.059	0.069	0.066

This table reports the summary statistics of the estimated learning speed and its determinants, including firm, manager, and industry attributes as of the turnover year. Variable definitions are in Appendix B.

We use a number of variables to measure the degree of prior uncertainty about CEOs' abilities to add value to their firms. First, the existence of an "heir apparent" usually indicates a well-anticipated succession, so the appointment of a new CEO who was expected to be appointed to the job should be associated with relatively low uncertainty about his ability. For this reason, we follow Naveen (2006) and classify heir-apparent CEOs in our sample as executives with the title "president" or "chief operating officer (COO)" prior to becoming CEO. Similarly, we expect an outsider CEO to have higher prior uncertainty than an insider CEO because of the unknown quality of the match between the outsider and the new firm. In addition, younger CEOs generally have shorter track records and less visibility than older CEOs, and thus should be associated with higher prior uncertainty about their abilities. Uncertainty about ability

Table 7
Continued

Panel C: Prior uncertainty, information environment, and the learning speed

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Learning slope				
Outsider CEO	0.016*						−0.002	0.019*
	(1.897)						(−0.194)	(1.825)
Heir apparent		−0.017**					−0.019**	−0.007
		(−2.345)					(−2.411)	(−0.848)
ln(CEO age)			−0.086**				−0.044*	−0.016
			(−2.456)				(−1.806)	(0.417)
# of previous positions				−0.007*				0.005
				(−1.986)				(1.481)
Number of analysts					0.003***		0.003***	0.002**
					(6.038)		(6.369)	(2.858)
Analysts forecast error						−0.029*	−0.015	−0.035
						(−2.067)	(−0.753)	(−1.630)
Log(MV)	−0.007	−0.007	−0.006	0.009	−0.018***	−0.002	−0.015***	−0.006
	(−1.610)	(−1.556)	(−1.512)	(0.883)	(−5.734)	(−0.626)	(−5.442)	(−1.198)
Log(Firm age)	−0.029***	−0.029***	−0.014*	−0.022**	−0.028***	−0.032***	−0.028***	−0.037***
	(−5.266)	(−5.425)	(−2.207)	(−2.562)	(−6.137)	(−.031)	(−6.387)	(−5.840)
Constant	0.287***	0.413***	0.955***	0.179**	0.662***	0.603***	0.165	0.216
	(14.343)	(8.776)	(8.136)	(2.511)	(13.98)	(12.496)	(1.436)	(1.528)
Year fixed effects	x	x	x	x	x	x	x	x
Obs.	1,568	1,568	1,295	604	1,481	1,481	1,295	512
Adj. R^2	0.442	0.442	0.34	0.119	0.456	0.453	0.472	0.612

This table reports the estimates from regressions of the estimated learning slopes on various firm and CEO attribute. Variable definitions, including the estimation of the learning slope, are reported in Appendix B. The Huber–White robust standard errors are clustered by industry. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

is also likely to be inversely related to the CEO's experience, so we create a variable *Prior experience* that equals to the number of previous executive positions the CEO held before taking the current position. We construct these variables using data on job title and CEO age from ExecuComp, and on prior managerial experience from BoardEx.

Since the theory predicts that the informativeness of the signals about CEO ability should affect the learning speed, we also construct measures of the quality of the information available about the firm that can be used to infer the CEO's ability. Other things equal, more transparent firms are more likely to have lower fundamental volatility (σ) and thus higher learning speed (δ/σ). We measure the firm's transparency using two analyst-based variables, both measured as of the year of turnover: *Number of analysts* is defined as the number of unique financial analysts that post forecasts for a firm in the fiscal year, while *Analyst forecast error* is calculated as the absolute difference between the mean analyst forecast of the annual earnings per share prior to the earnings announcement and the actual earnings in a given year. We expect the learning speed to be faster for more transparent firms, measured by higher analyst coverage and a smaller forecast error.

