Board Size, Firm Type, and Stock Return Volatility*

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Abstract

Prior research suggests that large boards are associated with lower firm value and lower volatility because of inefficiencies. We propose an alternative explanation, namely, that board size enhances the capacity for monitoring. Our empirical results show that stock return volatility is lower in firms with larger boards, but that firm value is not negatively affected. Test show that firms with larger boards prevent unnecessary or value-destroying risks by curbing acquisition expenses and financial leverage. Additionally, ours is the first study to investigate the association between board size and volatility for different firm types. We find that complex firms can benefit from large boards, which lead to higher CEO pay-for-performance sensitivity and lower stock price crash risk than firms with small boards. Research and development–heavy firms benefit more from medium-sized boards. Our results hold for a battery of robustness checks, including a variety of endogeneity tests.

JEL classification: G31; G34; M52

Keywords: Board size, volatility, complex firms, R&D-heavy firms, monitoring

This version: December 2019

* We thank Olaf Korn and seminar participants at Georg-August University Goettingen, the 41st Annual Congress of the European Accounting Association, and the 2019 Annual Meeting of the Financial Management Association. All remaining errors are our own. A previous version of this paper was circulated under the title "Board Structure and Stock Return Volatility."

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1 Introduction

The board of directors is the primary means for dispersed shareholders to monitor top management (John & Senbet, 1998), and it is therefore understandable that the structure of the board, especially its size, has received great attention in the literature. Predominantly, studies find a negative association between board size and performance (e.g., Yermack, 1996; Eisenberg, Sundgren & Wells, 1998). These outcomes are explained by either agency problems, such as free riding, or more complicated communications and coordination (e.g., Jensen, 1993), which we collectively refer to as the inefficiency explanation. With respect to the relation between board size and volatility, Cheng (2008) similarly finds a negative association and argues that this is also the result of communication inefficiencies.[1]

A priori, however, it is not clear if higher volatility is always in the shareholders' best interest. Classical agency theory (e.g., Holmström, 1999) assumes that managers are risk averse and that the principal needs to induce risk taking. Consequently, higher volatility would be desirable. On the other hand, executives' incentives are often misaligned (e.g., Dittmann & Maug, 2007), which can result in excessive risk taking and outcomes that are detrimental to shareholders. In such situations, boards executing their monitoring role can prevent such unnecessary risk taking. When managers have to justify their decisions to the shareholders or their representatives, they will avoid excessive risks that they would have otherwise taken and improve firm performance in the process (Lefebvre & Vieider, 2013). A functioning board could thus lead to both an increase in volatility, if it promotes undertaking value-enhancing risky projects, or a decreasing volatility, if it prevents excessive value-destroying risk taking.

With regard to the association between board size and lower volatility, we therefore propose an alternative explanation, namely, the monitoring explanation: larger boards have a greater capacity for monitoring, because they contain broader expertise and knowledge (Coles, Daniel & Naveen, 2008), and committee assignments can be split up among more people (Klein, 2002). Since monitoring is one of the main responsibilities of the board (Fama & Jensen,

[1] Wang (2012) shows that this result also holds after controlling for risk taking incentives. Other characteristics whose relation to volatility have been investigated are diversity (Bernile, Bhagwat & Yonker, 2018; Giannetti & Zhao, 2019), director independence and connectedness (Christy, Matolcsy, Wright & Wyatt, 2013), and board strength (Pathan, 2009).

1983), a greater capacity for it should prevent unnecessary or even value-destroying risk taking by the firm.

Distinguishing between the two explanations requires looking at the concurrent effect of board size on firm value. Lower volatility accompanied by stable or higher firm value suggests that the firm takes on fewer unnecessary or value-destroying risks, which would support the monitoring explanation. Greater volatility, on the other hand, that is accompanied by either stable value or even a lower one points to the board inefficiency explanation, since the firm is obviously taking on unnecessary or even value-destroying risks.[2] This paper is the first to explicitly study the association of board size with volatility in connection with the effect on firm value, contributing to understanding how board size affects risk taking.

Unlike previous papers, we measure board size via three dummy variables (for small, medium, and large boards) based on the empirical distribution of boards for two reasons. First, board size most likely has a nonlinear effect: adding an additional director to a board of three will have a different impact than adding an additional one to a board that already has 20 people on it. Second, we are particularly interested in the effects of extreme board sizes, both small and large, that a counter variable could not identify.

Our findings for a large universe of U.S. firms indicate that small boards are associated with an increase in volatility, whereas large boards are associated with a decrease. Interestingly and contrary to previous findings, however, when we analyze the association of board size with firm value, we find no statistically significant effect of the size category on Tobin's Q. Consequently, we argue that larger boards can be beneficial to firms wanting to decrease excessive risks, which is indicative of our monitoring explanation. Additional analyses of the potential transmission channels reveal that firms with smaller boards tend to spend more on acquisitions and have higher stock price crash risk, while firms with larger boards have lower net leverage, which can explain the reduced volatility. The effect is especially pronounced in periods of high overall market uncertainty. Our results support the conjecture that firms can in fact benefit from larger boards.

[2] Of course, higher (lower) volatility could also be accompanied by a higher (lower) value, in which case it would not be directly evident if this is in the interest of the shareholder.

In a second step, we analyze the association of board size for different firm types. In their seminal paper, Coles et al. (2008) show that the relation between board size and performance depends on the type of firm, since complex firms perform better when they have larger boards. The authors attribute their finding to the improved monitoring ability of large boards; however, they say nothing about the effect on volatility. Our study fills this gap, since it is the first one to analyze the association between board size and volatility in different firm types, first for complex firms and second for research and development (R&D)-heavy ones.[3] The former require broader expertise on the board, whereas R&D-heavy firms are particularly susceptible to managerial opportunism and thus require specific monitoring (Guldiken & Darendeli, 2016).

We find different results for the two categories. Complex firms only achieve the same volatility reduction as non-complex firms when they have (very) large boards, which supports the notion that only a board containing a large variety of expertise can effectively carry out its monitoring duties. This is supported when we analyze the effect of large boards on other aspects associated with monitoring, such as a CEO's pay-for-performance sensitivity or stock price crash risk. R&D-heavy firms already benefit from medium-sized boards, which lead to volatility reductions, increased operating performance, and stable firm value. Unlike for complex firms, however, the positive effect of board size wanes quickly for R&D-heavy firms, where we see no difference for large boards compared to non–R&D-heavy firms. This result supports the finding of Guldiken & Darendeli (2016) that increased monitoring will be effective only to a point.

These results are robust to a variety of different model specifications, controls for panel dynamics, and endogeneity tests. For instance, our findings hold for industry as well as firm fixed effects, wherever we can apply them. Moreover, we employ both an instrumental variable and a generalized method of moments (GMM) approach following (Wintoki, Linck & Netter, 2012) to mitigate endogeneity concerns.

Overall, the results contribute to the literature in two important ways. First, they extend the thus far limited research on the relation between board size and stock return volatility. We

[3] Notably, there is very little overlap between those groups in our sample, so they are indeed two distinctly different traits.

conclude that a positive monitoring effect is more likely than the inefficiency explanation for the effect of board size on volatility. It seems that larger boards prevent excessive risk taking through better monitoring, and boards could thus have been unnecessarily shrunk in the past. The effect is particularly strong in times of high market volatility. Second, we also extend the analysis by researching the effect of board size on different types of firms, namely complex and R&D-heavy ones. Prior research has shown that both groups can benefit in terms of value from greater board size, the former because of increased knowledge and the latter because of adequate monitoring capacity. We apply the same distinction to the analysis of volatility and find that similarly complex firms with large boards have lower volatility, whereas R&D-heavy firms are best served by medium-sized boards.

