Learning About Directors

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Abstract

This paper studies the importance of corporate boards through a learning model in which capital markets learn about incoming directors' quality. The model's predictions are tested across a large sample of director appointments. Estimates show that governance-related uncertainty accounts for about 10% of stock return volatility when a new director joins. The learning framework provides a theoretically-grounded approach to identify when directors matter more to investors. The analysis shows that director importance varies with board composition and firm attributes: investors perceive directors as more important on boards with greater generational diversity, in smaller firms, and firms with higher knowledge capital.

I. Introduction

Boards of directors are legally responsible for governing the firm and protecting the interests of shareholders. Yet, inasmuch as corporate directors are not perfect agents, providers of capital may find it beneficial to evaluate them. A debate going back to Smith (1776) and Berle and Means (1932) questions whether boards of directors are monitors of or are tools of management.[1] How can we gauge the impact of boards of directors on the success of a typical firm? How can we quantify the extent to which they affect value? Are there systematic patterns in how impactful some types of boards or directors are? These questions have been front and center in the governance debate for many years. The existing literature however often provides conflicting evidence, and it is challenging to arrive at clear conclusions due to methodological issues (see Hermalin and Weisbach (2003) and Adams, Hermalin and Weisbach (2010)). Despite the extensive literature, directors remain commonly viewed as "rubber-stampers", with limited substantive influence on value.[2] Understanding the importance of boards and the constituents of a well performing board remain important open questions.

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[1] Smith (1776) wrote: "The Directors of [joint stock] companies, however, being the managers of other people's money rather than their own, it cannot be expected that they should watch over it with the same anxious vigilance [as owners]… Negligence and profusion, therefore, must always prevail, more or less, in the management of the affairs of such a company." ([1937] p.700). One hundred fifty-six year later, Berle and Means (1932) argued: "…control will tend to be in the hands of those who select the proxy committee and by whom, the election of directors for the ensuing period will be made. Since the proxy committee is appointed by existing management, the latter can virtually dictate their successors." (p. 87).

[2] New York Times, 01/16/2010 "Taking Away Directors' Rubber Stamps". https://www.nytimes.com/2010/01/17/business/17shelf.html.

This paper contributes to broadening our understanding of the role of corporate boards by proposing a novel approach to evaluating them. This approach is based on a theoretical model of learning which yields a general method to assess the way in which market participants learn about the quality of new directors. The model builds on the work of Pastor and Veronesi (2003), (2009) and Pan, Wang and Weisbach (2015). It is based on the premise that in a world in which directors do not purely engage in window-dressing, but instead do influence the cash flow generating process, the arrival of a new director generates uncertainty for investors. This uncertainty inflates stock return volatility through a process described in Timmermann (1993). The arrival of a new director adds a random variable to the firm's value. Through their actions, new directors provide information to investors who, over time, figure out what that random variable is. As investors accumulate more information, their updates about director quality become smaller. The resolution of governance-related uncertainty leads to a decline in stock return volatility (Timmermann (1993)).

The model yields testable predictions about stock return volatility patterns which are tested on a sample of 16,798 directors appointed to 2,180 S&P 1,500 firms between 2000 and 2014. Analysis of volatility patterns over the five years following appointment shows that volatility typically increases by approximately 10% when a new director joins, followed by a gradual decline. Interpreted in light of the learning model, this volatility pattern suggests that investors perceive directors as contributors to the firm's cash flow-generating process, and as the market learns about them, governance-related uncertainty gets resolved. The decline in return volatility over the tenure of directors provides empirical support for the assumption that investors perceive directors' actions to be relevant in their valuation of the firm. The learning framework also allows for quantifying this importance: when a new director is appointed, governance-

related uncertainty accounts for about 10% of stock return volatility, approximately one-third the estimate documented for CEOs by Pan et al. (2015). This finding provides an important benchmark to assess governance uncertainty's effect on valuation compared to management uncertainty.

A concern with the learning interpretation is the potential endogeneity of director appointments, as some directors might be appointed during tumultuous times. As a first step to address the concern that firms may reshuffle their board in times of crisis, the entire analysis excludes appointments that occur within two years before or after a CEO turnover.[3] Two approaches further address endogeneity challenges. The first creates a "business-as-usual" sample by filtering out appointments coinciding with corporate turbulence. This sample includes only solo appointments (no other director appointed within six months), at companies that outperformed the market, with low return volatility in the year leading up to the appointment. A similarity score ensures incoming directors have similar profiles to those they replace, reducing the likelihood that appointments reflect strategy shifts.[4] The second approach yields a "plausibly exogenous" sample, including only appointments made to either satisfy new board independence listing requirements, or to replace directors who passed away or retired. Both samples exhibit return volatility patterns consistent with the learning model's predictions, mitigating endogeneity concerns. Additional tests further support the interpretation that these volatility patterns reflect market participants learning about incoming directors, rather than being byproducts of endogenous appointments.

[3] Stock return volatility is not abnormally high in the months preceding director appointments in this sample.

[4] The firms' exposure to systematic risk does not change over the learning period: (unreported) plots of the firms' market, SMB and HML betas over director tenure show no particular pattern.

While overall volatility patterns consistent with the learning model are useful to establish directors' importance, the model also motivates cross-sectional analyses that identify when directors generate more learning by markets. Cross-sectional variation in the magnitude of the decline in return volatility over a director's tenure represents a theoretically-grounded way to measure how characteristics affect the extent of market learning about directors, and therefore their importance for firm value. Examining cross-sectional volatility patterns in a large sample sheds light on the factors that matter to investors when evaluating directors, which is helpful to identify the channels through which directors impact firms.

The learning-based framework yields both validation of existing findings through an independent method as well as important new insights about board governance. For instance, the analysis shows that incoming independent directors with high compensation relative to the incumbent board generate more learning by markets, suggesting that the importance of directors identified through the learning framework aligns with their perceived importance as reflected in compensation. In addition, the audit and compensation committees emerge as the most relevant committees to investors (more so than the nomination committee), highlighting financial oversight as a fundamental role of board members.

Importantly, beyond committee roles and director types, the analysis shows that board composition and firm characteristics matter for directors' expected impact. Examining how director importance varies across board and firm characteristics provides new insights into the conditions under which board governance matters most, which remains relatively underexplored in the literature. One particularly striking finding is that markets learn more about incoming directors when the incumbent board has greater generational diversity. This finding suggests that investors expect directors to have more impact when joining boards that combine different

generations' perspectives. The value of generational diversity aligns with findings in the literature on the role of experiences in shaping beliefs and economic decision-making (Malmendier and Nagel (2011), (2016), Malmendier, Nagel, and Yan (2021)). While board diversity has received increased attention, the concept of generational diversity remains relatively understudied despite its potential influence on board decision-making dynamics.[5]

The learning framework provides a theoretically-grounded approach to measure director importance across firm types. The analysis shows that directors have more impact in smaller firms and in those with more knowledge capital, indicating that board governance is particularly important when firms' assets are harder to monitor and value. These patterns highlight how the importance of the board and optimal board composition may vary with firm characteristics and provide new evidence on the importance of contextualizing governance (Erel, Stern, Tan, and Weisbach (2021)).

By bringing insights from the literature on learning by financial markets into the study of corporate boards, this paper introduces a novel approach to evaluating directors' importance. Previous work has relied on event studies using director deaths (Nguyen and Nielsen (2010), Falato, Kadyrzhanova, and Lel (2014), Ahern and Dittmar (2012)) or specific settings like German firms (Jenter, Schmid, and Urban (2018)) and Israeli board minutes (Schwartz-Ziv and Weisbach (2013)). Burt, Harford, and Hrdlicka (2018) exploit the commonality in idiosyncratic returns of firms linked through a director and find that directors account for 6.5% of stock price

[5] See for example Boardready, an organization that tracks and promotes board diversity metrics. Their platform identifies generational diversity as a key dimension of board composition, distinct from traditional diversity measures, noting that age diversity on boards can enhance decision-making by combining different perspectives shaped by distinct generational experiences.

variation. The learning-based framework presents several key advantages. First, it provides theoretically-grounded estimates from a large sample of U.S. director appointments, avoiding reliance on price reactions around hard-to-identify announcement dates or small subsets of firms.[6] Second, it provides an independent test rooted in a theoretical model of learning that exploits the second moment of stock returns. While the first moment reflects the market's assessment of a director's anticipated effect at arrival, this initial valuation at time zero is highly uncertain. Because observed price reactions may be attenuated due to uncertainty and disagreement, a low or zero price impact does not necessarily imply director irrelevance. In that sense, the mean may not accurately depict the expected contribution of directors to the cash flow-generating process. In contrast, the second moment provides greater insight into whether an event significantly affects the cash flow generating process. Third, studying post-appointment return volatility captures the process by which the market learns about director ability as new information is revealed. As Pastor and Veronesi (2003) show, valuations are inherently tied to learning about firm profitability. Analyses of volatility patterns over director tenure reveal that uncertainty about ability dissipates over time, suggesting that announcement returns may not always provide a reliable assessment of director value as they capture a net effect that does not account for the uncertainty prevailing at time zero.

The learning framework enables a broad evaluation of director and board characteristics and provides confirmation of several key findings in the governance literature. Much of the literature typically examines one characteristic at a time (e.g., director independence), focusing on its relationships with observed board actions such as CEO turnover (Weisbach (1988), Yermack (1996) and Wu (2000)), takeover probabilities (Shivdasani (1993)), or CEO

[6] Thanks to an anonymous referee for pointing out this advantage of the proposed methodology.

compensation (Core, Holthausen, and Larcker (1999)). The learning framework corroborates findings on female directors (Adams and Ferreira (2009), Matsa and Miller (2012), Ahern and Dittmar (2012)), board groupthink (Coles, Daniel, and Naveen (2015)), and board size (Yermack (1996), Eisenberg, Sundgren, and Wells (1998)). In cases where existing literature presents conflicting evidence, such as the impact of director busyness (Core et al. (1999), Ferris, Jagannathan, and Pritchard (2003), Fich and Shivdasani (2006), Field, Lowry, and Mkrtchyan (2013), Falato et al. (2014)), the learning approach offers an independent assessment, indicating that market participants expect busy directors to contribute more to cash flows.

This novel approach to studying board governance is rooted in theoretical foundations that draw from seminal works on learning about managerial ability by Harris and Holmström (1982), Murphy (1986), Gibbons and Murphy (1992), and Holmström (1999). Pan et al. (2015) implement the learning process set up by Pastor and Veronesi (2003) to study learning about CEOs. This paper advances this line of research by showing that director ability introduces parameter uncertainty that markets learn about over time. By introducing this Bayesian learning framework – which proved useful for studying the value of management - to board governance, this paper offers a novel approach to addressing important outstanding questions about corporate boards.

II. Hypothesis and Data

The details of the theoretical framework of rational Bayesian learning that motivates the hypotheses can be found in Appendix A. The underpinning intuition is that in a world in which corporate directors matter, their arrival injects parameter uncertainty into the firm's cash flow-generating process. As uncertainty dissipates with the arrival of new information, investors update their assessment of a new director’s quality to a lesser extent. Return volatility

subsequently declines as a result of the resolution of governance-related uncertainty, in a process described in Timmermann (1993) and Pastor and Veronesi (2003), (2009).

The model serves the purpose of formally characterizing the relationship between the uncertainty surrounding the appointment of new directors and stock return volatility. Equation (1) below (derived in Appendix A, equation (A7)), summarizes how the model motivates the empirical analysis by decomposing return volatility into three components.

(1) $$volatility_t \approx \sigma\,(1 + MRA_t \times m_t)$$

The first component, σ, is the firm's fundamental dividend growth volatility. The second component, MRA_t, measures the sensitivity of the firm's valuation - expressed as the log price to dividend ratio, $\log(P/D)$ - to changes in the market's assessment of director ability. Director *j*'s ability to serve on the board of firm *i*, θ_j^i, is the uncertain parameter subject to learning. Therefore, $\frac{\partial \log(P/D)_t}{\partial \theta_{j,t}^i}$, the sensitivity of the log price-to-dividend ratio to the mean assessment of director ability can be interpreted as the marginal return to ability, MRA_t. The third component, m_t, reflects uncertainty about director ability. It is equal to $\delta_{j,0}^{i2}/(\sigma^2 + \delta_{j,0}^{i2} t)$, where $\delta_{j,0}^{i2}$ is the prior variance of director *j*'s ability to serve on the board of firm *i*. Uncertainty decreases over time through Bayesian learning. Return volatility can thus be expressed as fundamental volatility inflated by two factors: how much director ability matters for firm value and how uncertain that ability is.

The learning model yields three main predictions. First, because m_t has a negative and convex relationship with time, *t*, return volatility decreases over director tenure, and it does so in a convex manner: learning is faster at the beginning of director tenure. Second, return volatility increases with ex-ante uncertainty about director ability, captured by $\delta_{j,0}^{i2}$. Finally, equation (1) shows that fundamental volatility upon the arrival of a director is magnified due to the

conjunction of two effects: that director ability is relevant to investors, and that it is uncertain. Importantly, uncertainty about a director's ability decreases at a predetermined rate due to Bayes' rule, and this rate is faster for higher ex-ante levels of uncertainty.[7] The model therefore provides a theoretical framework to assess the importance of directors: controlling for the ex-ante uncertainty about the ability of a new director, the cross-sectional variation in the magnitude of the decline in return volatility provides an estimate of the marginal value of different kinds of directors.

The model's predictions are tested using regression models that estimate the relationship between the tenure of newly appointed directors and the stock return volatility of the firm they join, over the first five years of director tenure. The regression model is characterized by the following equation:

$$(2) \qquad Vol_{i,t} = \beta_{1,i,j} + \beta_2 f\left(tenure_{i,j,t}\right) + \beta_3 X_{i,t} + \lambda_t + \varepsilon_{i,t}$$

$Vol_{i,t}$ is firm *i*'s stock return volatility in month *t*, and $f\left(tenure_{i,j,t}\right)$ is a function of director *j*'s tenure on the board of firm *i*, allowing for the decreasing and convex relationship predicted by the model.[8] The specification includes firm-director pair fixed effects ($\beta_{1,i,j}$), firm level controls ($X_{i,t}$), and month fixed effects (λ_t) to account for macroeconomic factors affecting all firms' stock return volatility. Standard errors are clustered at the firm level.

[7] True productive ability is assumed constant in the model, such that over time, uncertainty goes to zero and return volatility converges to fundamental volatility. If ability was not constant, the learning process would be very similar, and the posterior variance would still move deterministically. However, instead of converging to zero, uncertainty would converge to a positive stationary state, as in Holmström (1999).

[8] *Tenure* is the number of months since the director joined the board, divided by 12.

The analysis tests whether return volatility significantly decreases with director tenure (H_1: $\beta_2 < 0$) against the null of no relationship (H_0: $\beta_2 = 0$). Cross-sectional variation in the volatility-tenure relationship is then examined by interacting $f(tenure_{i,j,t})$ with *c,* representing director, board, or firm characteristics measured as of the time of appointment. Directors with higher marginal return to ability should generate larger declines in volatility, holding uncertainty constant. Characteristic *c* is interacted with tenure in the following specification:

(3) $$Vol_{i,t} = \beta_{1,i,j} + \beta_2 f(tenure_{i,j,t}) + \beta_3 c \cdot f(tenure_{i,j,t}) + \beta_4 c + \beta_5 X_{i,t} + \lambda_t + \varepsilon_{i,t}$$

For each characteristic *c*, the analysis compares the average marginal effect of tenure on volatility between observations with and without that characteristic. This difference reveals whether markets learn more about directors with certain attributes, indicating which types of directors have higher marginal return to ability.