We also control for other factors that are likely to affect the learning slope. Pastor and Veronesi (2003) document that uncertainty about the firm's

Table 7
Continued

Panel D: Importance of the CEO and the learning speed

	(1)	(2)	(3) Learning slope	(4)	(5)
Industry HHI	−0.147*				−0.193
	(−1.957)				(−1.066)
Industry R&D		0.115*			0.145*
		(1.857)			(1.689)
Industry new products			0.039***		0.016
			(5.810)		(1.215)
Industry sales growth				−0.004	0.155
				(−0.049)	(1.185)
High-tech					0.037
					(1.419)
Utility					0.023
					(1.654)
Number of analysts	0.002**	0.002**	0.002	0.002**	0.002
	(2.023)	(2.096)	(1.606)	(2.163)	(1.527)
Analysts forecast error	−0.001***	−0.001***	−0.049**	−0.001***	−0.049**
	(−3.853)	(−3.911)	(−2.379)	(−3.777)	(−2.372)
Outsider CEO	−0.005	−0.006	−0.003	−0.005	−0.003
	(−0.292)	(−0.371)	(−0.118)	(−0.316)	(−0.156)
Heir apparent	−0.046***	−0.046***	−0.047**	−0.047***	−0.051***
	(−4.439)	(−4.411)	(−2.548)	(−4.471)	(−2.847)
Log(CEO age)	−0.090**	−0.092**	−0.079	−0.086**	−0.074
	(−2.152)	(−2.151)	(−1.443)	(−2.063)	(−1.379)
Log(MV)	−0.011*	−0.011*	−0.015**	−0.011*	−0.016**
	(−1.814)	(−1.960)	(−2.536)	(−1.909)	(−2.682)
Log(Firm age)	−0.016*	−0.013	0.002	−0.016	0.004
	(−1.681)	(−1.398)	(0.208)	(−1.675)	(0.364)
Year fixed effects	x	x	x	x	x
Obs.	1,295	1,295	576	1,295	576
Adj. R^2	0.472	0.472	0.486	0.472	0.486

This table reports the estimates from regressions of the estimated learning slopes on industry-level characteristics, controlling for various firm and CEO attributes as well as the year fixed effects. *High-tech (utility)* is an indicator variable that equals to 1 if the firm is in the high-tech (utility) industry. Variable definitions, including the estimation of the learning slope, are reported in Appendix B. The Huber–White robust standard errors are clustered by industry. T-statistics are reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

profitability and thus stock return volatility decreases over time as the firm grows and matures. We measure firm size by the logarithm of the market value of equity *Log(MV)* and firm age using *Log(Firm age)*, the logarithm of the number of years since IPO. We also control for turnover year fixed effects. Panel B of Table 7 reports summary statistics on these explanatory variables.

Panel C of Table 7 presents estimates of equations predicting the learning slope of a particular firm-CEO pair. Because a number of our independent variables are highly correlated with one another, we first present estimates in Columns (1) through (6) using each variable separately. In Column (7), we include all explanatory variables except for the CEO's prior experience, because including this variable reduces our sample size by about 60%. Finally, in Column (8) we report the results for the smaller subsample including CEO prior experience.

The estimates indicate that learning about CEO ability is faster in firms with more analyst coverage and lower analyst forecast errors, although the forecast error is not statistically significant in the specifications using all variables. Learning is also significantly faster in younger firms. As for the CEO characteristics, learning appears to be slower for heir apparent CEOs, but faster for outsider CEOs, younger CEOs, and less experienced CEOs.

All these findings are consistent with the notion that learning about CEO ability is faster when there is more uncertainty about the general or firm-specific CEO ability, and also when signals about that ability are more informative. The fact that the cross-sectional pattern of the volatility–tenure relation corresponds to that predicted by the learning model provides additional confirmation that the appropriate interpretation of such relation is that it reflects learning about ability, not some unobserved factor that is correlated with CEO turnover.

5.2.3 Measuring the importance of CEO ability through learning speeds. When there is more uncertainty about CEO ability, the market's learning about it will lead to larger movements in firm value. If an industry has a larger variance in CEO ability, ability-induced volatility will account for a larger fraction of the firm's total volatility and the market's learning about CEO ability will be faster. Therefore, learning speeds provide a novel way of measuring the importance of CEO ability. We use this logic to evaluate the circumstances under which CEOs are relatively important.