The remainder of this paper is organized as follows. Section 2 reviews the literature and outlines the hypotheses between board size and the volatility of stock returns. Section 3 describes our data set, while Section 4 presents the empirical analysis as well as a discussion of our results. Section 5 concludes the paper.

2 Literature review and research questions

2.1 Board size and volatility

Many prior studies have emphasized investigating the role of board size, and the negative effect of large boards on firm performance is well researched, for both large and small firms (Yermack, 1996; Eisenberg et al., 1998). This adverse outcome is usually attributed to one of two possible problems that arise in decision making when groups grow in size. First, free-rider problems are more likely in larger boards and chief executive officers (CEOs) can more easily have their say without running into unified opposition (Jensen, 1993). Second, increasing coordination and communication problems are likely to hinder efficient decision making (e.g., Hambrick, Cho & Chen, 1996; Kogan & Wallach, 1966).

When it comes to the association between board size and volatility, there are far fewer studies to draw on. Theoretically, board size should have a negative relation with volatility, since the arguments above about the decision making process apply as well. Studies support the notion that decisions made by groups exhibit less variability and are less extreme. Individual errors and different abilities often impact the final decision, which ultimately constitutes a compromise (Sah & Stiglitz, 1986, 1991). Such middle-of-the-road outcomes are, by definition, unlikely to move the firm in a vastly different direction. The averaging out of individual preferences or attitudes toward a problem to be solved is also supported by studies from the field of social psychology (e.g., Kogan & Wallach, 1966; Moscovici & Zavalloni, 1969). Empirically, Cheng (2008) and Wang (2012) provide evidence that larger boards lead to a reduction in the variability of corporate performance.

The explanation put forth by Cheng (2008), that increasing communication and coordination problems lead to a reduction in volatility, gives the impression that larger boards are less able to function properly and that the reduced volatility is the result of less efficient decision making. If that were the case, one would expect firm value to suffer concurrently, which Cheng does not investigate. We call this the board inefficiency explanation.

An alternative explanation is based on the board's monitoring function. Managers often receive incentives that overly emphasize risk-inducing components (Dittmann & Maug, 2007). Lefebvre & Vieider (2013) show that, when the board monitors management in such a situation, it can reduce excessive risk taking and improve firm performance at the same time. Moreover, large groups can learn to work effectively and efficiently if they grow slowly over time (Weber, 2006). Thus, the reduced volatility could actually be indicative of a positive development.

Having more directors could increase the board's ability to properly monitor managers, especially in complex situations (e.g., Boone, Field, Karpoff & Raheja, 2007). Smaller boards should then lead to an increase in volatility, either because they facilitate quick and maybe even extreme decision making or because the monitoring function is adversely impacted. If large boards lead to a volatility reduction because they are better able to monitor, one would expect firm value to increase or at least to not decrease. We call this the monitoring explanation. Since both possible explanations predict that board size will be associated with lower stock return volatility, we expect larger (smaller) boards to be associated with lower (higher) volatility.

Separating the two explanations for lower volatility requires looking at firm value as well. If the monitoring explanation holds, it indicates a positive development for the firm that should be reflected in its value as well. Put differently, a large board would be beneficial because it strengthens monitoring capacity. In turn, the firm would avoid unnecessary risks, which manifests in lower volatility. At the same time, since the eschewed risks are those that would hurt the firm, the firm's value should increase or, at the very least, not go down. Conversely, if smaller boards are associated with higher volatility because of compromised monitoring capabilities, this should hurt firm value, which should thus either fall or not increase, since higher volatility at a stable value is detrimental to shareholders as well.

The inefficiency explanation, on the other hand, posits that the association between large boards and low volatility is the result of either coordination and communication or free-rider problems. If that were the case, it is clearly a negative situation for the firm, and one would expect firm value to suffer. Since this explanation implies that the board no longer works to its best possible ability, the firm's value should reflect the inefficiency and decrease along with the volatility. A stable firm value is not compatible with this explanation, because stable value with lower volatility is beneficial to the shareholders, and not likely the result of problems of the board. According to the board inefficiency explanation, smaller boards would thus be the preferred choice, and volatility should increase along with firm value.

2.2 The role of firm types in the association between board size and volatility

Prior literature suggests that the efficacy of board characteristics is contingent on the type of firm (e.g., Coles et al., 2008), and therefore the association between board size and risk could be similarly moderated. So far, no paper has investigated if the association between board size and stock return volatility depends on the type of firm. A few papers study the association between board size and firm value for different firm types, though with a particular focus on complex and R&D heavy firms (e.g., Coles et al., 2008).

Complex firms in particular require different types of expertise on the board, and, when these firms have larger boards, they perform better (Coles et al., 2008).[4] Complexity is typically characterized by firm size, multiple business segments, and operations in different industries, which requires more directors on the board to provide the necessary expertise. Only when that is the case can the board properly monitor management. That is, additional directors should increase the board's monitoring capacity, since complex firms are so varied that they need more monitors to cover all areas. Boone et al. (2007) refer to this as the scope

[4] A similar effect has also been documented for complex bank holding companies (Adams & Mehran, 2012).

of operation hypothesis, which states that, when firms have a greater need for specialized knowledge, their boards tend to grow.

To our knowledge, the only study that investigates the relation between board size and a dimension of risk in complex firms is that by Darrat, Gray, Park & Wu (2016). They show that such firms are less likely to end up in bankruptcy if they have larger boards. Based on their results and the insight that complex firms benefit from larger boards in terms of value, we expect board size to be associated with lower volatility. However, given that complex firms require more expertise, we expect that the effect will apply to larger board size categories than it does in non-complex firms.

Another firm type that we investigate is that of R&D-heavy firms, since they have a particularly strong monitoring need. R&D investments are typically long term and the outcome is highly uncertain (e.g., Baysinger, Kosnik & Turk, 1991). Although increased R&D expenditures are associated with increased firm value (Hall, Jaffe & Trajtenberg, 2005), markets often react slowly to them (Eberhart, Maxwell & Siddique, 2004). Therefore, it is easy for managers to cut R&D expenses for various opportunistic reasons, such as to stabilize stock prices (Chakravarty & Grewal, 2011) or inflate earnings (Bushee, 1998), without having to fear the consequences from either the shareholders or the market.

According to the monitoring hypothesis of Boone et al. (2007), firms will increase monitoring through, for instance, increased board size, when the benefits of additional monitoring outweigh the costs. Because managers have ample incentives to cut R&D expenses, there is clearly a greater need for monitoring in R&D-heavy firms. While this could also require a certain breadth of experience on the board (e.g., to monitor technical or accounting aspects of R&D investing), the situation is still different from that in complex firms, where more directors help cover more areas. Greater R&D investment does not necessarily become more diverse and, so, there could be a limit to the usefulness of an additional director after some point. Second, overly intense monitoring can lead to antagonistic behavior on the part of the executives (Adams & Ferreira, 2007).