To examine the relationship between return volatility and director tenure and its cross-sectional variation, a dataset is constructed from the intersection of S&P 1,500 firms in BoardEx, CRSP and Compustat. The sample includes 16,798 new directors appointed between 2000 and 2014 to the boards of 2,180 firms, with return volatility patterns tracked through 2019, or until the start of the Covid-19 pandemic. Panel A of Table 1 presents director and board summary statistics at the firm-year level. The average board in the sample has 9.4 directors, 12% of whom are women. Among board members, 19% have previous experience as CEO of a public company and 10% have held directorships in the same industry. Directors are on average 61 years old with 6.5 years of tenure, and 79% are independent. Following Coles et al. (2015), who use the percentage of directors with tenure greater than nine years as a proxy for groupthink, 43% of board members are prone to groupthink. Following the literature's definition of "busy" directors (Core et al. (1999), Shivdasani and Yermack (1999), Ferris et al. (2003), Fich and Shivdasani

(2006)), 15% of board members sit on three or more boards. The average firm in the sample appoints a new director every two years, and directors typically serve for about eleven years. Panel B of Table 1 reports volatility measures and betas at the firm-month level. *Realized Volatility*, measured as the standard deviation of daily stock returns within a month, averages 11.4%. *Idiosyncratic Volatility*, calculated as the standard deviation of the residuals from a Fama-French three-factor model following Ang, Hodrick, Xing, and Zhang (2006), averages 8.4%. Panel C of Table 1 presents firm-level financial statistics at the firm-year level. All variables are defined in Appendix B.

[Insert Table 1 here]

III. The Stock Return Volatility and Director Tenure Relationship

This section examines whether volatility patterns are consistent with the model's predictions, first in the full sample, then in samples designed to address endogeneity concerns. Additional robustness tests are conducted to validate the interpretation of the results.

A. Estimating the Return Volatility-Director Tenure Relationship

The Bayesian learning model predicts that as markets learn about incoming directors, return volatility declines as governance-related uncertainty dissipates. This learning mechanism (formally derived in Appendix A) leads stock return volatility to go down, in a process described in Timmermann (1993) and Pastor and Veronesi (2003), (2009). This pattern should emerge only if investors view directors as influential in the cash flow-generating process. Figure 1 plots monthly idiosyncratic volatility against director tenure for appointments that do not occur within two years before or after a CEO turnover. Return volatility increases when a new director joins, followed by a gradual decline. This pattern aligns with Pastor and Veronesi's (2003) framework:

uncertainty about a new director magnifies the impact of news as markets evaluate both, direct implications of the news, as well as what they reveal about director quality. As learning occurs, uncertainty resolves, and volatility decreases.

[Insert Figure 1 here]

Table 2 reports results using three functional forms (quadratic, logarithmic, and reciprocal) to test the model's prediction of a convex relationship between volatility and tenure. Results are presented for both realized and idiosyncratic volatility, and all regressions control for firm level factors that affect return volatility. When the dependent variable is realized volatility, the regression models include the market beta, SMB beta and HML beta to control for factors that affect the volatility in average dividend growth. Panel A shows results for the full sample of 16,798 appointments, while Panel B (11,930 appointments) excludes appointments within two years before or after a CEO turnover. In both panels, the estimates show a negative and convex relationship between volatility and tenure, consistent with the learning model's predictions. This finding is consistent with investors perceiving directors to have an impact on cash flow generation and that investors learn about director quality over time. This interpretation, however, is complicated by the possibility that firms may appoint new directors in times of crisis, when return volatility tends to be high.

[Insert Table 2 here]

B. Constructing a Sample to Mitigate Endogeneity Challenges

Two approaches identify directors likely appointed for reasons unrelated to corporate turmoil: filtering the sample to retain only "business-as-usual" appointments and constructing a sample of "plausibly exogenous" appointments.

1. Business As Usual Appointments

This subset includes appointments that meet several criteria: the firm outperformed the S&P500 in the year leading to the appointment, it maintained below-average volatility in the six months before appointment (relative to the previous two years)[9], made no other director appointments within six months, and had no CEO turnover within two years before or after the appointment.[10]

2. Plausibly Exogenous Appointments

This subset includes two types of appointments. First, those made between 2002-2005 to satisfy new NYSE/NASDAQ board independence requirements.[11] The introduction of new exchange listing requirements has been used in the literature to study the effect of board structure on firm value (Wintoki (2007), Duchin, Matsusaka, and Ozbas (2010)), CEO compensation (Chhaochharia and Grinstein (2009)), firm transparency (Armstrong, Core, and Guay (2014)) and innovation (Balsmeier, Fleming, and Manso (2017)). The purpose of isolating exchange-mandated appointments in this study is not to study the effect of board structure since the exercise is not meant to compare treated vs. control firms in the context of new listing requirements. Rather, the purpose is to isolate appointments unlikely to have been initiated because of firm specific upheaval. The NYSE filed the proposed rule change with the SEC in August 2002, giving firms until 2004 to comply. Most firms needed only one new independent

[9] Changing these requirements to one or three months relative to the previous two years or relative to the previous year does not change the results.

[10] Appendix C provides a schematic representation of these filters.

[11] https://www.sec.gov/rules/sro/34-48745.htm. The new independence requirements were also generally tied to committee structure, not just board level independence (Adams (2017)). Independent boards that had to make board changes to satisfy new committee structure requirements are not picked up by this sample selection criteria.

director. This sample includes appointments that resulted in the board newly meeting the new 50% independence requirement. Second, appointments replacing directors who either passed away or retired (over age 70) are included in this subset, as these departures are typically unrelated to firm conditions (Fracassi and Tate (2012)). This sample is augmented with appointments replacing directors who left multiple boards simultaneously within two years, as these departures likely reflect personal circumstances rather than firm-specific conditions. This approach captures directors who retired for health reasons before reaching maximum age requirements.[12]

3. The Volatility-Tenure Relationship When Endogeneity Concerns Are Muted

Combining the 'business as usual' and 'plausibly exogenous' samples (while still excluding appointments within two years before or after CEO turnovers) yields 4,718 director appointments unlikely to have arisen due to corporate turmoil. Panel C of Table 2 examines whether the previously documented volatility-tenure pattern is also present in this subset. Columns 1-3 show a negative and convex relationship between volatility and tenure as in the full sample.[13] Column 4 further restricts to appointments where incoming directors share at least four of six attributes (gender, age, job expertise, board experience, industry experience) with

[12] The results are not sensitive to the inclusion of this set of directors.

[13] In unreported tests, *Tenure* and $Tenure^2$ are interacted with a dummy variable equal to 1 for appointments within this curated sample of 4,718 appointments. The estimated coefficient on *Tenure* ($Tenure^2$) is negative (positive) and statistically significant, as before. The coefficients on the interaction terms, however, are not significant, indicating a lack of statistically significant difference in the volatility-tenure relationship between the full sample and the sample of appointments in which endogeneity is muted. This provides additional reassurance that the documented pattern is not driven by endogenous appointments occurring at times of high volatility.

departing directors, helping ensure the appointments were not part of strategy shifts.[14] Results using this 2,998-appointment sample remain unchanged. Columns 5-7 and 8-10 show similar patterns in the business-as-usual and plausibly exogenous samples separately, suggesting director appointments matter to investors even absent corporate turbulence. Interpreted in light of the theory, results in Panel C of Table 2 provide further support that director appointments are meaningful events for investors.

C. Additional Tests

The evidence presented above is consistent with the notion that learning leads to a decrease in return volatility and supports the hypothesis that investors perceive directors as influential in shaping firm value. Further tests offer additional evidence.

1. Young Vs. Seasoned Boards

If volatility declines reflect learning about governance uncertainty, the effect should be stronger for young boards where there is more uncertainty to resolve. Using variation in average board tenure across firms, the analysis examines whether volatility patterns differ between young and established boards. Figure 2 compares the relationship between monthly idiosyncratic volatility and average board tenure for young boards in Panel A and seasoned boards in Panel B. The distinct decline in volatility as young boards mature, contrasted with the absence of a clear pattern for seasoned boards, supports the learning hypothesis.

[Insert Figure 2 here]

Table 3 confirms these patterns in a regression framework. Controlling for firm age and board size in addition to previous controls, results show that the decline in return volatility with

[14] The median score for all departing-incoming director pairs due to death or retirement, while also meeting the business-as-usual criteria, is four. Appendix D provides details on the construction of this similarity score.

board tenure is driven by young boards, consistent with higher initial uncertainty. Seasoned boards show no systematic relationship between board tenure and return volatility.[15]

[Insert Table 3 here]

2. Placebo Test

A placebo test confirms that the decline in volatility is specific to firms appointing new directors. Each sample firm is matched to a control firm of similar size in the same industry that had no director appointments within a two-year window. Regressions mirroring those in Panel A of Table 2 are estimated for control firms, using the focal firm's director tenure. Table 4 confirms no systematic decline in control firms' volatility, supporting the interpretation that volatility patterns reflect learning about new directors.

[Insert Table 4 here]

IV. Director Importance

A. Benchmarking the Importance of Directors Relative to CEOs

The evidence presented so far indicates that the appointment of a new director is relevant for investors' valuations. This section now explores how important director appointments are compared to top management. Pan et al. (2015) find that around a CEO turnover event, uncertainty about the new CEO accounts for about 26% of overall stock return volatility. This estimate provides a useful benchmark for assessing how investors perceive directors' importance relative to CEOs as of the time of their appointment. This section uses the methodology in Pan et al. and is summarized in Appendix E. Estimates in Panel C of Table 2 are used to obtain the

[15] The number of observations is larger than in previous tables because observations are not limited to the first five years of tenure of a newly appointed director as in previous specifications.

average decline in idiosyncratic volatility over the first three years of director tenure (1.8%). The average annual volatility in dividends (σ) is 23% and the average annual idiosyncratic return volatility at the time directors join (Vol_0) is 31%. Using the model, these estimates imply that on average, the uncertainty about a new director accounts for about 10% of return volatility at the time a new director joins.[16] The uncertainty associated with the arrival of a new director is therefore about one third the uncertainty associated with new leadership. This finding provides new insight into the relative importance of directors versus CEOs in the eyes of investors when they are appointed.

B. Learning Speeds and Future Performance

The results above are consistent with the learning model's predictions and support the idea that directors influence firms' cash flow generating process. One interpretational limitation of the learning framework is that the model is agnostic about the sign: while a larger decline in return volatility implies that investors expect a director to influence the cash flow generating process more, it does not directly indicate whether investors expect that influence to be associated with better firm performance. This section explores whether directors who generate more learning by markets are associated with better firm performance following their appointment.

The model shows that return volatility is inflated by uncertainty about director ability that resolves through learning over time. To measure the extent of market learning about individual directors, this paper builds on Pan et al. (2015), who develop an approach to estimate learning

[16] Using declines in return volatility over the first three years of tenure, the ratio of uncertainty about director ability to return volatility, $\frac{\delta_0}{Vol_0} = \sqrt{\frac{1}{3}\left[\frac{1}{1-1.8\%\times\frac{23\%}{31\%-23\%}}-1\right]} \times \frac{23\%}{31\%} \approx 10\%$. See Appendix E for methodological details.

speeds: the rate at which return volatility declines during a CEO's early tenure. In their setting, steeper volatility declines identify settings where uncertainty about CEO ability matters more and where more learning occurs. This section extends their approach to directors with the goal of examining whether directors who generate more learning are associated with better future firm performance.

For each director-firm pair, learning speeds are estimated by measuring how idiosyncratic volatility changes over the first three years of director tenure:

(4) $$vol_{i,t} = \alpha + \beta_{i,j} tenure_{i,j,t} + \varepsilon_{i,t}$$

where $vol_{i,t}$ is firm *i*'s monthly idiosyncratic volatility at time *t* and $tenure_{i,j,t}$ is the tenure of director *j* on the board of firm *i* at time *t*. $\beta_{i,j}$ represents the average decline in return volatility, capturing how much markets learn about the director during her early tenure on the board. The coefficients $\beta_{i,j}$ are multiplied by -1 so that higher values indicate more learning, and are normalized to yield a learning rank between 0 and 1.

To examine whether directors who generate more learning are associated with better performance, directors are sorted into deciles based on their learning rank. Figure 3 shows the evolution of firms' ROA for the three years following director appointments, comparing firms whose directors are in the top decile of learning ranks (circles) to those in the bottom decile (triangles). Panel A presents results for the full sample, while Panel B focuses on the union of the business-as-usual and plausibly exogenous appointments. Both panels exclude director appointments that occur within two years before or after a CEO turnover event. The results show a consistent pattern across both panels: firms that appoint directors associated with high learning by markets have higher subsequent operating performance than those associated with low learning.

[Insert Figure 3 here]

Table 5 confirms these findings in a regression framework. The analysis shows a positive relationship between directors' learning rank and ROA in the year following the appointment, both in the full sample (columns 1 and 2) and in the exogenous sample (columns 3 and 4). Based on estimates in column 4, a one standard deviation increase in the director learning rank (.29) is associated with a one percentage point higher ROA in the year following the appointment.

[Insert Table 5 here]

Taken together, the results in this section show that governance-related uncertainty contributes substantially to stock return volatility, and that the extent of market learning about directors is positively associated with firms' operating performance.

V. Evaluating Directors Within the Learning Framework

The board literature traditionally evaluates director and board effectiveness by examining how specific attributes relate to firm performance or board actions.[17] This paper introduces a novel methodology, applying a learning-based framework to measure the expected contribution to the cash flow generating process of different types of directors and boards.

We know from theory that the uncertainty about director ability decreases at a predetermined rate over time due to Bayes' rule, and that this rate is faster for higher *ex-ante* levels of uncertainty. Therefore, controlling for *ex-ante* uncertainty, cross-sectional analyses of declines in return volatility offer insights into directors' marginal return to ability. In other words, the magnitude of the decline in return volatility over the tenure of directors reflects their

[17] Hermalin and Weisbach (2003), Yermack (2006), Adams et al. (2010), and Adams (2017) provide excellent surveys of the literature.

marginal value. This section exploits the cross-sectional variation in the learning-induced changes in return volatility following the arrival of a new director. Controls for *ex-ante* uncertainty include director age, number of previous jobs, number of previous board seats and whether the director has experience as the CEO of a public company. Therefore, while Section III documents a negative and convex relationship between return volatility and tenure, consistent with markets learning about directors, following the model's predictions, this section examines how this relationship varies across settings, as steeper declines indicate more learning and higher expected contribution to cash flows. Table 6 provides a summary of the findings alongside a comparison with results previously documented in the literature.[18]

[Insert Table 6 here]

In Section III.B, showing that the documented return volatility pattern is not a byproduct of endogeneity was important to establish that investors pay attention to and learn about incoming directors. When conducting cross-sectional analyses of the impact of different kinds of directors, however, there are downsides to restricting the sample of director appointments. We can potentially learn more about the average effect of a particular director attribute in the cross-section by looking at a broader set of director appointments than by narrowing down to a subset of exogenous appointments. In particular, even if some directors are appointed during a period of firm level uncertainty, the coefficient estimate on the interaction between *Tenure* and a specific attribute is still informative about the average effect of that attribute. The analysis examines cross-sectional patterns in both the full sample and the more restricted sample combining

[18] Space constraints preclude an exhaustive list of the relevant literature. Therefore, many important papers are omitted from this table.

business-as-usual and plausibly exogenous appointments (both excluding appointments within two years before or after a CEO turnover). While the full sample offers more statistical power, the restricted sample better addresses endogeneity concerns. Examining which attributes appear to influence the volatility-tenure relationship across these two samples is helpful to inform on their relevance. Each attribute is interacted with *ln(Tenure)* to examine its effect on the volatility-tenure relationship. Figure 4 plots marginal effects. More negative values indicate stronger market learning about directors which, through the lens of the model, identifies settings where investors expect directors to have higher marginal return to ability. Table 8 examines whether the average marginal effect of the first year of tenure on volatility is significantly different between high and low values of each attribute.

[Insert Figure 4 here]

A. Director Characteristics

The first individual director attribute evaluated through the lens of the learning framework is independent director compensation, measured relative to the average compensation of incumbent independent directors. Columns 1 and 2 in Panel A of Table 7 and Panel A in Figure 4 reporting marginal effects show that higher compensation is associated with more market learning. Table 8 shows that monthly idiosyncratic volatility decreases by 0.15 percentage point more over the first year of tenure for directors with high relative compensation. This correspondence between boards' revealed valuation of directors through compensation and the learning framework's measure of importance helps validate the methodology.[19,20]

[19] Thanks to an anonymous referee for suggesting this test and interpretation.

[20] Director compensation often depends on committee assignments as directors are paid for the meetings they attend. Results are qualitatively unchanged when controlling for committee assignments.