No existing theory provides clear predictions about the relative importance of CEOs in different types of firms. Li, Lu, and Phillips (2014) find that in rapidly changing, competitive markets, CEO power is particularly related to firm valuation. However, more competitive industries also tend to have smaller rents to protect, which could potentially decrease the value of management in those industries. The extent to which the importance of management varies with the competitiveness of a firm's industry is therefore an empirical issue. For this reason, we use the cross-sectional variance in learning speed to evaluate the CEO's value impact and the extent to which an industry's competitiveness and growth affect CEOs' importance.

We measure the competitiveness of an industry in three ways. First, we use the traditional industry concentration measure, the average HHI of a Fama-French 48 industry over the three years since CEO turnover, which is likely to be negatively correlated with industry competitiveness. In addition, competition should be stronger in industries in which there is higher pressure to come up with new products in order to maintain market share. For this reason, we construct two measures that are meant to capture the product obsolescence risk and competition in the markets for new products: *Industry R&D* is the three-year average firm R&D expenditures to assets rate in a Fama-French 48 industry, and *Industry new products* is the three-year average number of corporate new product announcements per year (scaled by 1,000) in a Fama-French 48 industry.

Panel D of Table 7 shows that after controlling for the firm and CEO characteristics that affect the learning speed, learning about CEO ability is faster in less concentrated industries (Column 1) and in industries with higher product obsolescence risk and higher growth potential (Columns 2 and 3), but not faster in industries with higher realized sales growth rate (Column 4). In Column (5), we include all four industry competition and growth measures; in this specification, industry R&D is the only significant determinant among the four for the speed of learning. These results, although mostly statistically significant only at the 10% confidence level, suggest that learning about CEO ability is faster in industries with higher product obsolescence risk and higher growth potential, and that CEO ability is potentially more important in these industries.

In Column (5), we also include the technology industry dummy and the utilities industry dummy. The coefficient estimates of these industry dummies are insignificantly different from zero. Thus, the cross-industry differences in learning speeds appear to be well captured by the CEO-, firm-, and industry-level determinants of the learning speed we considered in this section.

5.3 Variation in the fraction of volatility explained by uncertainty about CEO

Given that learning speeds vary systematically across CEOs and firms, it is plausible that the fraction of volatility explained by uncertainty about CEO ability does as well. To evaluate the quantitative importance of these differences, we estimate the learning speed (m_t) as well as the volatility ratio (δ_t/σ) at the time of turnover for several subsamples, using the regression approach based on Equation (9) (specifically, Model 3 in Panel B of Table 2 using idiosyncratic volatility).

The estimates presented in Table 8 indicate that there is substantial cross-sectional heterogeneity in the magnitude of ability-induced volatility. The estimated m_0 and volatility ratio are substantially larger for younger CEOs (age <53) than for older ones (m_0: 35% vs. 13%, δ_0/σ: 59% vs. 36%), larger for outsider CEOs than for insiders (m_0: 26% vs. 18%, δ_0/σ: 51% vs. 43%). These estimates imply that the ability-induced volatility varies substantially with the experience and succession origin of the CEO. Firm and industry characteristics matter as well. For example, the estimated m_0 and volatility ratio are larger for more transparent firms, and larger in industries with higher growth potential.

6. Discussion and Conclusion

When management's quality is not known perfectly but nonetheless affects profitability, any news about the firm's profits will lead rational investors to update their assessment of the management's ability to generate future profits. Stock return volatility will vary depending on the magnitude of the market's updates in its assessment of CEO ability, which will be larger when there is

Table 8
Initial learning speed and volatility ratios in subsamples

	Tenure	*Tenure*^{2}	m_0	δ_0/σ
Young CEO	−0.561**	0.196***	0.349	0.591
Old CEO	−0.579***	0.074	0.128	0.358
Outsider CEO	−1.006***	0.257***	0.255	0.505
Insider CEO	−0.360**	0.066***	0.183	0.428
More analyst coverage	−0.294*	0.086*	0.293	0.541
Less analyst coverage	−0.759***	0.174***	0.229	0.479
Low industry R&D	−0.659***	0.104***	0.158	0.397
High industry R&D	−1.165***	0.396***	0.340	0.583