Empirically, Guldiken & Darendeli (2016), who use the equity ownership of board members as a proxy for their monitoring activity, find the association between monitoring and R&D investments to have an inverted U shape. With our measure—board size—we expect to find moderate increases in board size to lead to a reduction in volatility, since the net benefits of monitoring will be positive. For very large boards, however, we expect no significant differences between R&D-heavy and other firms, since the net benefits are more likely to approach zero.

3 Data set and descriptive statistics

We construct our sample beginning with all firms covered in the Institutional Shareholder Services (ISS) database (formerly RiskMetrics), from which we collect all board data, as well as data on external governance. Our sample begins in 1996, when most director-related data became available, and it ends in 2015. Following the literature, we exclude financial institutions (Fama–French 49 industries 45–48) and all dual-class firms, since their corporate governance structure will likely differ too much for any meaningful comparison.[5]

We merge the data set with accounting and financial data from Compustat, and we obtain data on CEO ownership and tenure from ExecuComp. Daily stock returns are from the Center for Research in Security Prices (CRSP). Our main variable of interest is stock return volatility, which we measure in two ways. First, in most of our analyses, we focus on overall stock return volatility calculated as the annualized standard deviation of daily stock returns for every firm's fiscal year.[6]

Second, we calculate the idiosyncratic volatility of the residuals from the Fama–French three-factor model.[7] It is conceivable that overall volatility is driven to a large extent by influences outside managerial control, in which case the board structure could have only a small or no effect. Higher idiosyncratic volatility has also been shown to be a reliable predictor of future firm performance (e.g., Fu, 2009). Therefore, it could be more informative about managerial action and thus be of interest when we analyze the effects of board size on volatility.

Our board characteristic of interest is board size, which serves as the main independent variable in our analyses. However, unlike previous studies, we do not count the number of directors (or use its natural logarithm) to measure board size. Instead we define three categories based on the board size percentiles in our sample. We define the bottom 25% of all

[5] We revisit the this issue in the robustness checks.

[6] Daily stock returns are also used by, for example, Bernile et al. (2018) to calculate volatilities.

[7] We collect data for the model, including the risk-free rate, from Kenneth French's data library (http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html).

boards as small, the middle 50% as medium-sized boards, and the top 25% as large boards.[8] In doing so, we are better able to disentangle the effects of the different board size categories, which allows us to draw more detailed conclusions on how each of those categories is related to volatility, value, and performance and whether those effects differ for different kinds of firms. Moreover, unlike studies that use a board size counter variable, we are able to single out the specific effects of the extreme categories (small and large boards).

Besides board size, we control for several other board and CEO characteristics that we expect to be related to stock return volatility, such as board independence and CEO–chair duality. Since Cremers & Nair (2005) point out the importance of interactions between internal and external governance mechanisms, we also control for external governance by using the Entrenchment Index (E index) of Bebchuk, Cohen & Ferrell (2009). As firm controls, we include measures for firm size, book leverage, performance, cash holdings, R&D expenditures, and growth opportunities, which we measure as capital expenditures over sales. All of the inputs are obtained from Compustat. Additionally, we control for firm age, which affects certain risk-related policies (Faff, Kwok, Podolski & Wong, 2016), based on the date when the trading data first became available in the CRSP database. An overview of our variables, including definitions and databases, can be found in Table A.1 in the Appendix.

Table 1 provides summary statistics for the volatility measures, as well as for governance and firm characteristics.

[*Insert Table 1 about here.*]

For the 19,477 observations (2,229 firms) in our data set, it can be seen that the average volatility is 40.4% and that the idiosyncratic value is, expectedly, somewhat lower. Additionally, an upper quartile of 48.9% and a maximum of 224.1% already show that volatility is very high for some firms.

The mean (median) board size is 9.2 (9.0), which makes this variable comparable to that observed by, for instance, Cheng (2008). Further, we use the 25th percentile, which is eight directors, and the 75th percentile, which is 11, as the boundaries for our board size categories.

[8] We also define different categories in our robustness checks. The inferences remain the same.

We always sort firms that exhibit exactly these values into the lower category (i.e., firms with eight directors belong to the small board category). That is why the observations in the categories are not exactly equal to 25%, 50%, and 25%. Rather, 15.9% of all observations fall into the large board category, while 44.9% count as medium boards, and 39.2% are small boards.[9] This classification is in line with the work of Jensen (1993), who argues that problems start to set in when boards have more than eight directors.

On average, the firms in our sample have boards that are 73.5% comprised of independent directors, and in 57.7% of the firm–year observations, the CEO is also the chairperson. Moreover, it can be seen that several variables exhibit extreme values. Firm size, as measured by total assets, ranges from $16 million to $479.9 billion, with a mean (median) of $7.64 billion ($1.91 billion). Similar observations can be made for book leverage, the return on assets, cash holdings, R&D expenditures, and our measure for growth opportunities. To alleviate concerns about these extreme values impacting our results, we winsorize these variables at the 1% and 99% levels.

4 Empirical analysis

4.1 Board size and volatility

We start our empirical analysis by focusing on the overall effects for all firms, thus testing whether our expectation that larger boards are associated with lower stock return volatility can be supported empirically. We run the following regression:

$$
\begin{aligned}
Volatility_{i,t} = \;& \beta_0 + \beta_1\, Board\_Size\_Category_{i,t} + \beta_2\, Independence_{i,t} \\
& + \beta_3\, CEO\_Duality_{i,t} + \beta_4\, CEO\_Ownership_{i,t} \\
& + \beta_5\, Ln(1 + CEO\_Tenure)_{i,t} + \beta_6\, E\_Index_{i,t} \\
& + \beta_7\, Ln(Total\_Assets)_{i,t} + \beta_8\, Book\_Leverage_{i,t} + \beta_9\, ROA_{i,t} \\
& + \beta_{10} Cash\_Holdings_{i,t} + \beta_{11} R\&D\_Expenditures_{i,t} \\
& + \beta_{12}\, CAPEX/Sales_{i,t} + \beta_{13}\, Firm\_Age_{i,t} + \lambda_{j(i)} + \phi_t + \epsilon_{i,t}
\end{aligned}
\tag{1}
$$

[9] Of the two extreme board size categories, the small board category comprises a considerably larger number of observations. One reason for this is there are 2,973 firm–year observations (15.3% of our sample) with a board size of eight that lie directly on the threshold with the medium category. If we classify boards of eight directors as medium sized, our main results remain qualitatively the same, with some results showing even higher significance levels. We address this issue in Section 4.4.2 and show that the impact on our results is negligible.

where $Volatility_{i,t}$ is either overall or idiosyncratic stock return volatility, and $Board\_Size\_Category_{i,t}$ is one of three dummy variables indicating a small, medium, or large board. The rest of the variables are control variables, defined in the Appendix. We run the regression three times, that is, once with a dummy for small boards, once for medium boards, and once for large boards. The coefficients of those dummy variables then always indicate the average difference of the effect for firms in the respective board size category, compared to all other firms. Moreover, we include year fixed effects (ϕ_t) and run the regressions once with industry fixed effects and once with firm fixed effects ($\lambda_{j(i)}$). On the one hand, Zhou (2001) argues that industry fixed effects are preferable in corporate governance studies, because many characteristics, such as the E index, do not show much variation over time.[10] On the other hand, Himmelberg, Hubbard & Palia (1999) argue in favor of firm fixed effects. Throughout our analyses we mostly follow Cheng (2008) and Zhou (2001) and use industry fixed effects. Because of the collinearity with our board size variables and, more importantly, with our measures for firm complexity and R&D intensity, we refrain from using firm fixed effects for the second part of our analyses.