[Insert Table 7 here]

The analysis next examines which board leadership positions generate more learning. Committee chairs should be particularly relevant for investors who should arguably have incentives to learn more about their ability. Coefficient estimates in Table 7 and marginal effects in Figure 4 indicate that investors learn more about the audit and compensation committee chairs, even after controlling for finance expertise. While the marginal effect for chairs of nominating committees is negative in the full sample, it is not significant. This result aligns with evidence that CEOs often influence the director selection process (Erel et al. (2021)), suggesting markets view nomination committee chairs as less important than other committee chairs.[21] Table 8 quantifies these effects: monthly idiosyncratic volatility decreases by 0.23 percentage point more for audit committee chairs and 0.18 percentage point more for compensation committee chairs over their first year (both statistically significant), compared to 0.11 percentage point more for nomination committee chairs (statistically insignificant). These results contribute to the literature by assessing the relative importance of different roles and functions on the board as perceived by investors.

[Insert Table 8 here]

The analysis next explores how director-specific attributes influence market learning. Panel B of Table 7 examines the role of director gender, a characteristic that has received considerable attention as firms have faced pressure to diversify their boards through quotas or other measures. Evidence on the importance of director gender is mixed in the literature. The

[21] Nguyen and Nielsen (2010) document larger stock price reactions to the death of audit and nominating committee members.

learning-based approach shows that female directors on average generate less learning by markets.[22] However, this pattern reverses when firms have high monitoring needs (Panel B of Figure 4), consistent with Adams et al. (2009)'s finding that female directors are more effective monitors.

The Bayesian learning model interprets the negative and convex volatility-tenure relationship as evidence of markets learning about new directors. A different interpretation could be that when new directors join, they may lack familiarity with the company and make suboptimal decisions that lead to increased return volatility. As they learn about the job, directors make fewer bad decisions, leading to a decline in volatility over time. The analysis of professional directors helps distinguish between these explanations.[23] Under the "directors learning their job" hypothesis, professional directors should show smaller volatility declines because they are better equipped to produce better decisions upon joining the board and can arguably be quicker to adapt to the production function of a particular firm. In contrast, the investor learning hypothesis predicts larger volatility declines: controlling for ex-ante uncertainty, the magnitude of the volatility decline captures the director's expected contribution

[22] Adams et al. (2009) show that women are better monitors, although increased monitoring comes at the cost of lower firm performance, especially for well-governed firms without extensive monitoring needs. Adams, Gray, and Nowland (2012) find that investors value female directors more than their male counterparts and Schwartz-Ziv (2017) shows that a critical mass of at least three female directors on a board changes the board dynamics, especially in times when the CEO is being replaced. Ahern and Dittmar (2012) argue that the national 2003 quota law in Norway, combined with a limited supply of qualified female candidates, was associated with deteriorating firm performance. Hwang, Shivdasani, and Simintzi (2019) find similar results for firms headquartered in California following the female director quota imposed in 2018.

[23] Professional have previously held a minimum of four directorships, including at least one in the same industry.

to firm value, which should be higher for these more experienced directors. The evidence supports the investor learning interpretation. Panel B of Table 7 in fact shows professional directors generate the strongest marginal effects among all director attributes. Table 8 shows that return volatility decreases by 0.204 percentage point more over the first year when the new director is a professional director. This finding provides new evidence on how director expertise contributes to value creation.[24]

Finally, the last director-level attribute examined through the learning framework is busyness, for which the literature finds mixed evidence. Additional directorships can provide valuable experience and business connections but may also limit directors' ability to monitor effectively or understand firm-specific issues.[25] This question is revisited through the learning-based approach. Busy directors generate on average more learning by markets, suggesting investors expect them to be more important contributors. Using Table 8 to interpret magnitudes,

[24] This result is robust to controlling for whether the incoming director has professional experience in the same industry. Faleye, Hoitash, and Hoitash (2018) and Masulis, Ruzzier, Xiao, and Zhao (2012) find that industry expertise is associated with increased firm value.

[25] Ferris et al. (2003) reports positive announcement returns around the appointments of busy directors. In contrast, Fich and Shivdasani (2006) finds that investors react positively to the departure of busy directors, suggesting that according to investors, busyness is not a desirable director attribute. Core et al. (1999) shows that busy outside directors are associated with increased CEO compensation. Field et al. (2013) provide evidence that the firm's life cycle is an important factor when examining the value effect of busy directors. They argue that while large established firms benefit relatively more from monitoring than advising services on the part of directors, young firms derive more value from their network and experience. In line with this argument, the authors show that busy directors are beneficial for younger firms because they rely more on advising than monitoring, and detrimental for large corporations that typically require the opposite.

busy directors are associated with 0.146 percentage point additional decline in return volatility over the first year of their tenure, compared to non-busy directors.

In addition to revisiting important findings in the literature, the learning framework provides key new insights into the types of directors that matter most to investors. The audit and compensation committees emerge as the most important, underscoring the particular importance investors place on financial oversight. Moreover, investors' evaluation of director importance aligns with their compensation, and professional directors are considered particularly impactful.

B. Board Characteristics

The learning framework also allows for the examination of how board characteristics influence incoming directors' expected contribution to firm value, with novel insights into previously underexplored dimensions of board composition. The premise in this section is that incoming directors' expected contribution to the cash flow generating process may depend on the type of board they are joining. For instance, while some firms may provide their directors with an environment conducive to leveraging their ability to contribute as board members, others may prevent them from engaging fully and playing their role of representing investors.

The analysis yields important new findings about board diversity. Gender-diverse boards (those with at least one female director) show lower learning about incoming directors. This finding could reflect reduced monitoring needs (Adams et al. (2009)), making it less necessary to learn about the ability of the incoming director, or that gender diverse boards are not as effective. More striking however is the new finding on the role of board generational diversity: markets learn more about directors joining boards with greater age dispersion. This previously underexplored dimension of board diversity suggests that generational diversity may enhance board effectiveness, possibly because different cohorts of directors bring complementary

attributes. The value of combining directors with different historical experiences is consistent with evidence that economic decision-making is shaped by lived experiences (Malmendier and Nagel (2011), (2016)). As experiences of economic conditions affect risk attitudes and expectations, directors from different generations may bring distinct perspectives on risk, growth opportunities, and governance. The learning framework shows investors value this combination of perspectives. For boards with high generational diversity - defined as boards where the standard deviation in directors' age exceeds ten years (i.e. one standard deviation above the mean of 7.5 years) - the decline in return volatility is 0.136 percentage point larger during an incoming director's first year. In contrast, variation in the number of qualifications does not appear to be as relevant to investors.

The literature has studied the impact of board size quite extensively and generally finds smaller boards to be better.[26] *Large Board* is an indicator equal to one for boards with more than ten members (the sample mean is 9.4). The learning framework confirms the results in existing literature: directors sitting on large boards are associated with lower marginal value. This result is the strongest result among board-level characteristics. The decline in return volatility over an incoming director's first year is 0.31 percentage point smaller when joining a large board. In the context of the learning model, this result has two non-mutually exclusive interpretations. It could be that a new director will not have as much impact if many other directors are already sitting around the table. One director among fourteen is not as relevant as one among five. It could also

[26] See for example Lipton and Lorsch (1992) and Jensen (1993). Yermack (1996), Eisenberg et al. (1998), Wu (2000) and more recently Jenter et al. (2018) provide detailed evidence that smaller boards are beneficial for firm value. Smaller boards are more likely to replace CEOs following poor performance and smaller boards are associated with increased CEO pay-for-performance.

be that decision-making is harder in larger groups settings, making it more difficult for a new director to contribute.

Several studies have examined the effect of CEO power on the ability of the board to perform its role.[27] Coles, Daniel, and Naveen (2014) show that co-opted boards are less effective monitors, as evidenced by lower pay-for-performance and lower sensitivity of CEO turnover to performance. Coles et al. (2015) use the fraction of directors with long tenures as a proxy for groupthink and find that groupthink has a negative effect on firm value for firms in dynamic industries. The learning framework corroborates these findings: groupthink is associated with decreased marginal value for incoming directors. While the interaction term in Panel C of Table 7 is not statistically significant, tests of differences in average marginal effects in Table 8 show that the average marginal effect of tenure on volatility is 0.10 percentage point larger in the first year for boards with low groupthink (significant at the 10% level).

The fraction of independent directors on the board shows no significant relationship with learning about new directors. In contrast, boards with large networks generate more learning. Interestingly, while results in Panel B show that investors learn more about busy directors, in cases where the incumbent board has a large fraction of busy directors, investors learn *less* about incoming directors, pointing to potential negative effects of distracted boards.

[27] Hermalin and Weisbach (1998) argue that CEOs are likely to increase their bargaining power vis-à-vis the board over the course of their tenure, as their perceived ability is higher given that they repeatedly passed the replacement option test. Shivdasani and Yermack (1999) find that powerful CEOs, as measured by the extent to which they are involved in the board nomination process, can select less independent boards. Baker and Gompers (2000) find similar results when CEO power is proxied by CEO tenure.

Put together, these findings illustrate how board characteristics shape investors' expectations regarding the contributions of newly appointed directors. The learning framework allows for a theoretically-grounded approach to assess director importance across board characteristics. The findings indicate for example that incoming directors generate more learning - and thus are perceived as more important by investors - when joining boards that are small, not prone to groupthink, and well-connected. Particularly notable is the new finding on the role of generational diversity: directors joining boards with greater age dispersion generate more learning. These patterns suggest that director characteristics can carry different weight depending on board composition, providing new evidence on the importance of contextualizing governance.

C. Firm Characteristics

Is board governance more important in certain types of firms? Beyond board composition, the learning framework sheds light on how firm characteristics may determine when directors matter most. Panel D of Table 7, Panel D of Figure 4, and Table 8 show that to investors, directors are more relevant in smaller firms, where they have a bigger impact on the cash flow generating process. Directors are also more important in high knowledge capital firms (Peters and Taylor (2017)).[28] This finding suggests that board governance is particularly important when firms' assets are harder to monitor and value. In technology firms, where complexity and human capital intensity are higher, investors learn more about directors, consistent with boards playing a more key role when firm value depends more heavily on intangible assets. Moreover, because directors presumably play a central role in times of crisis, their input may play a more crucial role when the firm is not performing well. Consistent with

[28] Unreported results also show that directors have higher marginal value in firms with higher intangible capital (the estimated replacement cost of the firm's intangible capital, *k_int* in Peters and Taylor (2017)).

this idea, *Underperformer* - an indicator equal to one if the firm's stock returns underperformed the S&P500 in the year leading up to the appointment - is associated with more learning by markets.

These findings reveal variation in how markets value director contributions across different firm types. That directors matter more in smaller firms, knowledge-intensive firms, and during periods of underperformance sheds new light into the conditions under which board governance matters more. These patterns complement findings on board composition in the previous section by showing that director importance depends also on firm-specific contexts, challenging one-size-fits-all approaches to governance.

VI. Conclusion

Corporate directors are in principle key pillars of a firm's governance. Yet, there has been a long-standing skepticism as to whether directors effectively carry out their mandate. To the extent that directors differ in their ability to represent the interest of shareholders, providers of capital may find it beneficial to evaluate them. This paper introduces a novel approach to evaluate directors based on the premise that stock return volatility partly reflects uncertainty about governance quality. As markets learn about newly appointed directors, governance-related uncertainty dissipates, leading to declines in return volatility. By relying on the theory to relate the decline in return volatility following the appointment of directors to their marginal return to ability, the analysis provides new evidence on director importance and explores the governance attributes that matter most to investors.

The framework yields several important insights. First, it provides novel empirical support for the view that boards matter. Investors learn about directors as they believe they influence the cash flow generating process. Second, it quantifies this importance: governance-

related uncertainty accounts for approximately 10% of stock return volatility when a new director joins, about one-third the estimate for CEOs (Pan et al. (2015)). Importantly, the documented learning-based decline in return volatility is shown not to be driven by endogenous director appointments and it is independent from learning about the CEO.

Going beyond the overall decline in volatility to study whether directors matter, the learning framework's ability to identify when directors matter most yields both validation of existing findings and important new insights. Despite its distinct methodological approach, the framework corroborates several key findings in the literature while also revealing important new patterns. For instance, independent directors with higher compensation generate more learning by markets, suggesting that the importance of directors identified through the learning framework aligns with their perceived importance as reflected in compensation. This correspondence between two independent measures of director importance provides additional validation for the learning-based methodology. The audit and compensation committees emerge as the most relevant committees to investors, while professional directors generate the strongest learning effect among individual director attributes. At the board level, board size is the most important factor. A striking finding is that markets learn more about directors joining boards with greater generational diversity, suggesting investors value the combination of different cohorts' perspectives and experiences for firm oversight. Beyond board composition, the analysis shows that firm characteristics influence director importance: directors matter more in smaller firms and those with higher knowledge capital. Together, these findings advance our understanding of how directors contribute to firm value by identifying the conditions under which board governance matters most to market participants, highlighting the need to consider a broad perspective when evaluating governance structures.

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FIGURE 1
Return Volatility and Director Tenure

Figure 1 illustrates the relationship between monthly idiosyncratic volatility and director tenure. It also reports the fitted values with 95% confidence interval obtained from a regression of monthly idiosyncratic volatility on *Tenure* and $Tenure^2$. The sample excludes director appointments that occur within two years before or after CEO turnovers.

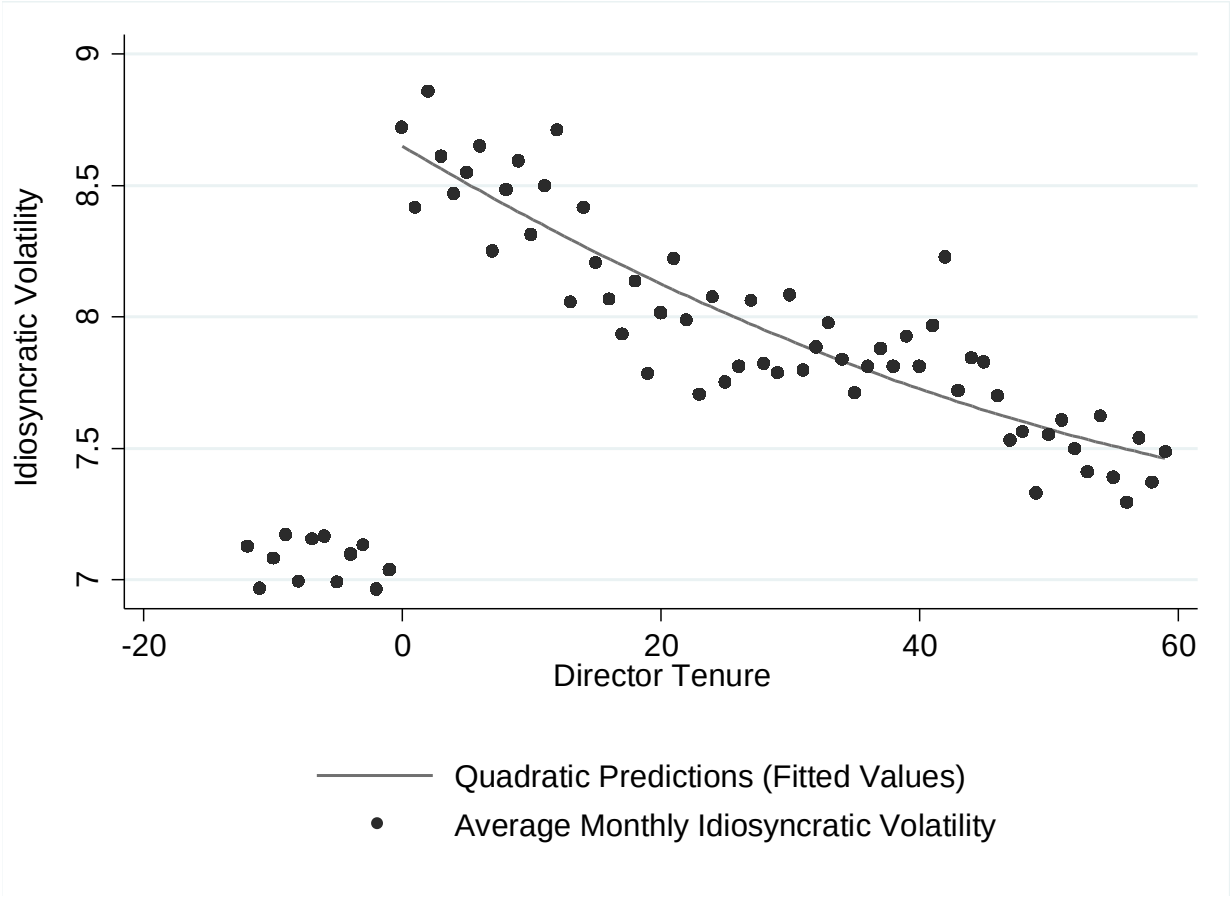


FIGURE 2
Return Volatility and the Average Tenure of Directors on the Board

Figure 2 illustrates the relationship between average monthly idiosyncratic volatility and the average tenure of directors on the board, for young boards (average tenure less than 50 months) in Panel A and seasoned boards (average tenure greater than 80 months) in Panel B. It also reports the fit from regressing monthly idiosyncratic volatility on average board tenure and average board tenure squared.