This table reports the estimated coefficients on *Tenure* and *Tenure*^{2} using the specification in Model (3) (idiosyncratic volatility) in Panel B of Table 2, for various subsamples based on CEO or firm or industry attributes. We also report the estimated learning speed at the time of CEO turnover (m_0), as well as the ratio of uncertainty about CEO ability to fundamental volatility at turnover (δ_0/σ). As discussed in Section 4, m_0 equals the coefficient on *Tenure*^{2} divided by the coefficient on *Tenure* and then times minus one. *Young (Old) CEO* is defined as a CEO younger than (at least) 53 years old when he takes office. *Outsider (Insider) CEO* is a CEO hired from outside (promoted from inside) of the firm. *Low industry R&D* includes firms with the three-year average industry R&D intensity lower than 2.7%—the bottom 25% of the distribution—at turnover. *High industry R&D* includes firms with the three-year average industry R&D intensity higher than 17.7%—the top 25% of the distribution—at turnover. ***, *, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

more uncertainty about the ability. Once the CEO becomes more well known, stock-return volatility should decline, since new information about the firm will cause less of an update to the market's expectation of future profits. The extent to which volatility declines over CEO tenure should depend on the prior uncertainty about a CEO's ability and the informativeness of signals available to the market.

This paper formalizes this idea using a stylized Bayesian learning model, and evaluates the model's implications on a large sample of CEOs in publicly traded U.S. firms. First, we document that there is indeed a decline of return volatility over CEO tenure. This decline is not a consequence of nonrandom timing of CEO turnovers or post-turnover changes or information revelation about the firm's fundamentals. Second, we find strong evidence for a convex learning curve: learning appears to be fastest in the first year of the CEO's tenure, and the majority of the volatility–tenure relation occurs in the three years following the turnover. Third, the model allows us to quantify the importance of uncertainty about management quality in determining the overall stock return volatility. Our estimates imply that uncertainty about management accounts for a nontrivial portion of total stock return volatility.

We also provide evidence on the way the market learns about CEO ability by examining market reactions to salient post-turnover corporate disclosures and the cross-sectional determinants of the learning speed. Consistent with the predictions of the learning model, we find that the market reaction to corporate news is larger in the earlier periods of a CEO's career, when uncertainty about CEO ability is higher, when the news contradicts rather than confirms the market belief, and when the disclosed corporate action is more informative about CEO ability. Also, learning is significantly faster in more transparent firms and when the prior uncertainty about CEO ability is higher. Finally, the speeds at which the market updates its assessment of the CEO provide a novel way of measuring the importance of CEO ability to firm value. The learning speeds appear to be faster in more competitive industries with higher growth potential and product obsolescence risk, suggesting that the choice of CEO is likely to be relatively important in such environments.

The results in this paper suggest that the demand for information could potentially depend on the uncertainty about management's abilities. To the extent that learning is "active" and endogenously chosen, we expect the market to produce more information when management's ability is more uncertain. For example, there could be an increase in the number of analysts following firms with more uncertainty about management quality, and also that the analysts following those firms could be more active at updating their forecasts, making more frequent reports, and being more active on earnings conference calls. While we do not provide any evidence on these predictions here, doing so would be an interesting topic for future research.

CEOs of public firms have become well-known public figures, generally believed to be important sources of value in firms. Yet, the common occurrence of high expectations surrounding new appointments, combined with disappointment when they do not deliver, indicates that there is often substantial uncertainty about a CEO's ability to add to his firm's profits. The empirical evidence we provide suggests that there is substantial variation in management quality, and that this variation leads to meaningful differences in firm profitability and valuations.