Table 2 illustrates the results of the estimations of the model from Equation (1). Using indicator variables for three different board size categories instead of the standard board size counter variable, we can confirm our initial supposition that larger boards are associated with lower volatility.

[*Insert Table 2 about here.*]

Panel A of Table 2 presents the results of our models in which the dependent variable is overall stock return volatility. In particular, the coefficient for small boards in Model (1) shows that, on average, firms with small boards exhibit stock return volatility that is 2.22% higher (p-value < 0.0001) than for firms with medium-sized or large boards. Firms with large boards, however, are associated with lower volatility (-1.41%, p-value $= 0.0003$) compared to firms with small or medium-sized boards, as can be seen in Model (3). The coefficients of Models (4) to (6) of Panel A illustrate that these results are largely confirmed when we control for firm instead of industry fixed effects. Panel B shows the results of the same

[10] Bernile et al. (2018), Cheng (2008), and others also use industry fixed effects.

regressions using idiosyncratic volatility as the dependent variable. It becomes apparent that the associations are virtually the same as for overall volatility, with only somewhat smaller coefficients. This finding holds for all of our further analyses, which is why we only report the results for overall volatility in the remainder of the paper.

Our first set of analyses thus confirms that the relation established in the literature—larger boards are associated with less volatility—hold for our sample period and for our way of measuring board size. However, to draw inferences on whether more or less volatility is beneficial or detrimental to the firm and its investors, we argue that corresponding effects on firm value and performance must also be considered. We focus on this relation in the next section.

4.2 Board size, firm value, and performance

As pointed out earlier, it is not a priori clear if higher or lower volatility is beneficial or not. For example, the result of reduced volatility associated with large boards could either harm investors, if caused by an inefficiently functioning board, or be to their advantage, if large boards provide for better monitoring. To tackle the question of whether the effect on volatility is beneficial or not, we next run the same regressions as in the previous section, but use measures for firm value (*Tobin's Q*) and firm performance (*ROA*) as the dependent variables.

The results of those estimations are presented in Table 3. As can be seen, none of our board category variables shows a coefficient that is statistically significant at any standard level, neither for *Tobin's Q* (Models (1)–(3)) nor for *ROA* (Models (4)–(6)).

[*Insert Table 3 about here.*]

Next, we go one step further and investigate whether the effects of board size on volatility, firm value, and performance are different for different types of firms.

4.3 Board size effect by firm type

Based on the studies of, for instance, Coles et al. (2008), who show that the effect of board size on firm value differs for different types of firms, we also perform our analyses for two different firm types, namely, complex and R&D-heavy ones. We expect the effect of board size to be different for those firms, compared to their non-complex or non–R&D-heavy counterparts, respectively, because they require broader expertise on the board or have a greater need for strong monitoring. Therefore, we first define complex and R&D-heavy firms and then perform our empirical tests for the effect on volatility, as well as on firm value and performance.

4.3.1 Defining complex and R&D-heavy firms

We follow Coles et al. (2008) in identifying complex and R&D-heavy firms. For the former, we perform principal components analysis (PCA) and consider the scope of operations, firm size, and financial leverage to be the three main dimensions that reflect a firm's complexity. We include in the PCA one proxy for each of the dimensions, namely, the number of business segments in different Fama–French 49 industries, the natural logarithm of sales, and book leverage. In doing so, we extract a common factor score that reflects a firm's complexity for each year in our sample. We then define the dummy variable *Complex* that takes the value of one if a firm–year observation has a factor score above the median, and zero otherwise.

To identify R&D-heavy firms, we first compute a firm's R&D intensity as the ratio of R&D expenditures to the book value of the firm's assets. We then define the dummy variable *R&D-Heavy*, which takes the value of one if a firm's R&D intensity is greater than the 75th percentile, and zero otherwise. About two-thirds of the observations that we sort into the non–R&D-heavy group do not have any R&D expenditures.[11]

Notably, complexity and R&D intensity appear to be very distinct firm traits, since they do not show much overlap throughout our sample. Of the 9,738 (4,869) firm–year observations for complex (R&D-heavy) firms, only 1,270 fall into both categories. We include both dummy variables in the following empirical analyses.

4.3.2 Board size and volatility by firm type

We start by analyzing whether the association of a certain board size with volatility differs between complex and R&D-heavy firms. As in the previous analysis, we include dummy variables for the three board size categories and estimate our model for each of the categories separately. Additionally, we include an interaction term between the respective board size

[11] A total of 14,607 observations (1,717 firms) have a R&D intensity that is below the 75th percentile. Of those, 9,929 observations (1,182 firms) are missing R&D expenditure data. In accordance with prior literature, we set those values to zero.

category and one of our two firm type dummies. This interaction term will show the additional effect of having a certain board size on volatility for complex or R&D-heavy firms, respectively. Accordingly, we run the following regression for each of the firm types:

$$\begin{aligned} Volatility_{i,t} = \quad & \beta_0 + \beta_1\, Board\_Size\_Category_{i,t} + \beta_2\, Firm\_Type_{i,t} \\ & + \beta_3\, Board\_Size\_Category_{i,t} \times Firm\_Type_{i,t} \\ & + \gamma\, Controls_{i,t} + \lambda_j + \phi_t + \epsilon_{i,t} \end{aligned} \tag{2}$$

where $Volatility_{i,t}$ is stock return volatility; $Board\_Size\_Category_{i,t}$ is one of three dummy variables indicating a small, medium, or large board; $Firm\_Type_{i,t}$ is one of the two dummy variables defined above to indicate complex or R&D-heavy firms; and $Controls_{i,t}$ is a vector of control variables. Because of collinearity with our firm type indicators, we do not always include the entire set of controls that we used in Equation (1) in the estimations by firm type. Throughout our analyses, we exclude $Ln(Total\_Assets)_{i,t}$ and $Leverage_{i,t}$ when we estimate the models for complex firms, and we do the same for $R\&D\_Expenditures_{i,t}$ when R&D-heavy firms are under investigation. Besides year fixed effects (ϕ_t), we now include only industry fixed effects (λ_j), since firm fixed effects are collinear with our firm type indicators.

Table 4 presents the results of our estimations. We are particularly interested in the coefficients of the interaction terms between the indicator variables for board size and the firm type dummy, since they illustrate whether boards of a certain size have different effects on volatility for complex firms (Models (1)–(3)) and R&D-heavy firms (Models (4)–(6)), compared to their non-complex and non–R&D-heavy counterparts, respectively.

[*Insert Table 4 about here.*]

The coefficient for small boards (3.42%, p-value < 0.0001) in Model (1) of Table 4 generally confirms the earlier finding for all firms, that firms with small boards are associated with higher stock return volatility than firms with medium-sized or large boards. There is no difference in the effect for complex firms, as can be seen from the coefficient of the interaction term, which does not show statistical significance. This changes when we look at Model (2), focusing on firms with a medium-sized board. In this category, we find that the effect on volatility is quite different for complex firms. While medium-sized boards are associated with lower volatility among non-complex firms (–2.30%, p-value < 0.0001), the coefficient on the interaction term is positive (1.98%, p-value $= 0.0004$), which means that complex firms with medium-sized boards have significantly higher volatility than non-complex firms in the same board category.