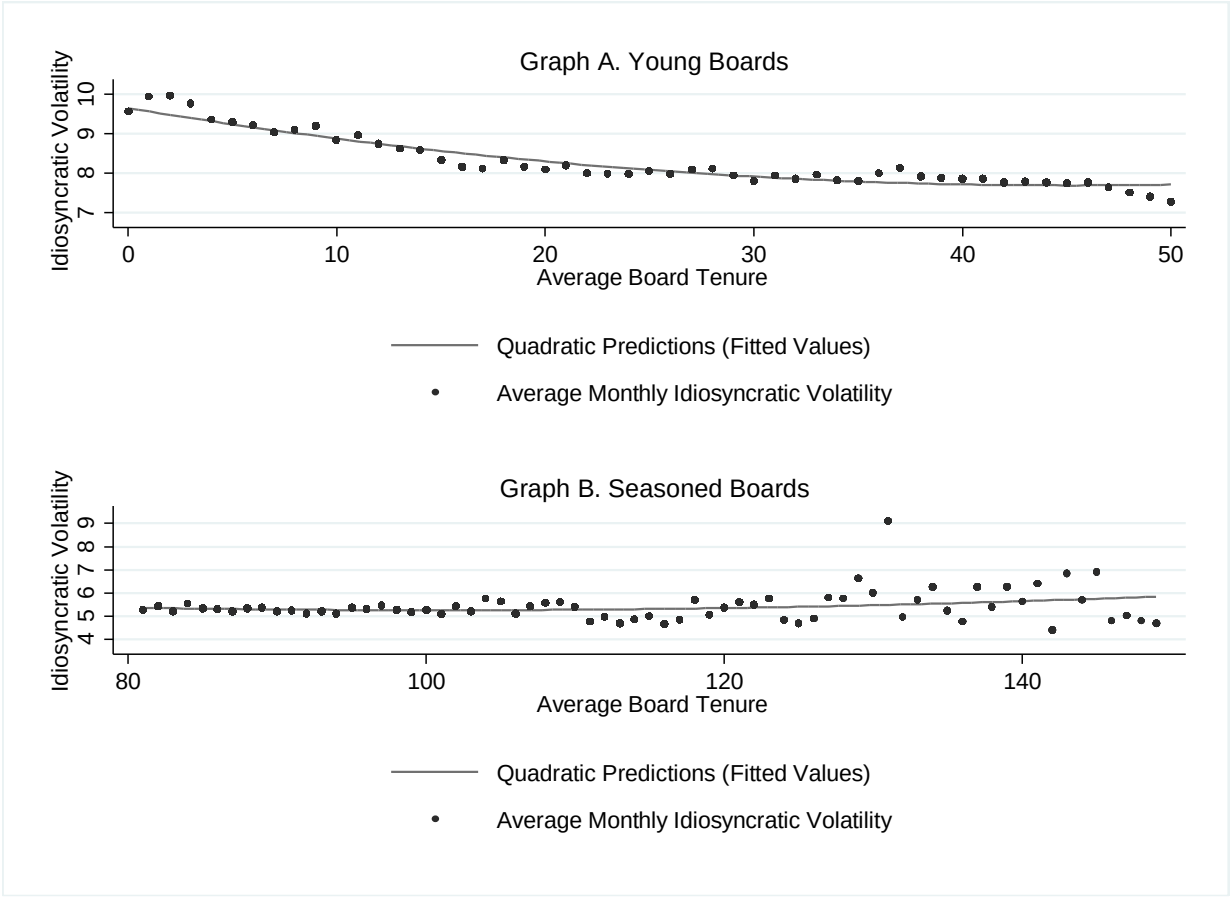
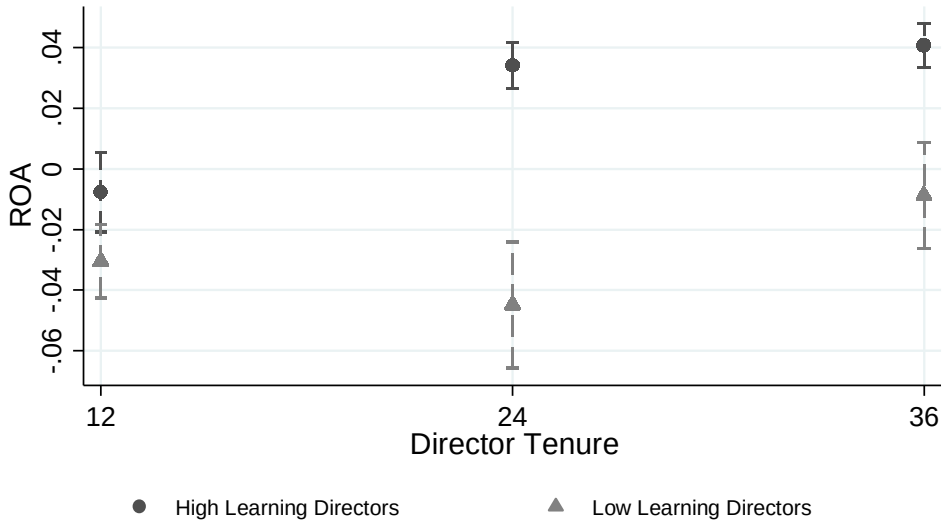


FIGURE 3

Operating Performance Following Director Appointments: High versus Low Learning Rank Directors

Figure 3 reports the relationship between director tenure and firm ROA for firms whose directors are in the top (blue circles) and bottom (orange triangles) deciles of learning rank. Learning ranks capture how much markets learn about directors, measured as the rate of decline in idiosyncratic volatility over their first three years of tenure, multiplied by -1 and normalized to create a ranking between 0 and 1. ROA is measured at one, two, and three years after the director appointment. Panel A presents results for all director appointments that do not occur within two years before or after CEO turnovers. Panel B restricts the sample to business-as-usual and plausibly exogenous appointments, also excluding those that occur within two years before or after CEO turnovers. The definition of all variables is in Appendix B.

Graph A. All Appointments
No CEO Turnover Overlap



Graph B. Business-as-Usual and Plausibly Exogenous Appointments
No CEO Turnover Overlap

FIGURE 4A
The Heterogeneity of the Volatility-Tenure Relationship
Panel A. Director Compensation and Board Committees

Panel A of Figure 4 reports the estimated average marginal effect (AME) of director tenure on idiosyncratic return volatility for director compensation and various board committee positions measured at the time of the appointment. The marginal effects are calculated using specification (1) in Panel A of Table 7 for director compensation and specification (3) in Panel A of Table 7 for the committee chair assignments and are reported with their 90% confidence intervals. Negative effects indicate monthly idiosyncratic volatility decreases over director tenure. The definition of all variables is in Appendix B.

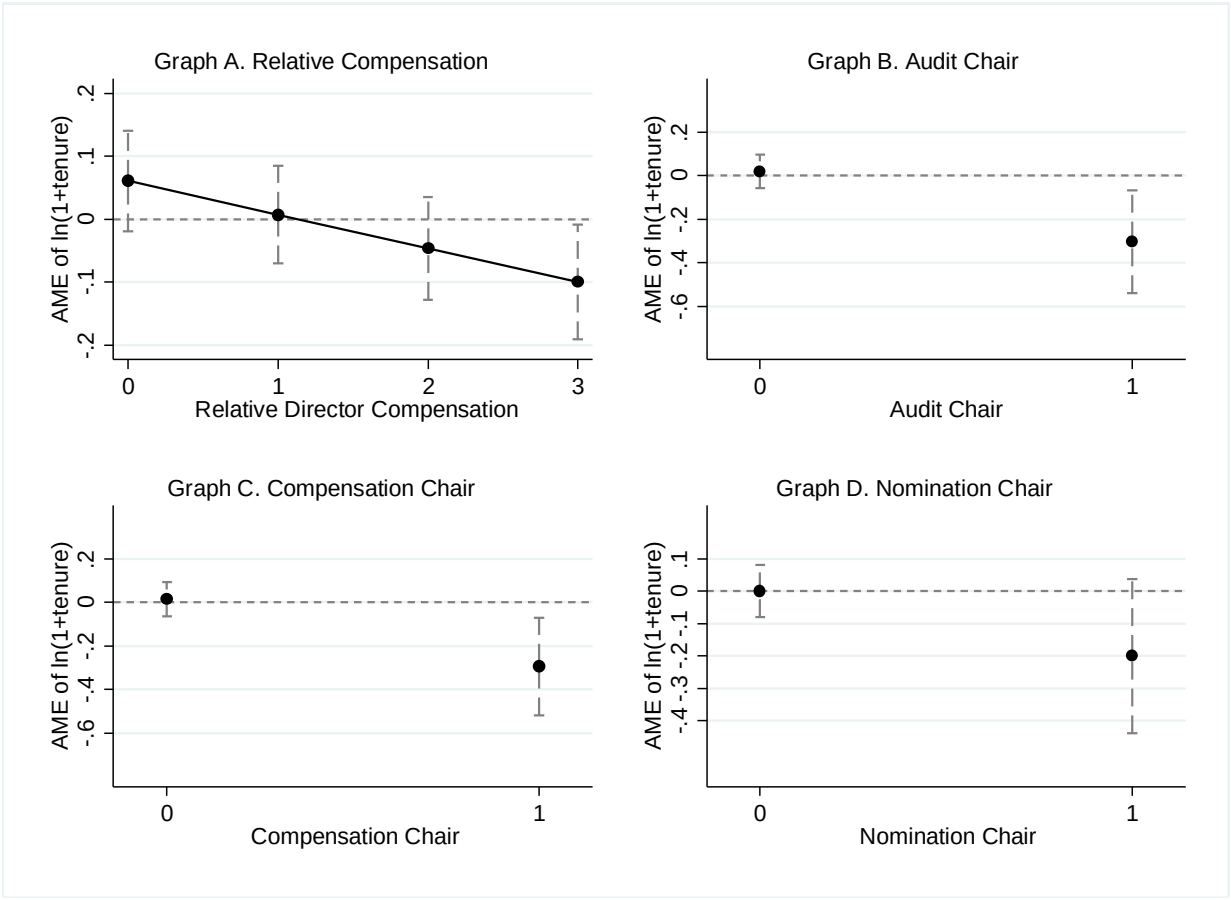


FIGURE 4B
The Heterogeneity of the Volatility-Tenure Relationship
Panel B. Individual Director Characteristics

Panel B of Figure 4 reports the estimated average marginal effect (AME) of director tenure on idiosyncratic return volatility for various individual director attributes measured at the time of the appointment. The marginal effects are calculated using Specification 1 in Panel B of Table 7 and are reported with their 90% confidence intervals. Negative effects indicate monthly idiosyncratic volatility decreases over director tenure. The definition of all variables is in Appendix B.

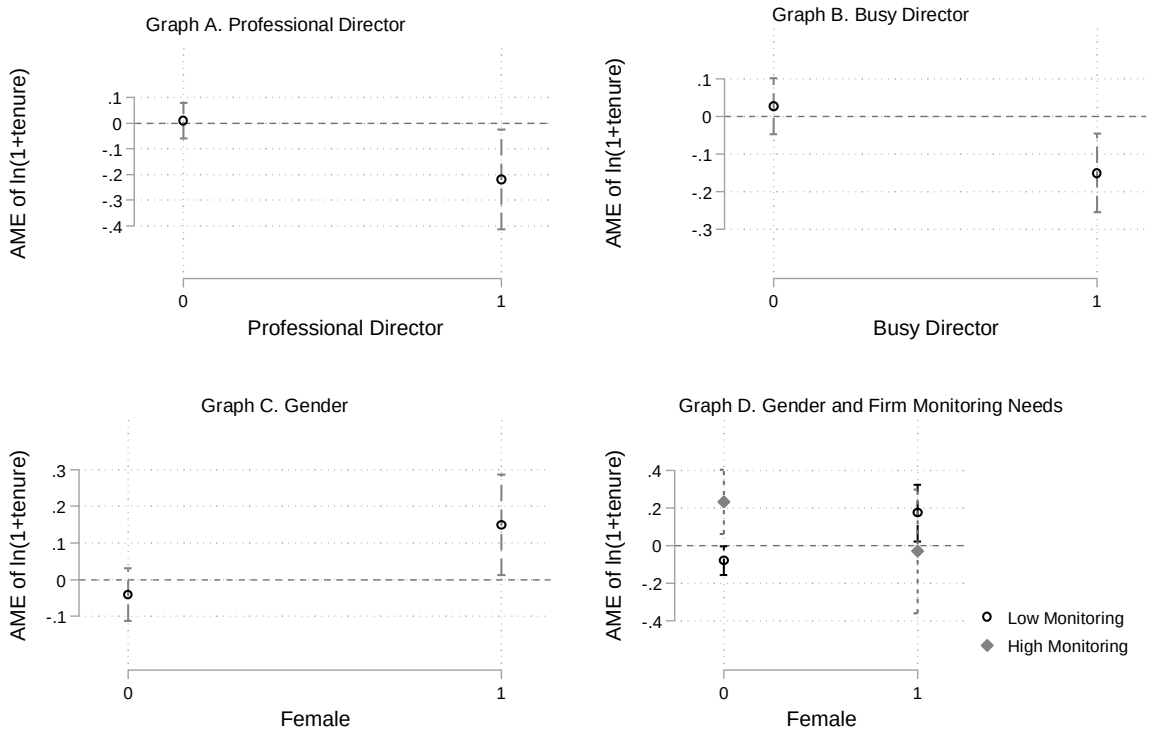


FIGURE 4C1
The Heterogeneity of the Volatility-Tenure Relationship: Board Level Characteristics

Panel C1 of Figure 4 reports the estimated average marginal effect (AME) of director tenure on idiosyncratic return volatility for various board level characteristics measured at the time of the appointment. The marginal effects are calculated using Specification 1 in Panel C of Table 7 and are reported with their 90% confidence intervals. Negative effects indicate monthly idiosyncratic volatility decreases over director tenure. The definition of all variables is in Appendix B.