Appendix A. Proof for Equation (6)

Let $f_t(\alpha)$ denote the probability density function of α at time t, and E be the expectation operator.

$$P_t = E_t\left[\int_t^{\infty} e^{-r(\tau-t)} D_\tau d\tau\right] = \int_{-\infty}^{r} E\left[\int_t^{\infty} e^{-r(\tau-t)} D_\tau d\tau | \alpha\right] f_t(\alpha) d\alpha$$

The integral is from $-\infty$ to r because α is bounded from above (less than r). Conditional on α, which is the CEO ability that controls the drift of the dividend growth process in Equation (2), we can apply Itō's lemma for $g(D_t) = log(D_t)$ to get $D_\tau = D_t e^{\left(\alpha - \frac{\sigma^2}{2}\right)(\tau-t)+\sigma(W_\tau - W_t)}$. Thus,

$$P_t = \int_{-\infty}^{r}\int_t^{\infty} E[e^{-r(\tau-t)} D_t e^{\left(\alpha - \frac{\sigma^2}{2}\right)(\tau-t)+\sigma(W_\tau - W_t)} |\alpha] d\tau f_t(\alpha) d\alpha$$

Since $W_\tau - W_t \sim N(0,\ \tau - t)$, we use the moment-generating function for this normal distribution to get

$$P_t = D_t \int_{-\infty}^{r}\int_t^{\infty} e^{-(r-g)(\tau-t)} d\tau f_t(\alpha) d\alpha$$

Then, using the property of the finite integral for an exponential distribution, $\int_0^{\infty} e^{-(r-g)s} ds = \frac{1}{r-g}$, we get: $P_t = D_t \int_{-\infty}^{r} \frac{1}{r-\alpha} f_t(\alpha) d\alpha$. Note that $f_t(\alpha) \sim N(\theta_t, \delta_t^2)$ and α <r. The dynamics of θ_t, δ_t^2 are

presented in Equation (4). Let $F\left(\theta_t,\delta_t^2\right)\equiv\log(\frac{P_t}{D_t})$. From Itō's lemma, $dF\left(\theta_t,\delta_t^2\right)=\frac{\partial F\left(\theta_t,\delta_t^2\right)}{\partial\theta_t}d\theta_t+o(dt)$, where *o(dt)* denotes the nonstochastic terms. Since $dlog\left(\frac{P_t}{D_t}\right)=\frac{dP_t}{P_t}-\frac{dD_t}{D_t}$, we have

$$\frac{dP_t}{P_t}=\frac{dD_t}{D_t}+\frac{\partial F\left(\theta_t,\delta_t^2\right)}{\partial\theta_t}d\theta_t+o(dt).$$

Combining the above equation with Equation (4), we have:

$$\frac{dP_t}{P_t}\approx\frac{dD_t}{D_t}\times[1+\left(\frac{\partial F\left(\theta_t,\delta_t^2\right)}{\partial\theta_t}\right)m_t]+o(dt)$$

Finally, taking standard deviation of both sides:

$$vol\left(\frac{dP_t}{P_t}\right)\approx vol\left(\frac{dD_t}{D_t}\right)\times\left[1+\left(\frac{\partial F\left(\theta_t,\delta_t^2\right)}{\partial\theta_t}\right)m_t\right]=vol\left(\frac{dD_t}{D_t}\right)\times\left[1+\left(\frac{\partial\log(\frac{P_t}{D_t})}{\partial\theta_t}\right)m_t\right]$$

Appendix B. Variable Definitions

Variables in the baseline specifications

Tenure	The event month count from month 0 to month 36 scaled by twelve, with month 0 being the event month when the CEO takes office.
Option-implied volatility	The average of implied volatility from daily prices of thirty-day at-the-money call options written on the firm's common stock in a month, aggregated to the monthly level.
Realized return volatility	The standard deviation of daily stock returns in a month, aggregated to the monthly level.
Idiosyncratic return volatility	The volatility of the residual return from the Fama-French three-factor model in a month, aggregated to the monthly level.
Market beta/SMB beta/HML beta	The coefficient estimate on the excess market return, the SMB factor, and the HML factor in the Fama-French (1993) three-factor model, respectively, estimated at the monthly level using daily stock returns.
Div. payer	An indicator variable that equals one if the firm pays out dividend to common stock holders in a year.
Leverage	Long-term debt/total assets, constructed for each firm-year.
Log(Assets)	Logarithm of the total book assets (in million dollars), constructed for each firm-year.
M/B	Market value of equity divided by book value of equity, constructed for each firm-year.
ROE	Net income scaled by the average book value of equity between the current and the previous periods, constructed for each firm-year.
VOLP	Residual volatility of the AR(1) process of ROE, following Pastor and Veronesi (2003).