A similar observation can be made for the large board category. In Model (3) of Table 4, the interaction term also shows a positive coefficient (1.67%), although it is only weakly statistically significant at the 10% level. While we find support for the notion that larger boards lead to overall lower volatility here, complex firms experience statistically significantly higher volatility than their non-complex counterparts, even for large boards. It is possible that the need for broad expertise for complex firms is so great that only extremely large boards lead to a similar volatility reduction as for non-complex firms. We will address this issue in Section 4.4.1. Regardless, these results provide additional support for the monitoring explanation. If complex firms are indeed harder to govern, board inefficiencies should manifest in smaller boards, relative to those of non-complex firms. The fact that this is not observed—where medium boards lead to higher volatility in complex firms than in non-complex firms—suggests that this is not a communication or coordination inefficiency problem.

For the second firm type in our study, the results appear to be quite different. Model (4) of Table 4 illustrates that R&D-heavy firms with small boards show 1.55% (p-value < 0.05) higher volatility than their peers within the same board size category (1.86%, p-value $<$ 0.0001). In contrast to complex firms, the direction of the effect already changes for R&D-heavy firms with medium-sized boards (Model (5)). The highly significant negative coefficient of the interaction term (–2.11%, p-value $= 0.0034$) indicates that, for those firms, volatility is considerably lower than for their non–R&D-heavy counterparts in the same category, which only experience slightly lower volatility. For R&D-heavy firms, medium-sized boards are already associated with significantly lower volatility, whereas, in complex firms, a medium board size is associated with higher volatility. Hence, the risk reduction effect of larger boards seems to set in earlier for R&D-heavy firms than for complex ones. When looking at firms with large boards, we find that R&D-heavy firms do not experience a difference in volatility (Model (6)). This result is in line with those of Guldiken & Darendeli (2016), who use board ownership concentration as a proxy for monitoring and find that the benefits of monitoring form an inverse U shape. In other words, medium levels of monitoring have a positive effect, but too intense a level of monitoring can stymie the success of R&D investing, which we also find, and this result supports the notion that board size is a proxy for the board's monitoring capacity.

Overall, the results in this section highlight that the effect of board size is distinctly different between complex and R&D-heavy firms, that is, it sets in earlier for the latter. This finding provides some indication that different board sizes could be appropriate for different kinds of firms. However, as in the earlier analyses, we also must consider the effects on firm value and performance, to infer whether more or less volatility is beneficial or detrimental for those types of firms. We focus on that in the next section.

4.3.3 Board size, firm value, and performance by firm type

Similar to the approach used in the first set of analyses, we now run the regressions of the previous section again, but using the two measures of firm value and performance as the dependent variables.

[*Insert Table 5 about here.*]

Table 5 presents the estimation results for complex firms (Panel A) and R&D-heavy firms (Panel B). In Panel A, Models (1) and (2) again show nonsignificant results for the coefficients of the board dummies and the interaction terms, implying that neither complex nor non-complex firms are valued differently compared to firms within one of the other respective board categories. The coefficient for large boards in Model (3), however, is positive (0.0593) and statistically significant at the 5% level.[12] The nonsignificant coefficient on the interaction term suggests no difference in value between the two groups.

When we link those results to the observations made for volatility in Table 4, it appears that complex firms cannot benefit, even from large boards, as much as their non-complex counterparts. This finding is supported when we look at the association between board size and performance in Models (4) through (6). Complex firms experience significantly weaker operating performance than their non-complex counterparts when they have a small board.

[12] In Table 3, we already find a weak indication of such a relation, but of no convincing statistical significance.

For medium and large boards, there is no significant difference. Complex firms thus experience higher volatility, but no significant difference in valuation or performance for large boards. A possible explanation for this is that our category of large boards is still too wide to represent boards that have a sufficient number of directors to adequately monitor such firms. We address this in Section 4.4.1.

Panel B of Table 5 provides the results for R&D-heavy firms. The association between board size and value is not statistically different between R&D-heavy firms and their non–R&D-heavy counterparts. Notably, we do see significantly better operating performance for R&D-heavy firms with medium and large boards, since both interaction terms are highly significant. It appears the market has not picked up on the better performance, since the performance does not seem to be reflected in higher market valuation.

Taken together, R&D-heavy firms appear to benefit most from medium-sized boards. Volatility is significantly lower than for non–R&D-heavy firms, while operating performance is significantly higher and firm value is unaffected. Large boards, on the other hand, are also associated with a higher return on assets, but there is no longer any distinction between the two groups of firms. This finding supports the notion that medium-sized boards are best suited to carry out their monitoring tasks in R&D-heavy firms and reduce unnecessary risks. There appears to be no such effect for large boards.

4.4 Alternative specifications of board size categories

Although the board size categories are based on the empirical distribution of the number of directors, our way of defining the categories is a discretionary choice. Therefore, in this section, we provide additional analyses in which we apply alternative specifications. We first subdivide our board size measures and repeat our main analyses with the resulting six board size categories. We then show that alternative specifications of our three categories do not influence our inferences.

4.4.1 Subdividing board size categories

In Section 4.3, we show that complex firms (in sum) only experience lower volatility when the board is large, whereas R&D-heavy firms experience a similar situation when they have a medium-sized board. We submit that complex firms require a large number of directors to ensure well-functioning monitoring that prevents excessive risk, whereas, for R&D-heavy firms, fewer directors are necessary to obtain a similar effect.

However, against our expectations, complex firms with large boards still appear to be associated with higher volatility compared to their non-complex peers. It could be that, for complex firms, only very large boards provide adequate monitoring and that our large board category is still too wide to capture this effect. Thus, we further subdivide each of our three board size categories into two subcategories, so that we obtain the following six categories: *extra-small boards*, consisting of fewer than seven directors; *small boards*, of seven or eight directors; *medium-small boards*, of nine directors; *medium-large boards*, of 10 or 11 directors; *large boards*, of 12 or 13 directors; and *extra-large boards*, of more than 13 directors. We re-estimate Equation (1) for each of the six categories and each of our firm types.

[*Insert Table 6 about here.*]

The results presented in Table 6 generally support our earlier findings for complex and R&D-heavy firms. Additionally, they offer more detailed insights, especially for the extreme board categories. Complex firms (Panel A) show significantly higher volatility throughout Models (2) to (5), compared to their non-complex counterparts. For extra-large boards (Model (6)), complex firms do not exhibit higher volatility than non-complex ones; volatility is 4.38% lower than for firms with smaller boards. If reduced volatility is mainly associated with the reduction of excessive risk, then these results indicate the need for complex firms to have even extremely large boards with enough directors to cover all necessary areas of expertise.

As in the earlier analyses, the results for R&D-heavy firms in Panel B of Table 6 look quite different. While extra-small boards seem to considerably increase the risk associated with R&D-heavy firms (Model (1)), R&D-heavy firms already show somewhat lower volatility when they have a small board, compared to their non–R&D-heavy peers (Model 2). Hence, the volatility reduction effect already becomes apparent with rather small boards. R&D-heavy firms also show significantly lower volatility with medium boards (Models (3) and (4)), and even higher volatility in the case of an extra-large board (Model (6)). These results support our argument that R&D-heavy firms initially profit from the addition of directors to the board, but—unlike complex firms—when the board exceeds a certain size, it stops functioning properly, leading again to excessive risk.