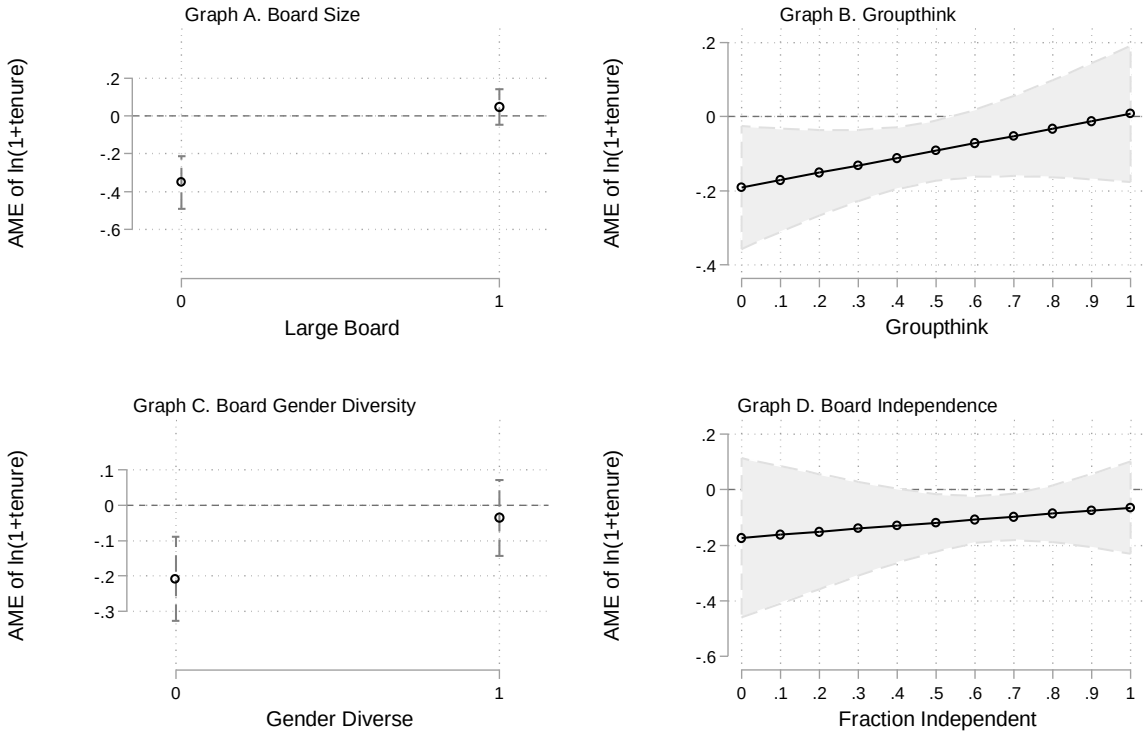


FIGURE 4C2
The Heterogeneity of the Volatility-Tenure Relationship: Board Level Characteristics (continued)

Panel C2 of Figure 4 reports the estimated average marginal effect (AME) of director tenure on idiosyncratic return volatility for various board level characteristics measured at the time of the appointment. The marginal effects are calculated using Specification 2 in Panel C of Table 7 and are reported with their 90% confidence intervals. Negative effects indicate monthly idiosyncratic volatility decreases over director tenure. The definition of all variables is in Appendix B.

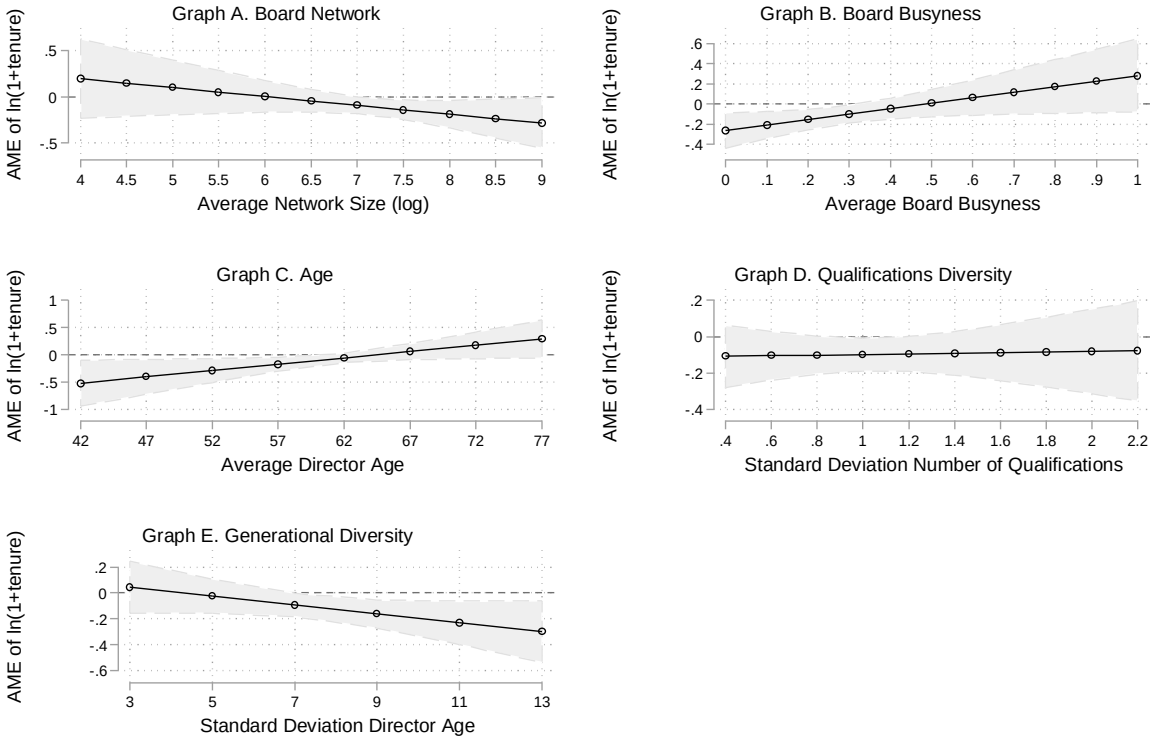


FIGURE 4D
The Heterogeneity of the Volatility-Tenure Relationship: Firm Level Characteristics

Panel D of Figure 4 reports the estimated average marginal effect (AME) of director tenure on idiosyncratic return volatility for various firm level characteristics measured at the time of the appointment. The marginal effects are calculated using Specification 1 in Panel D of Table 7 and are reported with their 90% confidence intervals. Negative effects indicate monthly idiosyncratic volatility decreases over director tenure. The definition of all variables is in Appendix B.

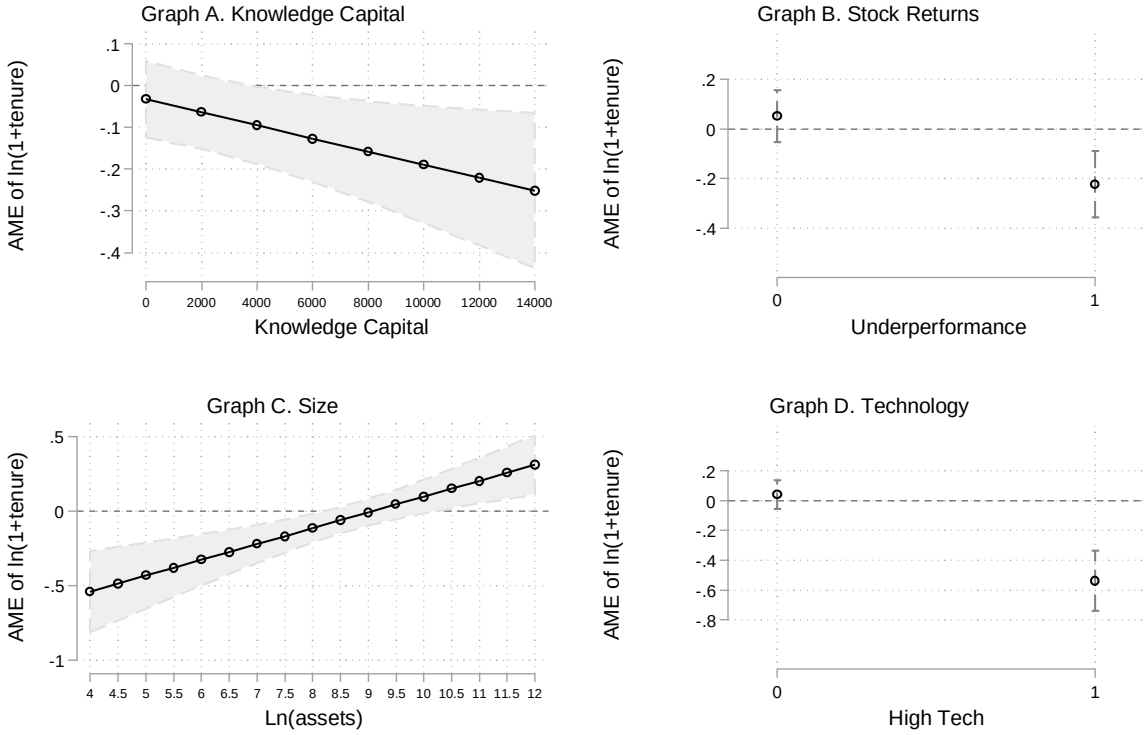


TABLE 1
Summary Statistics

Table 1 reports summary statistics. Director, board and firm characteristics are at the firm-year level, except for variables marked with * which are at the firm level as of a new director appointment. Market variables are at the firm-month level. The definition of all variables is in Appendix B.

Panel A: Director and Board Characteristics

	N	Mean	Std.	25%	Median	75%
Tenure	24,870	6.45	3.50	3.96	6.07	8.46
Time between appointments	20,917	1.83	1.28	1.05	1.50	2.17
Time stays on board	24,870	11.25	4.44	8.25	10.86	13.79
Female	24,805	0.12	0.14	0.00	0.10	0.19
Age	21,928	61.36	5.83	58	61.73	65
Independent	24,870	0.79	0.19	0.71	0.84	0.93
Finance experience	24,870	0.06	0.10	0.00	0.00	0.11
Professional director	24,870	0.05	0.11	0.00	0.00	0.18
Busy	24,870	0.15	0.19	0.00	0.09	0.22
Industry experience	24,870	0.12	0.18	0.00	0.00	0.19
Number previous public directorships	24,837	1.98	1.05	1.08	1.75	2.58
Director compensation	6,864	0.72	0.96	0.39	0.59	0.85
Board size	24,870	9.38	2.62	7.50	9.00	11.00
Groupthink	24,870	0.44	0.29	0.22	0.43	0.63
Age diversity*	15,039	7.50	2.24	5.90	7.20	8.80
Qualification diversity*	15,039	1.00	0.37	0.70	1.00	1.20
Average board network size*	13,656	1,256	800	676	1083	1632

Panel B: Market Variables

	N	Mean	Std.	25%	Median	75%
Realized volatility	290,015	11.3	7.17	6.41	9.30	13.8
Idiosyncratic volatility	290,015	8.31	5.51	4.51	6.74	10.31
Market beta	290,015	1.05	1.04	0.57	1.01	1.48
SMB beta	290,015	0.64	1.57	-0.18	0.51	1.34
HML beta	290,015	0.22	2.08	-0.70	0.19	1.13

Panel C: Firm Level Variables

	N	Mean	Std.	25%	Median	75%
Firm age	23,016	23.0	18.71	10.0	18.00	33.0
Ln (assets)	24,864	7.66	1.76	6.42	7.54	8.76
Dividend payer	24,334	0.54	0.50	0	1	1
Leverage	24,773	0.19	0.19	0.02	0.15	0.29
Ln (M/B)	24,297	0.86	0.76	0.38	0.79	1.26
ROA	24,862	0.04	0.14	0.01	0.04	0.08
Knowledge capital*	14,250	656	3412	0	0	137

TABLE 2
Return Volatility and Director Tenure
Panel A: Full Sample

Panel A of Table 2 reports regression results for the return volatility-director tenure relation estimated over the first five years of a director's tenure for the full sample using three functional forms of tenure and two measures of return volatility. The sample excludes CEOs. *Tenure* is the number of months elapsed since the new director joined the board, divided by 12. All regressions control for firm level factors that affect the firm's return volatility. When the dependent variable is realized volatility, the regressions include the market beta, SMB beta and HML beta to control for factors that affect the volatility in average dividend growth. All model specifications include firm-director pair fixed effects and year-month fixed effects. Standard errors are clustered at the firm level. The definition of all variables is in Appendix B. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	1	2	3	4	5	6
	Idiosyncratic Volatility	Realized Volatility	Idiosyncratic Volatility	Realized Volatility	Idiosyncratic Volatility	Realized Volatility
Tenure	-0.532***	-0.571***				
	(-15.622)	(-13.896)				
Tenure^2	0.023***	0.021***				
	(3.635)	(2.755)				
Ln(1+tenure)			-0.334***	-0.287**		
			(-3.260)	(-2.238)		
-1/(1+tenure)					-0.347***	-0.280*
					(-2.932)	(-1.874)
Ln(assets)	-1.267***	-1.240***	-1.267***	-1.240***	-1.267***	-1.240***
	(-9.897)	(-8.046)	(-9.894)	(-8.044)	(-9.892)	(-8.042)
Div payer	-1.227***	-1.330***	-1.228***	-1.331***	-1.228***	-1.330***
	(-6.861)	(-6.490)	(-6.860)	(-6.488)	(-6.858)	(-6.486)
Leverage	2.755***	3.031***	2.754***	3.030***	2.753***	3.030***
	(7.112)	(6.495)	(7.108)	(6.491)	(7.105)	(6.489)
Ln(MB)	-0.624***	-0.665***	-0.624***	-0.665***	-0.624***	-0.665***
	(-7.323)	(-6.566)	(-7.320)	(-6.564)	(-7.318)	(-6.564)
ROA	-1.364***	-1.638***	-1.364***	-1.638***	-1.363***	-1.638***
	(-4.308)	(-4.686)	(-4.306)	(-4.682)	(-4.302)	(-4.678)
Market beta		0.922***		0.922***		0.922***
		(8.801)		(8.800)		(8.800)
SMB beta		0.407***		0.407***		0.407***
		(15.725)		(15.723)		(15.723)
HML beta		0.151***		0.151***		0.151***
		(3.525)		(3.526)		(3.526)
Constant	21.071***	22.877***	23.310***	25.565***	23.455***	25.727***
	(20.226)	(18.248)	(22.765)	(20.731)	(23.040)	(21.009)
Observations	652,239	652,239	652,239	652,239	652,239	652,239
Firm-director pairs	16,201	16,201	16,201	16,201	16,201	16,201
Adj R^2	0.309	0.559	0.309	0.559	0.309	0.559
Firm-Director FE	yes	yes	yes	yes	yes	yes
Year-month FE	yes	yes	yes	yes	yes	yes

TABLE 2
Return Volatility and Director Tenure
Panel B: No CEO Turnover Overlap

Panel B of Table 2 reports regression results for the return volatility-director tenure relation estimated over the first five years of a director's tenure for the sample of director appointments that excludes appointments within two years before or after a CEO turnover event, using three functional forms of tenure and two measures of return volatility. *Tenure* is the number of months elapsed since the new director joined the board, divided by 12. All regressions control for firm level factors that affect the firm's return volatility. When the dependent variable is realized volatility, the regressions include the market beta, SMB beta and HML beta to control for factors that affect the volatility in average dividend growth. All model specifications include firm-director pair fixed effects as well as year-month fixed effects. Standard errors are clustered at the firm level. The definition of all variables is in Appendix B. Robust t-statistics in parentheses.*** p<0.01, ** p<0.05, * p<0.1

	1	2	3	4	5	6
	Idiosyncratic Volatility	Realized Volatility	Idiosyncratic Volatility	Realized Volatility	Idiosyncratic Volatility	Realized Volatility
Tenure	-0.482***	-0.559***				
	(-13.800)	(-13.217)				
Tenure^2	0.013**	0.017**				
	(1.980)	(2.030)				
Ln(1+tenure)			-0.189*	-0.224*		
			(-1.782)	(-1.673)		
-1/(1+tenure)					-0.198	-0.222
					(-1.645)	(-1.456)
Ln(assets)	-1.088***	-1.111***	-1.088***	-1.111***	-1.088***	-1.111***
	(-7.990)	(-6.786)	(-7.990)	(-6.787)	(-7.990)	(-6.787)
Div payer	-1.129***	-1.248***	-1.130***	-1.248***	-1.130***	-1.248***
	(-6.086)	(-5.877)	(-6.088)	(-5.878)	(-6.087)	(-5.878)
Leverage	2.603***	2.876***	2.603***	2.876***	2.603***	2.875***
	(6.405)	(5.880)	(6.404)	(5.878)	(6.403)	(5.877)
Ln(MB)	-0.649***	-0.685***	-0.648***	-0.685***	-0.648***	-0.685***
	(-7.054)	(-6.411)	(-7.052)	(-6.409)	(-7.052)	(-6.408)
ROA	-1.726***	-2.091***	-1.726***	-2.091***	-1.726***	-2.091***
	(-5.343)	(-5.655)	(-5.338)	(-5.650)	(-5.336)	(-5.649)
Market beta		1.127***		1.127***		1.127***
		(33.079)		(33.078)		(33.077)
SMB beta		0.454***		0.454***		0.454***
		(22.066)		(22.065)		(22.064)
HML beta		0.102***		0.102***		0.102***
		(5.407)		(5.407)		(5.407)
Constant	19.632***	21.701***	22.196***	24.607***	22.274***	24.726***
	(17.380)	(16.148)	(19.940)	(18.553)	(20.152)	(18.770)
Observations	466,796	466,796	466,796	466,796	466,796	466,796
Firm-director pairs	11,543	11,543	11,543	11,543	11,543	11,543
Adj R^2	0.302	0.562	0.302	0.562	0.302	0.562
Firm-Director FE	yes	yes	yes	yes	yes	yes
Year-month FE	yes	yes	yes	yes	yes	yes