Turnover types	
Turnovers due to health or illness	Include cases where (i) news searches revealed that the CEO departure was related to a health condition or death (from Fee et al. (2013)), or (ii) the turnover reason provided in ExecuComp is "deceased."
Turnovers due to retirement	This sample includes turnovers due to health or illness as discussed above, and cases where the turnover reason provided in ExecuComp is "retired" or the departing CEOs are older than 65 years old, and the cumulative monthly industry-adjusted stock return during the twelve months before the new CEO's inauguration month (see the variable definition for *Cum. industry-adj. return month[–12,–1]* below) is nonnegative.
No management shakeup	CEO turnovers not accompanied by top management (top-four highest paid non-CEO executives) changes during the thirty-six months after turnover.
Cum. industry-adj. return month[–12,–1]	Cumulative industry (Fama-French 48)-adjusted return during the twelve months before the inauguration month.
Industry-adj. monthly IVOL month[–12,–1]	The median of the monthly industry (Fama-French 48)-adjusted idiosyncratic volatility during the twelve months before the inauguration month.
Pre-turnover ind-adj. IVOL ≤ 0 & stock return ≥ 0 & ROA ≥ 0	Turnovers that satisfy the following three conditions: (i) the median of the monthly industry-adjusted idiosyncratic volatility during the twelve months before the inauguration month (see the variable definition for *Industry-adj. monthly IVOL month[–12,–1]* above) is less than or equal to 0; (ii) the cumulative monthly industry-adjusted stock return during the twelve months before the inauguration month (see the variable definition for *Cum. industry-adj. return month[–12,–1]* above) is nonnegative; and (iii) the industry-adj. ROA in the fiscal year prior to the inauguration month is nonnegative. ROA is defined as the earnings before interest, tax, and depreciation scaled by the beginning of fiscal year total book assets.
Outright forced turnovers	Outright forced turnovers include the "overtly forced" group from Fee et al. (2013) with cases for which news searches indicated that the CEO was forced to leave or left under pressure.

Post-turnover corporate disclosure and market reaction to news	
Downsizing announced	An indicator variable that equals one if the company makes downsizing announcement (Events 1, 21 in Capital IQ) in a month.
Expansion announced	An indicator variable that equals one if the company makes expansion announcements (Events 3, 31 in Capital IQ) or M&A announcements (from SDC Platinum) in a month.
CAPX announced	An indicator variable that equals one if the company makes expansion announcements (Events 3, 31 in Capital IQ) in a month.

Post-turnover corporate disclosure and market reaction to news—Continued	
M&A announced	An indicator variable that equals one if the company makes M&A announcements (from SDC Platinum) in a month.
New product announced	An indicator variable that equals one if the company makes new product or service related announcements (Event 41 in Capital IQ).
Dividend change announced	An indicator variable that equals one if the company announces a dividend increase or decrease (Event 46 and 47 in Capital IQ).
Earning surprise announced	An indicator variable that equals one if a company's actual quarterly earning exceeds 10% deviation from the forecast median.
Restatement/write-off/fraud announced	An indicator variable that equals one if the company makes announcements regarding restatements of operating results (Event 43 in Capital IQ) or impairments/write-offs (Event 73 in Capital IQ) or securities fraud investigation (from the Federal Securities Research database).
|AR|	Absolute value of the market-adjusted announcement-day return, where market return is the "value-weighted market return" from CRSP. Both market and firm returns are ex-dividend.
|Change/surprise|	Absolute value of the dividend per share change or earnings surprise per share.
Market volatility	Cross-sectional standard deviation of the daily returns of all CRSP firms (ex-dividend) on a trading day.
Growth rate	The percentage growth in EPS (from I/B/E/S) or sales (from Compustat quarterly) relative to the same quarter last year, winsorized at 1%, or the percentage growth in regular dividend (from CRSP) relative to the last quarter.