4.4.2 Alternative specifications of the three board size categories

We now address the issue of defining the thresholds of the three board size categories used throughout most of our analyses. As mentioned above, our approach to measuring board size is based on the empirical distribution of the board size variable; however, using this criterion and sorting the observations that fall exactly on the thresholds (eight or 11 directors, respectively) into their respective lower categories are still discretionary choices. Therefore, we test how alternative specifications of the categories affect our results.[13]

First, we deviate from the categorization described in Section 3 by sorting observations with a board size of eight into the medium board category.[14] This makes the fractions of observations that fall into the two extreme categories more comparable, since 23.9 % of the observations are now defined as small boards, while 15.9 % are categorized as large boards. Even with this change, the main results of our analysis remain the same. If anything, they are more pronounced. Complex firms, for example, exhibit significantly higher volatility compared to non-complex firms when the board is small. Furthermore, complex firms have comparably lower value when they have a medium-sized board. Both results underline the advantages of large boards for those firms.

Second, we define the three board size categories via terciles of board size. Small boards then have fewer than nine directors, medium boards nine or 10, and large boards more than 10. Although numbers of observations in the categories are now comparable, having only boards with nine or 10 directors constituting the medium category seems to be a rather narrow definition. Regardless, the main results remain largely unchanged. Firms with large boards now show higher firm valuation, which supports our earlier argument as well. Only firms with large boards no longer show statistically significantly lower volatility (at the 10% level) in the firm fixed effects models. Overall, the exact specification of our size categories does not appear to drive our results.

[13] Any untabulated results in the remainder of the paper are available from the authors upon request.

[14] A total of 2,973 observations (15.3 % of the sample) fall directly on the threshold.

4.5 Periods of high market uncertainty

So far, our results seem to indicate that larger boards reduce unnecessary risk taking. This effect could be particularly useful to firms in periods of high overall market uncertainty, which we proxy via the Chicago Board Options Exchange Volatility Index (VIX). More specifically, we consider a year as highly volatile if the yearly average of the VIX is above its sample period median. We then interact that dummy with our board size categories both for all firms and for the two specific firm types. The results are presented in Table 7.

[*Insert Table 7 about here.*]

Columns (1) through (3) of Table 7 contain the results using all firms. It can be seen that the direction of the association is the same as in Table 2, but the effect is much stronger now. The increase for small boards is almost twice as high and the decrease for medium boards is almost 2.5 times greater. This result is in stark contrast to the results of Bernile et al. (2018). While they find that—similar to our result—board diversity generally reduces firm-level volatility, they also show that diversity exacerbates uncertainty at the firm level when the market itself is volatile. Board size, however, appears to offer a mechanism that is ideally suited to prevent excessive risk taking, especially in times when it should be avoided the most.

For complex firms, having a medium-sized board might not be enough to reduce stock return volatility in periods of high market volume. The triple interaction term in column (5) of Table 7 is significant at the 5% level, and it almost cancels out the value-reducing effect experienced by non-complex firms. Only when these firms have large boards is there no longer a volatility-increasing effect during high-VIX periods. We observe no significant effect for R&D-heavy firms with small boards in high-VIX periods, but those firms benefit from medium boards. As with our previous analysis, there are no added benefits to having a large board, even when markets are highly volatile. Again we find support for our initial assumption that the net benefits of larger boards approach zero more quickly for R&D-heavy firms than for other types (e.g., complex firms).

4.6 Possible channels affecting volatility

To shed light on the question of *how* the board possibly influences volatility, we follow the literature and examine several (financial) policies that directors can influence and which are related to firm risk. In particular, we consider as possible channels measures for R&D expenditures and acquisition expenses (both scaled by total assets), net market leverage—measured as the ratio of total debt to the market value of assets—and the natural logarithm of the number of business segments. Those measures are then used as the dependent variable when we re-estimate the models from Equation (1) or (2), respectively. The results of the estimations are presented in Table 8. For brevity, in Panels A and B we only focus on the two extreme board size categories, small and large boards. In Panel C, we report the medium category instead of the large one, because it showed a significant effect for R&D-heavy firms in the previous analyses.

[*Insert Table 8 about here.*]

The results of the estimations are presented in Table 8. Panel A shows the results for all firms without conditioning on specific firm types. In line with their comparably higher volatility, firms with small boards spend more on acquisitions (Model (3)) and are less diversified (Model (7)). Firms with large boards, however, spend less on acquisitions (Model (4)) and exhibit significantly lower market leverage (Model (6)).

Panel B of Table 8 illustrates that the higher volatility associated with small boards in complex firms is also likely to be induced by some of the financial policies. Complex firms with small boards tend to spend more on acquisitions (Model (3)) and rely more heavily on debt (Model (5)). Complex firms with large boards, on the other hand, spend less on acquisitions (Model (4)) while relying less on debt (Model (6)). The former also holds for non-complex firms. Surprisingly, the R&D expenditures of complex firms are significantly smaller when the firm has a small board (Model (1)), even though small boards are associated with considerably higher volatility.

Volatility effects also seem to be reflected in the financial policies of R&D-heavy firms, as can be seen in Panel C of Table 8. For those firms, higher volatility related to small boards seems to be driven by higher R&D expenditures (Model (1)), greater reliance on debt (Model (5)), and a less diversified portfolio of business segments (Model (7)). The reduced volatility in the cases of medium boards can potentially be attributed to lower R&D expenditures (Model (2)) and more diversification through a greater number of business segments (Model (8)).

In summary, this analysis provides evidence that the association we find between our board size categories and volatility is affected through the implementation of risk-related financial policies.

4.7 Further evidence of monitoring

To further support our finding that the volatility reduction associated with larger boards is due to better monitoring, we conduct additional tests, using measures that are more directly related to improved monitoring. They are CEO pay-for-performance sensitivity (PPS), earnings management, and stock price crash risk.

First, a well-functioning board should better align the interests of the managers with those of the shareholders, that is they should increase the PPS of the CEO's pay. We measure the PPS with *Delta*, according to Coles, Daniel & Naveen (2006).[15] Second, board monitoring should reduce earnings management leading to a more truthful reporting of firm performance (Peasnell, Pope & Young, 2005). Our proxy for earnings management is *Abnormal Accruals*, which we estimate using the modified-Jones (1991) model according to (Dechow, Sloan & Sweeney, 1995). Since the incentive to manage earnings upwards is particularly high if the firm is about to face a loss, we follow Peasnell et al. (2005) and also interact our board size categories with the dummy variable *Below*, which takes the value of one if pre-managed earnings are below zero.[16] The coefficient on this interaction is expected to be negative if monitoring works better. Third, effective board monitoring should prevent extremely negative outcomes, which is to say that stock price crashes should occur less frequently. We follow the approach of Andreou, Louca & Petrou (2017) to identify stock price crashes by using weekly returns to predict the firm-specific residuals of the same lead-lag market index model. A firm-year with a stock price crash is then identified by the dummy variable *Crash* that takes the value of one if at least one firm-specific weekly return is 3.2 standard deviations

[15] We thank Coles et al. (2006) for providing their data on delta and vega online.

[16] As in Peasnell et al. (2005), we use cash flows from operating activities as a proxy for pre-managed earnings.

lower than the average firm-specific weekly returns in that fiscal year (Andreou et al., 2017). Similar to the analysis illustrated in the previous section we take each of these measures as the dependent variable and re-estimate our models.