TABLE 2
Return Volatility and Director Tenure
Panel C: Business-as-usual and Plausibly Exogenous Appointments

Panel C of Table 2 reports regression results for the return volatility-director tenure relationship estimated for the subset of director appointments that is the union of the "business as usual" and the "plausibly exogenous" subsets of director appointments in Columns 1 through 4. Column 4 further restricts the sample of appointments to those where the incoming and departing directors share a high similarity score (see details in Appendix D). To be included in the business-as-usual subset, the appointing firm's stock returns must have outperformed the S&P500 over the year leading up to the appointment and its average monthly volatility over the six-month period leading up to the appointment must be lower than its average monthly volatility over the previous two years. In addition, co-appointments (when multiple directors are appointed within six months) are excluded. Plausibly exogenous appointments comprise those made to comply with new exchange listing requirements appointments or to replace a director who either retired or passed away. As in Panel B of Table 2, director appointments within two years before or after a CEO turnover are excluded. Columns 5 through 7 (8 through 10) report results for the Business as Usual (Plausibly Exogenous) sample only. The dependent variable is monthly idiosyncratic volatility. *Tenure* is the number of months elapsed since the new director joined the board, divided by 12. All regressions control for firm level factors that affect the firm's return volatility. All model specifications include firm-director pair fixed effects as well as year-month fixed effects. Standard errors are clustered at the firm level. The definition of all variables is in Appendix B. Robust t-statistics

Dependent Variable:	Pooled: Business as Usual + Plausibly Exogenous				Business as Usual			Plausibly Exogenous		
Idiosyncratic Volatility	1	2	3	4	5	6	7	8	9	10
Tenure	-0.163***			-0.169***	-0.177			-0.135*		
	(-2.978)			(-2.624)	(-1.497)			(-1.789)		
Tenure^2	0.024**			0.026*	0.070**			0.018		
	(2.064)			(1.898)	(2.153)			(1.184)		
Ln(1+tenure)		-0.354**				-0.808**			-0.279	
		(-1.965)				(-2.128)			(-1.182)	
-1/(1+tenure)			-0.366*				-0.761**			-0.283
			(-1.827)				(-2.088)			(-1.064)
Ln(assets)	-1.244***	-1.244***	-1.245***	-1.075***	-1.459***	-1.467***	-1.472***	-1.239***	-1.239***	-1.239***
	(-5.772)	(-5.774)	(-5.776)	(-4.513)	(-3.831)	(-3.827)	(-3.823)	(-5.221)	(-5.220)	(-5.220)
Div payer	-1.292***	-1.294***	-1.295***	-1.115***	-0.626*	-0.631*	-0.632*	-1.427***	-1.427***	-1.427***
	(-4.882)	(-4.886)	(-4.889)	(-4.139)	(-1.741)	(-1.750)	(-1.752)	(-4.426)	(-4.428)	(-4.428)
Leverage	3.171***	3.170***	3.169***	2.809***	2.355***	2.362***	2.364***	2.996***	2.995***	2.994***
	(5.505)	(5.505)	(5.504)	(4.506)	(2.610)	(2.616)	(2.615)	(4.445)	(4.443)	(4.442)
Ln(MB)	-0.758***	-0.757***	-0.757***	-0.700***	-0.769***	-0.767***	-0.766***	-0.787***	-0.787***	-0.786***
	(-4.614)	(-4.611)	(-4.608)	(-3.724)	(-4.003)	(-3.995)	(-3.987)	(-3.974)	(-3.973)	(-3.972)
ROA	-1.040*	-1.041*	-1.041*	-2.241***	-1.257	-1.256	-1.260	-1.051	-1.052	-1.052
	(-1.838)	(-1.838)	(-1.839)	(-2.622)	(-1.230)	(-1.230)	(-1.233)	(-1.643)	(-1.644)	(-1.646)
Constant	18.012***	17.658***	17.661***	16.545***	17.875***	15.457***	15.867***	18.178***	17.985***	17.949***
	(10.349)	(10.440)	(10.408)	(8.447)	(6.011)	(5.250)	(5.428)	(9.652)	(9.801)	(9.687)
Observations	146,948	146,948	146,948	96,178	30,471	30,471	30,471	94,812	94,812	94,812
Firm-director pairs	4,556	4,556	4,556	2,896	2,577	2,577	2,577	2,275	2,275	2,275
Adj R^2	0.295	0.295	0.295	0.297	0.242	0.242	0.242	0.278	0.278	0.278
Firm-Director FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year-month FE	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

TABLE 3
Young vs. Seasoned Boards

Table 3 reports estimates for the relationship between idiosyncratic return volatility and average board tenure. Specification 1 uses the full sample. Specification 2 examines the volatility-tenure relationship in the set of firms with young boards (bottom tercile of average director tenure) and Specification 3 in the set of firms with seasoned boards (top tercile of average director tenure). All model specifications include firm fixed effects as well as year-month fixed effects. Standard errors are clustered at the firm level. The definition of all variables is in Appendix B. Robust t-statistics in parentheses.*** p<0.01, ** p<0.05, * p<0.1.

Dependent Variable: Idiosyncratic Volatility	1	2	3
	Full Sample	Young Boards	Seasoned Boards
Average board tenure	-0.174***	-0.486***	-0.146
	(-3.402)	(-3.333)	(-0.832)
Average board tenure^2	0.013***	0.089**	0.011
	(2.900)	(1.988)	(0.891)
Number of directors	-0.073***	-0.062*	-0.018
	(-3.227)	(-1.692)	(-0.506)
Firm age	0.851***	0.969***	0.151***
	(55.969)	(31.475)	(8.287)
Ln(assets)	-1.239***	-1.469***	-0.513***
	(-12.046)	(-8.511)	(-2.732)
Div payer	-1.271***	-1.701***	-0.419**
	(-9.190)	(-5.988)	(-2.243)
Leverage	3.073***	1.343**	3.398***
	(8.788)	(2.345)	(5.053)
Ln(MB)	-0.654***	-0.530***	-0.523***
	(-8.336)	(-4.646)	(-4.292)
ROA	-2.270***	-1.750***	-2.915***
	(-5.690)	(-4.538)	(-4.140)
Constant	12.054***	14.206***	5.683***
	(15.329)	(11.739)	(3.346)
Observations	927,713	316,546	298,152
R-squared	0.334	0.293	0.256
Firm FE	yes	yes	yes
Year-Month FE	yes	yes	yes
Number of firms	2,159	2,152	1,458

TABLE 4
Placebo Test

Table 4 reports estimates from placebo tests examining the volatility-tenure relationship in firms without director appointments. Each firm appointing a new director (focal firm) is matched to a control firm closest in size (total assets) in the same industry that experiences no director appointments within two years before or after the focal firm's appointment. The specifications mirror those in Panel A of Table 2, using the first five years of director tenure from the focal firm and volatility and controls from the matched firm. All specifications include firm and year-month fixed effects. Standard errors are clustered at the firm level. The definition of all variables is in Appendix B. Robust t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1

	1	2	3	4	5	6
	Idiosyncratic Volatility	Realized Volatility	Idiosyncratic Volatility	Realized Volatility	Idiosyncratic Volatility	Realized Volatility
Tenure	-0.036	-0.016				
	(-1.155)	(-0.374)				
$Tenure^2$	0.008	0.004				
	(1.328)	(0.520)				
Ln(1+tenure)			-0.002	0.009		
			(-0.081)	(0.231)		
-1/(1+tenure)					-0.024	0.007
					(-0.363)	(0.081)
Ln(assets)	-1.272***	-1.208***	-1.254***	-1.208***	-1.254***	-1.208***
	(-5.620)	(-4.627)	(-5.609)	(-4.627)	(-5.609)	(-4.627)
Div payer	-1.234***	-1.343***	-1.207***	-1.344***	-1.208***	-1.344***
	(-6.372)	(-5.424)	(-6.290)	(-5.425)	(-6.290)	(-5.426)
Leverage	2.303***	1.925***	2.245***	1.925***	2.245***	1.924***
	(3.912)	(2.750)	(3.858)	(2.749)	(3.858)	(2.749)
Ln(MB)	-0.710***	-0.734***	-0.696***	-0.734***	-0.696***	-0.734***
	(-5.458)	(-4.874)	(-5.536)	(-4.874)	(-5.536)	(-4.874)
ROA	-2.095***	-2.582***	-2.054***	-2.583***	-2.054***	-2.583***
	(-4.587)	(-4.731)	(-4.520)	(-4.732)	(-4.521)	(-4.732)
Market beta		1.064***	0.271***	1.064***	0.271***	1.064***
		(17.807)	(8.910)	(17.807)	(8.910)	(17.807)
SMB beta		0.453***	0.149***	0.453***	0.149***	0.453***
		(15.983)	(7.854)	(15.983)	(7.854)	(15.983)
HML beta		0.025	0.040**	0.025	0.040**	0.025
		(0.776)	(2.118)	(0.776)	(2.117)	(0.776)
Constant	20.806***	21.770***	19.886***	21.753***	19.872***	21.764***
	(12.369)	(9.644)	(11.951)	(9.636)	(11.888)	(9.611)
Observations	698,558	698,558	698,558	698,558	698,558	698,558
R-squared	0.336	0.549	0.341	0.549	0.341	0.549
Firm FE	yes	yes	yes	yes	yes	yes
Year-month	yes	yes	yes	yes	yes	yes

TABLE 5
Learning Rank and Future Operating Performance

Table 5 reports estimates from regressions of following year ROA on individual director learning rank. The dependent variable is ROA the year following the director appointment. Learning ranks capture how much markets learn about the director, measured as the normalized rate of decline in idiosyncratic volatility over their first three years of tenure. Columns 1 and 2 present results for the full sample of director appointments that do not overlap with CEO turnover. Columns 3 and 4 restrict the sample to business-as-usual and plausibly exogenous appointments that do not overlap with CEO turnover. All specifications include industry and year fixed effects. T-statistics based on standard errors clustered at the firm level are reported in parentheses. The definition of all variables is in Appendix B. Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

Dependent Variable: ROA_{t+1}	1	2	3	4
Learning rank	0.063***	0.061**	0.031**	0.035***
	(2.686)	(2.558)	(2.263)	(2.689)
Ln(assets)		-0.002		-0.000
		(-0.511)		(-0.127)
Div payer		0.030***		0.018***
		(3.498)		(3.707)
Leverage		-0.087***		-0.091***
		(-4.589)		(-6.418)
Ln(MB)		0.054***		0.049***
		(12.047)		(11.181)
Constant	0.001	-0.032***	0.032***	-0.006
	(0.097)	(-2.741)	(4.331)	(-0.368)
Observations	10,900	10,584	3,597	3,504
R-squared	0.038	0.117	0.027	0.166
Industry FE	yes	yes	yes	yes
Year FE	yes	yes	yes	yes

TABLE 6
Summary of Previous Empirical Evidence and Evidence from the Learning-based Methodology

Table 6 summarizes the cross-sectional results in Section V and presents a comparison with results previously documented in the literature. Space constraints preclude an exhaustive list of the relevant literature. Therefore, many important papers are omitted from this table. (+) indicates a positive relationship between the attribute and the estimated marginal value of the incoming director, (-) indicates a negative relationship, and (~) indicates a non-significant relationship.

	Literature	Finding	Learning-based Methodology
Board Committees			
Compensation Committee	N/A	N/A	**(+)** Chairs of compensation committees have higher marginal value
Audit Committee	Nguyen and Nielsen (2010)	Larger stock price reaction to death of audit committee member.	**(+)** Chairs of audit committees have higher marginal value.
Nominating Committee	Nguyen and Nielsen (2010)	Larger stock price reaction to death of nominating committee member.	**(~)** Chairs of nominating committees do not have significantly higher marginal value.

TABLE 6 (continued)

	Literature	Finding	Learning-based Methodology
Director Characteristics			
Director Compensation	N/A	N/A	**(+)** More highly compensated directors have higher marginal value.
Professional Director	N/A	N/A	**(+)** Professional directors have higher marginal value.
Female	Adams and Ferreira (2009)	Female directors are better monitors, but at the cost of lower firm performance.	**(-)** Female directors on average have lower marginal value.
	Matsa and Miller (2012), Ahern and Dittmar (2012)	Female directors are associated with decreased firm value and profitability.	**(+)** When the firm has high monitoring needs, incoming female directors have higher marginal value.
Busy	Fich and Shivdasani (2006)	Busy directors are associated with lower firm value.	
	Core, Holthausen, and Larcker (1999)	Busy outside directors are associated with increased CEO compensation.	
	Ferris, Jagannathan, and Pritchard (2003)	Positive announcement returns to appointments of busy directors.	**(+)** Busy directors have higher marginal value.
	Falato, Kadyrzhanova, and Lel (2014)	Busy directors are detrimental to board monitoring quality and shareholder value.	
	Field, Lowry, and Mkrtchyan (2013)	Busy directors are beneficial for small young firms but detrimental for large firms.	

TABLE 6 (continued)

	Literature	Finding	Learning-based Methodology
Board Characteristics			
Busy Boards	N/A	N/A	**(-)** Directors joining boards with a larger fraction of busy directors have lower marginal value.
Generational Diversity	N/A	N/A	**(+)** Directors joining boards with greater standard deviation in director age have higher marginal value.
Directors Age	N/A	N/A	**(-)** Directors joining boards whose members are older on average have lower marginal value.
Board Qualification Diversity	N/A	N/A	**(~)** The marginal value of incoming directors does not vary with the dispersion in the number of qualifications held by incumbent board members.
Board Network Size	Barnea and Guedj (2008)	Firms with more connected directors have weaker governance.	**(+)** Directors joining more connected boards have higher marginal value.
Groupthink	Coles, Daniel, and Naveen (2015)	Groupthink has a negative effect on firm value for firms in dynamic industries.	**(-)** Directors joining boards less subject to groupthink have higher marginal value.
Board Size	Yermack (1996), Eisenberg, Sundgren, and Wells (1998)	Inverse association between board size and Tobin's Q.	**(-)** Directors joining smaller boards have higher marginal value.
Gender Diversity	Schwartz-Ziv (2017)	Gender-balanced boards are more likely to replace underperforming CEOs, more active during periods when CEOs are being replaced.	**(-)** Directors joining a gender diverse board have lower marginal value.

TABLE 6 (continued)

	Literature	Finding	Learning-based Methodology
Firm Characteristics			
Knowledge Capital	N/A	N/A	**(+)** Directors have higher marginal value in firms with more knowledge capital.
Firm Size	N/A	N/A	**(-)** Directors have higher marginal value in small firms.
Prior Stock Performance	Mace (1971)	Interview evidence that boards' activeness is limited to crisis situations.	**(-)** Directors have higher marginal value when the firm has recently performed poorly.
	Larcker, So, and Wang (2013)	Board network resources are most valuable for firm with poor performance.	
Industry Complexity	Coles, Daniel, and Naveen (2015)	Groupthink is more detrimental for firms in more dynamic industries.	**(+)** Directors have higher marginal value in complex and human capital-intensive industries.