Determinants of the learning slope	
Learning slope	We run firm-CEO specific regressions of idiosyncratic volatility on *Tenure* and a constant term. For each firm-CEO pair, the learning slope is the estimated coefficient on *Tenure* multiplied by –1 and then normalized with its empirical cumulative distribution function so it is between zero and one.
Number of analysts	The number of unique financial analysts that post forecasts for a firm in the fiscal year.
Analyst forecast error	Analyst forecast error, measured as the absolute difference between the (latest) mean analyst earnings forecast prior to an annual earnings announcement and the actual earnings.
Firm age	Age of the firm since IPO, using the first day appear in CRSP (or the IPO date in Compustat if missing), constructed for each firm-year.
Log(MV)	Logarithm of the market value of equity (in million dollars), constructed for each firm-year using the end of fiscal year stock price.
CEO age	The age of the CEO.
Outsider CEO	An indicator that equals one if the CEO is hired from outside (i.e., with the firm for less than three year when becoming the CEO).

Determinants of the learning slope—Continued

Heir apparent	An indicator that equals one if before becoming the CEO, the person was an executive with the title "president" or "chief operating officer (COO)" or both who is distinct from the CEO and the chairman.
Number of prior positions	Number of positions the CEO took prior to become the chief executive (both within the current company and in other companies).
Industry R&D	We first calculate the average of the R&D intensity (R&D expense scaled by total book assets) across all firms in an industry-year, and then take the three-year average. Industry is defined by the Fama-French 48-industry classification.
Industry new products	For turnovers between 2002 and 2006, we use the new product/service announcement data from Capital IQ to calculate the total number of such announcements (scaled by 1,000) in an industry-year, and then take the three-year average. Industry is defined by the Fama-French 48-industry classification.
Industry HHI	We use the sales HHI to measure the industry level competition each year and then take the three-year average. Industry is defined by the Fama-French 48-industry classification.
Industry sales growth	We compute the average firm sales growth from year t to year t+1 in an industry-year, and then take the three-year average. Industry is defined by the Fama-French 48-industry classification.

References

Ang, A., R. J. Hodrick, Y. Xing, and X. Zhang. 2006. The cross-section of volatility and expected returns. *Journal of Finance* 61:259–99.

Bennedsen, M., F. Pérez-González, K. Nielsen, and D. Wolfenzon. 2007. Inside the family firm: The role of families in succession decisions and performance. *Quarterly Journal of Economics* 122:647–91.

Bennedsen, M., F. Pérez-González, and D. Wolfenzon. 2013. Estimating the value of the boss: Evidence from CEO hospitalization events. Working Paper, Stanford University.

Berk, J., and R. Green. 2004. Mutual fund flows and performance in rational markets. *Journal of Political Economy* 112:1269–95.

Bertrand, M., and A. Schoar. 2003. Managing with style: The effect of managers on firm policies. *Quarterly Journal of Economics* 118:1169–1208.

Boot, A. W. A. 1992. Why hang on to losers? Divestitures and takeovers. *Journal of Finance* 47:1401–23.

Bushman, R., Z. Dai, and X. Wang. 2010. Risk and CEO turnover. *Journal of Financial Economics* 96:381–98.

Chung, J., B. A. Sensoy, L. H. Stern, and M. S. Weisbach. 2012. Pay for performance from future fund flows: The case of private equity. *Review of Financial Studies* 25:3259–3304.

Clayton, M., J. Hartzell, and J. Rosenberg. 2005. The impact of CEO turnover on equity volatility. *Journal of Business* 78:1779–1808.

Cox, D. R. 1972. Regression models and life tables (with discussion). *Journal of the Royal Statistical Society*, Series B, 34:187–220.

Cremers, M., and Y. Grinstein. Forthcoming. Does the Market for CEO Talent Explain Controversial CEO Pay Practices? *Review of Finance*.