[*Insert Table 5 about here.*]

Table 5 illustrates the results of the estimations across all firms as well as for the two specific firm types. Across all firms (Panel A) the results highlight the adversely affected monitoring capacity of small boards. Firms with such appear to manage earnings more intensely—especially when their pre-managed earnings are low—and they experience stock price crashes more frequently. Firms with large boards do not exhibit this kind of behavior. In fact, they even seem to report earnings more truthfully when their performance is bad.

In line with our earlier findings, complex firms (Panel B) with medium boards provide lower PPS, that is lower deltas. Only with large boards, do complex firms offer the same performance incentives as non-complex firms.

Regarding earnings measurement, we find that firms with medium boards are associated with greater abnormal accruals, especially when pre-managed performance is negative, indicating that medium-sized boards might not be enough to provide adequate monitoring. While large boards cannot completely prevent earnings management in complex firms, they do lead to a reduction and in cases where the pre-managed earnings are negative there is no statistical differences anymore between complex and non-complex firms anymore. Finally, we see that stock price crash risk is significantly higher in complex firms with small boards than in non-complex ones. An increase to medium boards, however, leads to a statistically significant reduction in crash risk.

The results for R&D-heavy firms show that earnings management already appears to be reduced when they have a medium-sized board, underscoring the idea that the monitoring effect sets in earlier in those firms. We do not find any significant relationship with incentives provided through compensation or with stock price crash risk for R&D-heavy firms.

Overall, the results in this section provide support in favor of our monitoring explanation and this effect seems to be strongest in complex firms.

4.8 Robustness checks

Besides the alternative specifications of our board size categories, we perform further robustness checks in which we address endogeneity concerns and check the sensitivity of the results to some of our choices throughout our analyses. These tests, discussed in the following, generally confirm our main findings.

4.8.1 Endogeneity concerns

As in most empirical corporate finance studies, endogeneity concerns play a role when examining the relation between board size and stock return volatility. To the best of our knowledge, no generally accepted fully exogenous approach, such as a natural experiment, exists, but several attempts have been made to mitigate these concerns. We address the issue in the following ways.

First, we have included fixed effects throughout our analyses to control for unobserved factors in a firm's competitive environment that could influence both board size and volatility. Second, to address simultaneity concerns, we follow Coles et al. (2008) and replace the board categories by their one-period-lagged values and repeat the analyses. The results generally support our earlier findings. Moreover, complex firms no longer show a statistically significant difference in volatility when they have large boards. The same holds when we lag all governance and CEO variables by one year. Third, we also obtain similar results when—similar to Cheng (2008)—we replace the board category and remaining governance variables with their first values that appear in our data set. The significance levels are somewhat lower in this case, but the results still hold.

Fourth, we follow Wang (2012) and use greater lags of our potentially endogenous board size variables as instruments[17] and conduct two-stage least squares (2SLS) estimations.[18] In the first stage, we obtain the predicted values for each board category by using the second and

[17] Nakano & Nguyen (2012), who focus on Japanese firms, use the percentage of a firm's free float as an instrument for board size. However, when we do the same with our sample, the first-stage results show hardly any correlation between free float (collected from Datastream) and board size. Thus, it does not appear to be a good instrument in the U.S. setting.

[18] Reed (2015) suggests that the use of lagged values as instruments instead of simply replacing endogenous variables by their lagged values is preferable when dealing with a possible simultaneity bias.

third lags of these variables as instruments.[19] The predicted values from those estimations are then used in the second stage to re-estimate our main models.

To be valid instruments, our lagged variables must meet the relevance and the exclusion conditions. We do not face a weak instrument problem in any of our models, as suggested by the highly significant first-stage F-statistics of the excluded instruments reported in Table 10 and the highly significant coefficient estimates (untabulated) of the lagged board categories or the lagged interaction terms in the respective first-stage regressions. Hence, the relevance condition is met. The exclusion condition, however, cannot be tested directly. Ideally, we would find an instrument that affects volatility only through its effect on board size. From an economic perspective, whether the lagged values of the endogenous variables fully meet this criterion could be debatable.[20] Nevertheless, we follow the literature and consider this analysis one way of checking the robustness of our results. From an econometric point of view, a test of overidentifying restrictions can be used as an indirect test to verify instrument validity (Larcker & Rusticus, 2010). We provide the *p*-values of the Hansen J-statistic, which tests the joint null hypothesis that all instruments are valid. In none of our models can this null hypothesis be rejected.

[*Insert Table 10 about here.*]

Table 10 presents exemplary first-stage results (Panel A) and the second-stage results for the estimations by firm type (Panels B and C).[21] There are a few notable differences compared to the results in Table 4. Small boards seem to especially increase volatility in complex firms, whereas R&D-heavy firms with small boards do not show firm type-specific differentiation. Furthermore, just as in the tests discussed in this section so far, complex firms no longer exhibit a difference in volatility for large boards.

Fifth, we follow the methodology suggested by Wintoki et al. (2012) and re-estimate our models using the dynamic panel GMM estimator developed by Arellano & Bond (1991), Arellano

[19] In the same manner, the second and third lags of the board categories are each interacted with our firm type dummies to provide instruments for the interaction terms for the estimations by firm type. Panel A of Table 10 presents an example of the first-stage results for the case of complex firms with small boards. The further models are estimated accordingly.

[20] See, for example, the discussion of Roberts & Whited (2013).

[21] The results without firm type differentiation are not tabulated here, but they confirm the findings from the main analysis.

& Bover (1995), and Blundell & Bond (1998) that addresses both unobserved heterogeneity and simultaneity. This approach considers that the relation between board size and volatility could be dynamic, that is, board size not only could affect volatility but also could be a consequence of past volatility. The estimation procedure comprises a "stacked" system of equations that uses past values of the endogenous variables as instruments.

Similar to Wintoki et al. (2012), we address concerns with respect to the serial correlation of the transient errors and only include every other year in this analysis. We also assume all independent variables to be endogenous, except *Firm Age* and the fixed effects. We then augment our models by including the first lagged value of stock return volatility as an additional independent variable. The second lagged values of the independent variables are then utilized as instruments in the estimation procedure. Because of their stickiness, the board categories are instrumented by their third lagged values.

To verify the validity of the approach, we provide standard test statistics. With one exception throughout the models presented in Table 11, the null hypothesis of the Hansen test of overidentification cannot be rejected at the 10% level, which supports the validity of the instruments. Only in the case of R&D-heavy firms with medium boards would it be rejected at the 10% level. Furthermore, the test statistics show that second-order serial correlation is not an issue.

[*Insert Table 11 about here.*]

The results illustrated in Table 11 reveal the same patterns as in our main analyses. However, we no longer see a difference in volatility for R&D-heavy firms with medium boards. The coefficient of the interaction term is still negative, but not statistically significant at the 10% level. This could be due to the above-mentioned problem with instrument validity in this case. Moreover, complex firms again do not exhibit a difference in volatility when they have a large board. The remaining results are in line with our main analysis, but with higher coefficient estimates and somewhat lower statistical significance in some cases.

Overall, the tests in this section mitigate endogeneity concerns and confirm our earlier findings. The most notable differences from the results of the main analysis are that, for complex firms, large boards, and not only *very* large boards, already seem to be sufficient to obtain a similar reduction in volatility as in non-complex firms. This result appears consistently throughout all the tests presented in this section.