TABLE 7
Cross-sectional Analysis
Panel A: Compensation and Position on the Board and the Volatility-Tenure Relationship

Panel A of Table 7 examines how the incoming director's compensation and position on the board affects the return volatility-tenure relationship. The dependent variable is monthly idiosyncratic volatility. Specifications 1 and 3 use the full sample of director appointments, excluding those that occur within two years before or after a CEO turnover. Specifications 2 and 4 use the sample of exogenous appointments: the union of the "business as usual" sample and the plausibly exogenous sample, also excluding those that occur within two years before or after a CEO turnover. All model specifications include controls for the ex ante uncertainty about director ability (director age, number of previous board seats, number of previous jobs, number of positions as CEO of public company), and the set of firm level control variables (not reported for brevity), as well as firm and year-month fixed effects. Standard errors are clustered at the firm level. The definition of all variables is in Appendix B. Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

	1	2	3	4
Ln(1+tenure)	0.065	0.130	0.045	0.207
	(1.211)	(1.474)	(0.230)	(0.536)
Director compensation	0.065***	0.061***		
	(5.031)	(5.532)		
Director compensation × ln(1+tenure)	-0.054***	-0.049***		
	(-3.983)	(-3.350)		
Independent			-0.178	-0.566
			(-0.678)	(-1.114)
Independent × ln(1+tenure)			0.045	0.046
			(0.232)	(0.118)
Nominating committee chair			0.224	-0.114
			(1.180)	(-0.341)
Nominating committee chair × ln(1+tenure)			-0.201	0.005
			(-1.414)	(0.017)
Audit committee chair			0.480**	0.288
			(2.507)	(1.004)
Audit committee chair × ln(1+tenure)			-0.321**	-0.182
			(-2.322)	(-0.851)
Compensation committee chair			0.470***	0.412
			(2.666)	(1.616)
Compensation committee chair × ln(1+tenure)			-0.309**	-0.265
			(-2.386)	(-1.382)
Finance expertise			0.181	0.313
			(1.556)	(1.644)
Finance expertise × ln(1+tenure)			-0.198**	-0.184
			(-2.017)	(-1.179)
Constant	15.765***	14.024***	21.711***	17.628***
	(11.031)	(6.341)	(15.770)	(7.443)
Controls for director uncertainty	yes	yes	yes	yes
Firm level controls	yes	yes	yes	yes
Observations	117,657	36,564	212,028	67,355
Number of firms	685	516	1,549	1,054
Adj R^2	0.334	0.308	0.325	0.313
Firm FE	yes	yes	yes	yes

Year-month FE	yes	yes	yes	yes

TABLE 7
Cross-sectional Analysis
Panel B: Individual Director Characteristics and the Volatility-Tenure Relationship

Panel B of Table 7 examines how incoming director characteristics affect the return volatility-tenure relationship. The dependent variable is monthly idiosyncratic volatility. Specification 1 uses the full sample of director appointments, excluding those that occur within two years before or after a CEO turnover. Specification 2 uses the sample of exogenous appointments: the union of the "business as usual" sample and the plausibly exogenous sample, also excluding those that occur within two years before or after a CEO turnover. All model specifications include controls for the ex-ante uncertainty about director ability (director age, number of previous board seats, number of previous jobs, number of positions as CEO of public company), and the set of firm level control variables (not reported for brevity), as well as firm and year-month fixed effects. Standard errors are clustered at the firm level. The definition of all variables is in Appendix B. Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

	1	2
Ln(1+tenure)	-0.017	0.181**
	(-0.351)	(2.062)
Professional director	0.156	0.218
	(1.054)	(0.850)
Professional director × ln(1+tenure)	-0.230*	-0.277
	(-1.947)	(-1.545)
Busy	0.228***	0.094
	(2.650)	(0.676)
Busy × ln(1+tenure)	-0.178***	-0.088
	(-2.664)	(-0.781)
Female	-0.340***	-0.243
	(-3.017)	(-1.403)
Female × ln(1+tenure)	0.254***	0.135
	(2.709)	(0.841)
High monitoring needs	-0.392**	0.148
	(-2.547)	(0.652)
High monitoring needs × ln(1+tenure)	0.312***	0.142
	(2.761)	(0.663)
Female × high monitoring needs	0.739***	1.343*
	(2.593)	(1.850)
Female × high monitoring need × ln(1+tenure)	-0.515**	-1.019*
	(-2.393)	(-1.677)
	(-6.211)	(-2.806)
Constant	23.724***	16.847***
	(21.476)	(8.147)
Controls for director uncertainty	yes	yes
Firm level controls	yes	yes
Observations	230,513	72,365
Number of firms	1,576	1,087
Adj R^2	0.328	0.311
Firm FE	yes	yes
Year-month FE	yes	yes

TABLE 7
Cross-sectional Analysis
Panel C: Board Characteristics and the Volatility-Tenure Relationship

Panel C of Table 7 examines how board composition affects the volatility-tenure relationship. The dependent variable is monthly idiosyncratic volatility. Specifications 1 and 2 use the full sample of director appointments, excluding those that occur within two years before or after a CEO turnover. Specifications 3 and 4 use the sample of exogenous appointments: the union of the business-as-usual sample and the plausibly exogenous sample, also excluding those that occur within two years before or after a CEO turnover. All model specifications include controls for the ex-ante uncertainty about director ability (director age, number of previous board seats, number of previous jobs, number of positions as CEO of public company), and the set of firm level control variables (not reported for brevity), as well as year-month fixed effects. Standard errors are clustered at the firm level. The definition of all variables is in Appendix B. Robust t-statistics in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

	1	2	3	4
Ln(1+tenure)	-0.611***	-0.752	-0.474*	2.792*
	(-3.446)	(-0.811)	(-1.650)	(1.885)
Large board	-1.012***		-0.800***	
	(-6.828)		(-4.455)	
Large board × ln(1+tenure)	0.399***		0.210*	
	(3.995)		(1.366)	
Groupthink	-0.212		-0.047	
	(-0.867)		(-0.125)	
Groupthink × ln(1+tenure)	0.199		0.015	
	(1.055)		(0.042)	
Gender diverse board	-0.066		0.011	
	(-0.454)		(0.064)	
Gender diverse board × ln(1+tenure)	0.172**		0.107	
	(1.792)		(0.703)	
Fraction independent	-0.095		-0.569	
	(-0.271)		(-1.263)	
Fraction independent × ln(1+tenure)	0.108		0.473	
	(0.423)		(1.174)	
Average network size		0.144		0.247
		(1.174)		(1.587)
Average network size × ln(1+tenure)		-0.096		-0.230*
		(-1.176)		(-1.952)
Average busy		-0.505		-0.241
		(-1.24)		(-0.478)
Average busy × ln(1+tenure)		0.545*		0.374
		(1.196)		(0.908)
Standard deviation number qualifications		-0.030		-0.156
		(-0.162)		(-0.675)
Standard deviation number qualification × ln(1+tenure)		0.016		0.123
		(0.119)		(0.599)
Standard deviation director age		0.109***		0.089*
		(3.319)		(1.892)
Standard deviation director age × ln(1+tenure)		-0.034		-0.068*
		(-1.418)		(-1.712)
Average director age		-0.063***		-0.015
		(-3.163)		(-0.638)
Average director age × ln(1+tenure)		0.023*		-0.016
		(1.774)		(-0.845)
Constant	21.962***	22.804***	15.675***	13.943***
	(45.947)	(15.755)	(20.841)	(7.420)
Controls for director uncertainty	yes	yes	yes	yes
Firm level controls	yes	yes	yes	yes
Observations	230,513	189,291	72,365	58,028
Number of firms	1,576	1,441	1,087	942
Adj R^2	0.383	0.382	0.366	0.368
Year-month FE	yes	yes	yes	yes

TABLE 7
Cross-sectional Analysis
Panel D: Firm Characteristics and the Volatility-Tenure Relationship

Panel D of Table 7 examines how firm characteristics affect the return volatility-tenure relationship. The dependent variable is monthly idiosyncratic volatility. Specifications 1 uses the full sample, excluding those that occur within two years before or after a CEO turnover. Specification 2 uses the sample of exogenous appointments: the union of the "business as usual" sample and the plausibly exogenous sample, also excluding those that occur within two years before or after a CEO turnover. All model specifications include controls for the ex ante uncertainty about director ability (director age, number of previous board seats, number of previous jobs, number of positions as CEO of public company), and the set of firm level control variables (not reported for brevity), as well as year-month fixed effects. The coefficients on knowledge capital and its interaction with ln(1+tenure) are multiplied by 1000 for ease of interpretation. Standard errors are clustered at the firm level. The definition of all variables is in Appendix B. Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.

	1	2
Ln(1+tenure)	-0.759***	-0.777*
	(-2.610)	(-1.747)
Knowledge capital	0.018	0.079***
	(1.638)	(4.652)
Knowledge capital × ln(1+tenure)	-0.016*	-0.052***
	(-1.889)	(-3.239)
Ln(assets)	-0.636***	-0.704***
	(-13.183)	(-12.773)
Ln(assets) × ln(1+tenure)	0.106***	0.109**
	(3.199)	(2.220)
Poor performance	0.686***	0.482**
	(5.490)	(2.269)
Poor performance × ln(1+tenure)	-0.274***	-0.163
	(-2.908)	(-0.867)
Tech	0.651***	0.859***
	(3.204)	(3.356)
Tech × ln(1+tenure)	-0.580***	-0.659***
	(-4.371)	(-3.234)
Constant	13.578***	19.231***
	(27.908)	(27.097)
Controls for director uncertainty	yes	yes
Firm level controls	yes	yes
Observations	174,150	59,167
Number of firms	1,344	934
Adj R^2	0.373	0.370
Year-month FE	yes	yes

TABLE 8
Tests of Differences in Volatility-Tenure Relationship Across Director, Board, and Firm Characteristics

Table 8 reports differences in the average marginal effect (AME) of the first year of director tenure on idiosyncratic return volatility across various director, board, and firm characteristics. Using Specifications 1 in panels A through D of Table 7, the marginal effect of the first year of director tenure on volatility is estimated for each characteristic. The difference test compares these AMEs between high and low values of each characteristic. Positive (negative) differences indicate that the characteristic is associated with a larger (smaller) decline in return volatility over the first year of director tenure, suggesting more (less) learning by markets. For continuous variables, "Low" ("high") equals one when the value is more than one standard deviation below (above) the sample mean, zero otherwise. P-values are reported in parentheses. The definition of all variables is in Appendix B. *** p<0.01, ** p<0.05, * p<0.1, respectively.

	AME Difference
Position on Board (N = 212,028)	(p-value)
Audit chair	0.232**
	(0.015)
Compensation chair	0.177**
	(0.047)
Nomination chair	0.108
	(0.271)
Director Compensation (N = 117,657)	
High director compensation	0.151***
	(0.000)
Individual Director Characteristics (N= 230,513)	
Professional director	0.204**
	(0.011)
Busy director	0.146***
	(0.001)
Female director	-0.130**
	(0.028)
Board Characteristics (N = 229,949)	
Large board	-0.309***
	(0.000)
Low groupthink	0.102*
	(0.058)
Gender diverse board	-0.220***
	(0.000)
High board independence	0.077
	(0.147)
High board network	-0.018
	(0.711)
Busy board	-0.124**
	(0.045)
High average director age	-0.101
	(0.124)
High qualification diversity	-0.019
	(0.786)
High generational diversity	0.136*
	(0.066)
Firm Characteristics (N = 174,150)	
Knowledge capital	0.168***

	(0.000)
Large firm	-0.224***
	(0.001)
Underperformer	0.205***
	(0.002)
Tech	0.494***
	(0.000)

Appendix A. A Bayesian Learning Model of Director Ability

The learning model draws on the work by Harris and Holmström (1982), Murphy (1986), Gibbons and Murphy (1992), and Holmström (1999) in the context of learning about managerial ability as well as on the work of Pastor and Veronesi (2003), (2009). The setup mirrors the stylized model of Pan, Wang, and Weisbach (2015).

In the model, ability refers to an individual's capacity to facilitate the generation of cash flows, conditional on firm characteristics and incumbent board members' characteristics. When a newly appointed director joins a board, her personal aptitude and capacity to influence this board are uncertain, as is the degree of complementarity between her expertise and that of current board members. The uncertainty surrounding her ability resolves over time as these parameters are gradually revealed to the market. Dividend growth follows a geometric Brownian motion:

$$\frac{dD_{it}}{D_{it}} = \alpha_j^i dt + \sigma dW_t \tag{A5}$$

where D_{it} is firm *i*'s dividend at time *t*, α_j^i is director *j*'s unobserved ability, which affects the average dividend growth rate, σ is the dividend growth volatility, and dW_t is a Wiener process. Director *j* has ability α_j^i to contribute to the generation of cash flows of firm *i*. This ability is an unknown and unobservable parameter, but it is subject to learning. Rational market participants learn about ability according to Bayes' rule. Assuming that α_j^i follows a truncated normal distribution with prior mean $\theta_{j,0}^i$ and prior variance $\delta_{j,0}^{i2}$, at any time *t*, market participants' posterior beliefs about ability are normally distributed with mean $\theta_{j,t}^i$ and variance $\delta_{j,t}^{i2}$:

$$\alpha_{j,t}^i \sim N\left(\theta_{j,t}^i, \delta_{j,t}^{i2}\right),\ \alpha_{j,t}^i < r \tag{A6}$$

where according to Bayes' rule, $\theta_{j,t}^i$ is a weighted average of prior mean, $\theta_{j,0}^i$, and the mean of the signals observed up to time *t,* with weights inversely proportional to the variances of the two

means. The signal takes the differential form $\frac{ds_t}{dt} = s'_t = \alpha_j^i + \sigma\frac{dW_t}{dt}$. Applying Bayes' rule, and following Pastor and Veronesi (2003), (2009), the posterior variance is

$$\delta_{j,t}^{i2} = \left(\frac{1}{\delta_{j,0}^{i2}} + \frac{t}{\sigma^2}\right)^{-1}$$

The posterior mean

$$\theta_{j,t}^i \approx \theta_{j,0}^i \frac{\frac{1}{\delta_{j,0}^{i2}}}{\frac{1}{\delta_{j,0}^{i2}} + \frac{t}{\sigma^2}} + \frac{1}{t}\int_0^t s'_x dx \frac{\frac{t}{\sigma^2}}{\frac{1}{\delta_{j,0}^{i2}} + \frac{t}{\sigma^2}}$$

can thus be written as:

$$\theta_{j,t}^i \approx \theta_{j,0}^i \frac{\delta_{j,t}^{i2}}{\delta_{j,0}^{i2}} + \frac{1}{t}\int_0^t s'_x dx \, t\frac{\delta_{j,t}^{i2}}{\sigma^2}$$

Rearranging yields

$$\theta_{j,t}^i \approx \delta_{j,t}^{i2}\left(\frac{\theta_{j,0}^i}{\delta_{j,0}^{i2}} + \frac{1}{\sigma^2}\int_0^t s'_x dx\right)$$

which in differential form is

$$\frac{d\theta_{j,t}^i}{dt} \approx \frac{d\delta_{j,t}^{i2}}{dt}\left(\frac{\theta_{j,0}^i}{\delta_{j,0}^{i2}} + \frac{1}{\sigma^2}\int_0^t s'_x dx\right) + \frac{\delta_{j,t}^{i2}}{\sigma^2}s'_t$$

The differential form for the posterior variance is

$$\frac{d\delta_{j,t}^{i2}}{dt} = -\frac{1}{\sigma^2}\left(\frac{1}{\delta_{j,0}^{i2}} + \frac{t}{\sigma^2}\right)^{-2}$$

$$= -\frac{1}{\sigma^2}\left(\delta_{j,t}^{i2}\right)^2$$

Substituting $\frac{d\delta_{j,t}^{i2}}{dt}$ in $\frac{d\theta_{j,t}^i}{dt}$, we have:

$$\frac{d\theta_{j,t}^{i}}{dt} = -\frac{\left(\delta_{j,t}^{i2}\right)^{2}}{\sigma^{2}}\left(\frac{\theta_{j,0}^{i}}{\delta_{j,0}^{i2}} + \frac{1}{\sigma^{2}}\int_{0}^{t} s_{x}' dx\right) + \frac{\delta_{j,t}^{i2}}{\sigma^{2}} s_{t}'$$

Let $m_t = \frac{\delta_{j,t}^{i2}}{\sigma^2}$,

$$\frac{d\theta_{j,t}^{i}}{dt} = -\frac{\delta_{j,t}^{i2}}{\sigma^{2}}\left(\theta_{j,0}^{i}\frac{\delta_{j,t}^{i2}}{\delta_{j,0}^{i2}} + \frac{\delta_{j,t}^{i2}}{\sigma^{2}}\int_{0}^{t} s_{x}' dx\right) + m_t s_{t}'$$

$$= -m_t\theta_{j,t}^{i} + m_t s_{t}'$$

Therefore,

$$d\theta_{j,t}^{i} = m_t\left(s_{t}' dt - \theta_{j,t}^{i} dt\right)$$

The Bayesian update for the uncertain ability parameter is therefore:

(A7) $$d\theta_{j,t}^{i} \approx m_t\left[\frac{dD_{i,t}}{D_{i,t}} - \theta_{j,t}^{i} dt\right]$$

(A8) $$\text{with } m_t = \frac{\delta_{j,t}^{i2}}{\sigma^2} = \frac{\delta_{j,0}^{i2}}{\sigma^2 + \delta_{j,0}^{i2}\, t}$$

(A9) $$\text{and } \delta_{j,t}^{i2} = \frac{\sigma^2\delta_{j,0}^{i2}}{\sigma^2 + \delta_{j,0}^{i2}\, t}$$

When agents observe a higher-than-expected signal about ability, $\left[\frac{dD_{i,t}}{D_{i,t}} - \theta_{j,t}^{i} dt\right]$ is positive. Agents update their beliefs according to Equation (A3) and the magnitude of the revision, which can be interpreted as the learning speed, is captured by m_t. This implies that conditional on the realization of the signal, the larger the uncertainty about the director, the larger the revision of assessed ability. Therefore, the Bayesian learning framework predicts a positive relationship between the uncertainty about the director's ability and the magnitude of the revision of assessed ability.