Fama, E. F., and K. R. French. 1993. Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics* 33:3–56.

Fee, C. E., C. J. Hadlock, and J. R. Pierce. 2013. Managers with and without style: Evidence using exogenous variation. *Review of Financial Studies* 26:567–601.

Friedman, J. H. 1991. Multivariate adaptive regression splines. *Annals of Statistics* 19:1–67.

Gibbons, R., and K. J. Murphy. 1992. Optimal incentive contracts in the presence of career concerns: Theory and evidence. *Journal of Political Economy* 100:468–505.

Hermalin, B. E. 2005. Trends in corporate governance. *Journal of Finance* 60:2351–84.

Hermalin, B. E., and M. S. Weisbach. 1998. Endogenously chosen boards of directors and their monitoring of the CEO. *American Economic Review* 88:96–118.

———. 2012. Information disclosure and corporate governance. *Journal of Finance* 67:195–233.

Holmström, B. 1999. Managerial incentive problems: A dynamic perspective. *Review of Economic Studies* 66:169–82.

Johnson, B. W., R. Magee, N. Nagarajan, and H. Newman. 1985. An analysis of the stock price reaction to sudden executive death: Implications for the management labor market. *Journal of Accounting and Economics* 7:151–74.

Karpoff, J. M., A. Koester, D. S. Lee, and G. S. Martin. 2014. An analysis of database challenges in financial misconduct research. Working Paper, University of Washington.

Kanodia, C., R. Bushman, and J. Dickhaut. 1989. Escalation errors and the sunk cost effect: An explanation based on reputation and information asymmetries. *Journal of Accounting Research* 27:59–77.

Li, M., Y. Lu, and G. Phillips. 2014. CEOs and the product market: When are powerful CEOs beneficial? Working Paper, University of Southern California.

Lim, J., B. A. Sensoy, and M. S. Weisbach. 2015. Indirect incentives of hedge fund managers. Working Paper, Ohio State University.

Naveen, L. 2006. Organizational complexity and succession planning. *Journal of Financial and Quantitative Analysis* 41:661–83.

Milbourn, T. 2003. CEO reputation and stock-based compensation. *Journal of Financial Economics* 68:233–62.

Murphy, K. J., and J. Zábojník. 2007. Managerial capital and the market for CEOs. Working Paper, University of Southern California.

Murphy, K. J., and J. L. Zimmerman. 1993. Financial performance surrounding CEO turnover. *Journal of Accounting and Economics* 16:273–315.

Pan, Y., T. Y. Wang, and M. S. Weisbach. 2014. CEO investment cycles. Working Paper, Ohio State University.

Parrino, R. 1997. CEO turnover and outside succession: A cross-sectional analysis. *Journal of Financial Economics* 46:165–97.

Pastor, L., and P. Veronesi. 2009. Learning in financial markets. *Annual Review of Financial Economics* 1:361–81.

———. 2003. Stock valuation and learning about profitability. *Journal of Finance* 58:1749–89.

Schwartz-Ziv, M., and M. S. Weisbach. 2013. What do boards really do? Evidence from minutes of board meetings. *Journal of Financial Economics* 108:349–66.

Taylor, L. 2013. CEO wage dynamics: Estimates from a learning model. *Journal of Financial Economics* 108:79–98.

———. 2010. Why are CEOs rarely fired? Evidence from structural estimation. *Journal of Finance* 65:2051–87.

Timmermann, A. G. 1993. How learning in financial markets generates excess volatility and predictability in stock returns. *Quarterly Journal of Economics* 108:1135–45.

Vancil, R. 1987. *Passing the baton: Managing the process of CEO succession*. Boston: Harvard Business School Press.

Warner, J., R. L. Watts, and K. H. Wruck. 1988. Stock prices and top-management changes. *Journal of Financial Economics* 20:461–92.

Weisbach, M. S. 1995. CEO turnover and the firm's investment decisions. *Journal of Financial Economics* 37:155–88.

———. 1988. Outside directors and CEO turnover. *Journal of Financial Economics* 20:431–60.