Unlike the posterior mean, the posterior variance $\delta_{j,t}^{i2}$, which captures how much uncertainty there remains about ability, does not depend on the realization of the signal. The

posterior variance decreases non-stochastically over time and $\delta_{j,t}^{i2}$ has a negative and convex relationship with *t*. Therefore, the model predicts a decreasing and convex learning curve: the uncertainty about ability dissipates over time and learning is faster at the beginning of tenure. The revised variance $\delta_{j,t}^{i2}$ is always smaller than the initial variance $\delta_{j,0}^{i2}$ and represents the uncertainty about parameter θ. As is standard in nearly all existing literature with learning models, ability α_j^i is assumed constant. As market participants learn about ability, the uncertainty dissipates and eventually $\delta_{j,t}^{i2} \to 0$.

Timmermann (1993) shows that when agents do not know the true data-generating process for dividends, learning generates excess stock return volatility. Pastor and Veronesi (2009) formalize this intuition and derive an approximation for return volatility. Let $f_t(\alpha_j^i)$ be the truncated (pr(α_j^i < r) = 1) normal distribution of α_j^i at time *t*, with mean $\theta_{j,t}^i$and variance $\delta_{j,t}^{i2}$, as in equations (A2) through (A5). Let $F(\theta_{j,t}^i, \delta_{j,t}^{i2}) \equiv \log(P_t/D_t)$. Using Itô's lemma, $dF(\theta_{j,t}^i, \delta_{j,t}^{i2}) = \frac{\partial F(\theta_{j,t}^i, \delta_{j,t}^{i2})}{\partial \theta_{j,t}^i} d\theta_{j,t}^i + o(dt)$. Since $d\log(P_t/D_t) = \frac{dP_t}{P_t} - \frac{dD_t}{D_t}$,

$$\frac{dP_t}{P_t} = \frac{dD_t}{D_t} + \left(\frac{\partial F(\theta_{j,t}^i, \delta_{j,t}^{i2})}{\partial \theta_{j,t}^i}\right) d\theta_{j,t}^i + o(dt)\ ,$$

where $o(dt)$ represents non-stochastics terms of order (dt). Substituting for $d\theta_{j,t}^i$ and rearranging:

$$\frac{dP_t}{P_t} \approx \frac{dD_t}{D_t} \times \left[1 + \left(\frac{\partial F(\theta_{j,t}^i, \delta_{j,t}^{i2})}{\partial \theta_{j,t}^i}\right) m_t\right] + o(dt)$$

Taking the standard deviation on both sides, we obtain return volatility:

$$vol\left(\frac{dP_t}{P_t}\right) \approx vol\left(\frac{dD_t}{D_t}\right) \times \left[1 + \left(\frac{\partial F(\theta_{j,t}^i, \delta_{j,t}^{i2})}{\partial \theta_{j,t}^i}\right) m_t\right]$$

(A10) $\text{Return Volatility}_t \approx \text{Dividend Growth Volatility} \times \left[1 + \left(\frac{\partial \log(P/D)_t}{\partial \theta_{j,t}^i}\right)\left(\frac{\delta_{j,0}^{i2}}{\sigma^2 + \delta_{j,0}^{i2} t}\right)\right]$

Equation (A6) motivates the empirical analysis in the paper. $\frac{\partial \log\left(\frac{P}{D}\right)_t}{\partial \theta_{j,t}^i}$ represents the sensitivity of the $\log(\frac{P}{D})$ to the mean assessment of ability and can therefore be interpreted as the marginal return to director ability. $\left(\frac{\delta_{j,0}^{i2}}{\sigma^2 + \delta_{j,0}^{i2} t}\right)$ is m_t, which can be rewritten as the ratio of uncertainty about the director's ability over uncertainty about the firm's dividends (see equation (A4)) and is related to the learning speed. Equation (A6) therefore shows how return volatility is augmented due to uncertainty. Return volatility comprises three components: fundamental volatility (that is dividend growth volatility, which would be the volatility had there not been extra uncertainty arising from the arrival of the new director), *ex-ante* uncertainty about the director's ability, and the director's marginal return to ability (MRA). For ease of exposition, equation (A6) can be rewritten as:

(A11) $$Volatility_t \approx \sigma\,(1 + MRA_t \times m_t)$$

If directors take actions that influence the generation of cash flows, then MRA > 0. In that case, return volatility is positively related to the uncertainty about director ability, *via* m_t. Note that we know from equation (A4) that m_t declines at a predetermined rate over time due to Bayes' rule, and that this rate is faster for higher *ex-ante* levels of uncertainty about ability. This implies that conditional on *ex-ante* uncertainty, the cross-sectional analysis of declines in volatility provides estimates of directors' marginal value. In other words, the extent of the decline in volatility depends on the marginal value of that director.

In sum, the model presented above implies that if directors do contribute to the generation of cash flows, we should observe a decline in return volatility over their tenure.

Moreover, this decline should be proportional to their contribution, i.e., it should be more pronounced when directors are more value relevant. By exploiting the empirical analysis arising from these predictions, this paper offers a new methodological approach to study the value of corporate boards.

Appendix B. Variable Definitions

Board and director level variables are from BoardEx, financial variables from Compustat, and market variables from CRSP.

Director Level Variables	
Tenure	Time since a director joined a board (in years). Constructed from BoardEx start and end role dates.
Director compensation	Independent director compensation scaled by the average compensation for incumbent independent directors on the board (as of the year the incoming director joins the board)
Director age	Age of the director (in years)
Female	Indicator equal to one if the director is female. From BoardEx, supplemented with manually collection
Independent	Indicator equal to one if the director is an independent director
Busy	Indicator equal to one if the director serves simultaneously on three or more boards
Experience CEO public firm	Indicator equal to one if the director is or has previously been CEO of a public corporation
Board exp same industry	Indicator equal to one if the director is serving or has previously served on the board of a firm in the same industry.
Job exp same industry	Indicator equal to one if the director is working or has previously worked for a firm in the same industry.
Industry experience	Indicator equal to one if the director has had a job in the same industry or has previously held a directorship in the same industry.
Number previous boards	Number of previous directorships held
Finance experience	Indicator equal to one if the director has a job description in BoardEx that includes one of the following key words: "investment" "broker" "banker" "banking" "economist" "finance" "treasurer" "audit" "cfo" "financial" "controller" "accounting" "accountant" "actuary" "floor trader" "equity" "general partner" "market maker" "hedge fund"
Professional director	Indicator equal to one for directors who have held at least four previous directorships and have previously held directorships in the same industry
Learning rank	The normalized rate of decline in idiosyncratic volatility over the director's first three years of tenure. Constructed by estimating the rate of decline in idiosyncratic volatility over a director's first three years of tenure, multiplying by -1 so that higher values indicate more learning, and normalizing to create a ranking between 0 and 1.

Appendix B (continued)

Board Level Variables	
Avg board tenure	Average tenure of the directors of a board (in years)
Avg board tenure square	Square of *Average board tenure*
Young boards	Each month, boards are ranked using the average tenure of their members. Young boards are those in the first tercile
Seasoned boards	Boards are ranked based on the average tenure of their members, each month. Young boards are those in the third tercile
Gender diverse board	Indicator equal to 1 if at least one woman serves on the board
Board size	Number of directors on the board
Large board	Indicator equal to 1 if board size is larger than the sample mean (10 directors)
Groupthink	Percentage of directors on the board with tenure greater than 9 years
Independent ratio	Ratio of the number of independent directors over total number of directors
Network size	Average network size of the independent directors on the board
Board busyness	Fraction of the board's directors who serve simultaneously on three of more boards
Board age	Average age of the directors on the board
Age diversity	Standard deviation of the directors' age
Qualification diversity	Standard deviation of the directors' number of qualifications

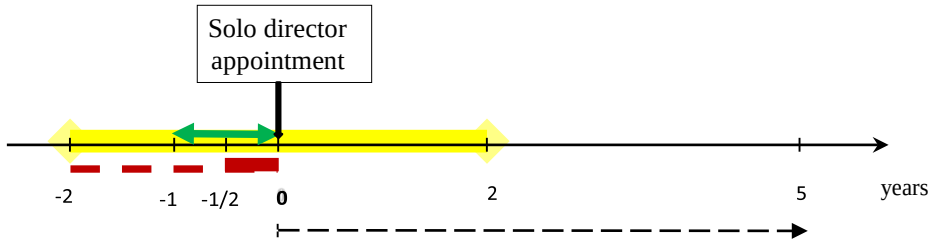
Appendix B (continued)

Firm Level Variables	
Ln(assets)	Natural logarithm of total firm assets (item AT in Compustat)
Dividend payer	Indicator equal to one if the firm pays dividends (item DVC in Compustat)
Leverage	Long-term debt over total assets (item DLTT/AT in Compustat)
MB	Market to book ratio: Stock price at year end*common shares outstanding over total common equity ((PRCC_C*CSHO)/CEQ in Compustat)
ROA	Return on assets: net income over total assets (NI/AT in Compustat)
Firm age	Age of the firm (in years) since the first appearance of the firm in CRSP, as in Fama and French (2004)
High monitoring need	Indicator equal to one for firms with total assets above the median whose CEO combines the title of chairman of the board and president and has been in place for at least five years
Tech	Indicator variable equal to one if the firm's sic code is in Business Equipment -- Computers, Software, and Electronic Equipment using the Fama French ten industry classification
Knowledge capital	The replacement cost of the firm's knowledge capital: the portion of intangible capital that comes from R&D (*G* in Peters and Taylor, 2017)
Underperformance	Indicator equal to one if the firm's stock returns underperformed the S&P500 returns in the twelve months leading up to the director appointment

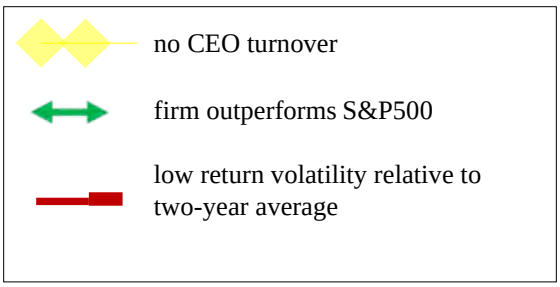
Market Level Variables	
Idiosyncratic volatility	Variance of the residuals of a daily Fama-French three factor model as in Ang et al. (2006), aggregated monthly, winzorized at 1%
Realized volatility	Standard deviation of daily stock returns, aggregated monthly, winzorized at 1%
Market beta	Estimated coefficient on the excess market return in a daily Fama-French three factor model, aggregated monthly
SMB beta	Estimated coefficient on the SMB factor in a daily Fama-French three factor model, aggregated monthly
HML beta	Estimated coefficient on the HML factor in a daily Fama-French three factor model, aggregated monthly

Appendix C. Schematic for Selection Criteria the "Business as Usual" Sample

This figure provides a schematic representation of the filters used to obtain the "business as usual" sample. As everywhere in the analysis, director appointments that occur within two years before or after a CEO turnover are excluded from the sample. Further, the firm's stock returns must outperform the S&P500 over the one-year period leading up to the appointment and its average monthly volatility over the six-month period leading up to the appointment must be lower than its average monthly volatility over the previous two years. Co-appointments (when multiple directors are appointed within six months) are excluded.



Return volatility pattern over director tenure



Appendix D. Similarity Score Between Departing and Incoming Directors

A similarity score counts the number of shared characteristics from a pool of six characteristics for incoming-departing director pairs when the departing director left due to death or retirement and the firm operates in an environment of good stock return performance and low return volatility at the time of appointment. All variables are constructed from BoardEx data and supplemented with manual data collection when necessary. An incoming-departing director pair receives one point for each shared characteristic, with a total of six possible points.

Gender	from BoardEx, supplemented with manual collection.
Generations	depression babies (born before 1926) mature generation (born 1927-1945) baby boomers (born 1946-1964) generation X (born 1965-1980) generation Y (born after 1981)
Job expertise	based on the directors' job history in BoardEx. Word searches are used to define eleven categories: management academia politics military human resources technology science marketing law finance consulting
Board experience	indicator variable equal to one for directors who have held a minimum of two public directorships.
Industry directorship	indicator variable equal to one for directors who have held directorships in the same industry as the firm they are joining/leaving.
Industry work experience	indicator variable equal to one for directors who have worked in the industry of the firm they are joining/leaving.

Similarity score summary statistics

Mean	3.49
25%	3
Median	4
75%	4
Std dev	1.22
Min	0
Max	6

Appendix E. Estimating Director Related Uncertainty

The Bayesian learning framework is used to quantify how much of the observed return volatility (Vol_0) can be attributed to the uncertainty about a new director at the time of appointment. This quantity is captured by the ratio δ_0/Vol_0. This exercise directly relies on the methodology derived in Pan et al. (2015) and combines three key estimates: the average decline in return volatility over director tenure, the average volatility in corporate dividends (σ) and the average volatility at the time a director joins (Vol_0).

Take the return volatility approximation, derived in Appendix A equation (A6), which describes how learning about director quality influences the firm's stock return volatility:

$$\text{Return Volatility}_t \approx \sigma \times \left[1 + \left(\frac{\partial \log(P/D)_t}{\partial \theta^i_{j,t}}\right)\left(\frac{\delta^{i2}_{j,0}}{\sigma^2 + \delta^{i2}_{j,0} t}\right)\right] = \sigma \times \left[1 + (\text{MRA}_t)(m_t)\right]$$

and let $Vol' = \frac{Vol}{\sigma} - 1$ be the percentage excess volatility, that is, the amount by which return volatility is inflated relative to fundamental dividend growth. Using the above equation, $Vol' = MRA_t m_t$. As is shown in Appendix A, m_t captures the speed at which markets learn, and it is driven by the ratio of uncertainty about director quality (δ) to uncertainty about the firm's cash flow (σ). The percentage change in excess volatility from time 0 to time *t* is $\frac{\Delta Vol'}{Vol'_0} = \frac{\Delta m}{m_0} + \frac{\Delta MRA}{MRA_0} \times \left(1 + \frac{\Delta m}{m_0}\right)$. Since the marginal return to ability is hypothesized constant over time, $\frac{\Delta Vol'}{Vol'_0} = \frac{\Delta m}{m_0}$. Using equation (A4) in Appendix A, the learning speed $m_t = \frac{\delta^{i2}_{j,t}}{\sigma^2} = \frac{\delta^{i2}_{j,0}}{\sigma^2 + \delta^{i2}_{j,0} t}$,

$$\frac{\Delta m}{m_0} = \frac{m_t}{m_0} - 1 = \frac{\delta_t^2/\sigma^2}{\delta_0^2/\sigma^2} - 1 = \frac{1}{1 + \delta_0^2/\sigma^2 \; t} - 1 = \frac{1}{1 + m_0 t} - 1$$

$$\approx \frac{\Delta Vol'}{Vol'_0} = \frac{\Delta Vol}{Vol_0} \times \frac{Vol_0}{Vol_0 - \sigma}$$

When t=3, $m_0 = \frac{1}{3}\left[\frac{1}{1-\frac{\Delta Vol'}{Vol'_0}} - 1\right]$ and the percentage of total volatility attributable to the uncertainty about new directors is $\frac{\delta_0}{Vol_0} = \sqrt{\frac{1}{3}\left[\frac{1}{1-\frac{\Delta Vol'}{Vol'_0}} - 1\right]} \times \frac{\sigma}{Vol_0}$.