4.8.2 Additional sensitivity checks

To further support our results, we conduct the following additional tests. We re-estimate our models with dual-class firms, which we previously excluded. This leads to an increased sample size of 21,208 observations. There are only two notable differences with respect to the results: first, the coefficient for medium boards becomes negatively significant, while the coefficient for small boards becomes nonsignificant in the fixed effects models for all firms. Second, at the 10% significance level, firms with large boards are associated with higher market value, supporting our conjecture regarding the benefits large boards could provide. Thus, the inclusion of those firms further corroborates our findings.

Additionally, the risk taking incentives provided to the CEO have been shown to drive firm risk (Coles et al., 2006). Therefore, we rerun all of our analyses, but including the sensitivity of CEO wealth to stock return volatility (vega) as a further control variable.[22] Apart from a nonsignificant interaction term in the 2SLS model for complex firms with medium boards, the results remain virtually the same.

Moreover, we replace some of our variables with alternative proxies. For example, we include *Market Leverage*, which is measured as the ratio of total debt to the market value of assets, instead of *Book Leverage*, and we replace our measure for growth opportunities, *CAPEX/Sales*, through the ratio *Market-to-Book*. The results are essentially unchanged.

5 Conclusion

In the past, a number of studies on the board of directors have pointed out that larger boards have a negative effect on firm value and performance. Further examination revealed that the effects are different for different types of firms. With regard to stock return volatility, the insights are much more limited. So far, the only study to investigate the effects of board size on volatility is that of Cheng (2008), who shows that larger boards are associated with

[22] We thank Coles et al. (2006) for providing their data on vega online. However, since their data end in 2014—which would reduce our sample by about 2,000 observations—we decided to perform the analyses throughout the paper without vega and provide that analysis as a robustness check.

lower volatility and attributes this result to increasing problems in their communications and decision making process.

Our study is the first to investigate in more detail the effects of board size on stock return volatility. Based on the seminal work of Coles et al. (2008), we analyze the effects of board size on the volatility of complex and R&D-heavy firms. Moreover, we provide an alternative explanation, namely, that larger boards might be able to prevent excessive risk taking through better monitoring, which highlights the benefits large boards could provide.

To differentiate between the two opposing arguments, we investigate the effects on volatility in connection with the effect on firm value, contributing to understanding how board characteristics affect risk taking. We indeed find support for the monitoring explanation, since large boards are associated with lower volatility, but not with a negative effect on firm value.

Similar to studies focused on returns, we, too, can show that the results depend on the type of firm. While increases in board size reduce the volatility across all firms, as shown by Cheng (2008), complex firms experience economically significant reductions only for (very) large boards. This can be explained by the variety of expertise that is necessary to properly monitor the varied aspects of those firms. However, R&D-heavy firms already have reduced volatility, better operating performance, and stable firm value when they have medium-sized boards. The benefits of adding directors to the board disappear quickly for those firms, unlike for complex firms.

The findings presented in this paper are relevant to several interest groups. On the one hand, shareholders can gain a clearer understanding of what board size might be most appropriate for their firm. On the other hand, the results are relevant to investors focusing on low-volatility investing to identify appropriate stocks.

Appendix

Table A.1 Variable Definitions

Variable	Definition	Data Source
Stock Return Volatility Measures		
Volatility (%)	Annualized standard deviation of daily stock returns for a firm's fiscal year.	*CRSP*
Idiosyncratic Volatility (%)	Annualized standard deviation of daily residuals, obtained from estimations of the Fama–French three-factor model, for a firm's fiscal year. The factor model is estimated on a yearly basis using data from Kenneth R. French's data library (market return, risk-free rate, and risk factors), available at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.	*CRSP, French's data library*
Firm Value & Performance		
Tobin's Q (%)	Book value of assets less the book value of common equity plus the market value of equity divided by the book value of assets.	*Compustat*
ROA (%)	Return on assets. Net income divided by the book value of assets.	*Compustat*
Board Governance & CEO		
Small Board	Dummy variable equal to 1 if the number of directors on the board is between 3 and 8; 0 otherwise.	*ISS Directors*
Medium Board	Dummy variable equal to 1 if the number of directors on the board is between 9 and 11; 0 otherwise.	*ISS Directors*
Large Board	Dummy variable equal to 1 if the number of directors on the board is between 12 and 22; 0 otherwise.	*ISS Directors*
Independence (%)	Number of independent directors divided by the total number of directors on the board. Following the definitions of the ISS database, a director is determined to be independent if the director is not an employee or former executive of the company; does not have a significant transactional, professional, financial, or charitable relationship with the company; and is not a family member of a current employee of the company.	*ISS Directors*
CEO Duality	Dummy variable equal to 1 if the CEO is also the chair of the board; 0 otherwise.	*ISS Directors*
CEO Ownership (%)	Percentage of a company's shares owned by the CEO, excluding options.	*ExecuComp*
CEO Tenure	Years since the CEO took over office. In our models, we apply the natural logarithm of 1 plus the CEO's tenure.	*ExecuComp*
External Governance		
E Index	Entrenchment index of Bebchuk et al. (2009). This measure is calculated by adding one point for each of the following six governance provisions in place: a staggered board, limitations on bylaw or charter amendments, the requirement of a supermajority to approve a merger, golden parachutes, and poison pills. Therefore, this index can take values between zero and six.	*ISS Governance*
Further Controls and Channels		
Total Assets	Book value of assets. In our models, we apply the natural logarithm of total assets.	*Compustat*
Book Leverage (%)	Sum of long-term debt and current liabilities, divided by the book value of total assets.	*Compustat*
ROA (%)	*See above.*	*Compustat*
Cash Holdings (%)	Cash and short-term investments, divided by the book value of assets.	*Compustat*
R&D Expenditures (%)	R&D expenditures divided by the book value of assets.	*Compustat*
CAPEX/Sales (%)	Capital expenditures divided by net sales.	*Compustat*
Firm Age	Number of years since the first trade in CRSP, with 1925 being the earliest possible year.	*CRSP*
Acquisition Expenses (%)	Acquisition expenses divided by the book value of assets.	Compustat
Net Market Leverage (%)	Sum of long-term debt and current liabilities less cash holdings, divided by the sum of market equity and book debt.	
Business Segments	Number of business segments. In our models, we apply the natural logarithm of total assets.	Compustat

This table provides an overview of the different variables, their definitions, and their source.

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Table 1 Summary statistics

	Number of Observations	Mean	Standard Deviation	Minimum	25th Percentile	Median	75th Percentile	Maximum
Volatility Measures								
Volatility (%)	19477	40.375	20.199	7.317	26.481	35.546	48.925	224.052
Idiosyncratic Volatility (%)	19477	33.582	17.923	6.938	21.377	29.370	40.917	219.554
Firm Value & Performance								
Tobin's Q (%)	19477	195.875	133.075	40.403	120.742	155.667	220.870	2953.554
ROA (%)	19477	4.117	12.860	-458.310	2.085	5.074	8.765	87.199
Board Governance & CEO								
Board Size	19477	9.242	2.298	3.000	8.000	9.000	11.000	22.000
Small Board	19477	0.392	0.488	0.000	0.000	0.000	1.000	1.000
Medium Board	19477	0.449	0.497	0.000	0.000	0.000	1.000	1.000
Large Board	19477	0.159	0.365	0.000	0.000	0.000	0.000	1.000
Independence (%)	19477	73.476	15.488	0.000	66.667	77.778	85.714	100.000
CEO Duality	19477	0.577	0.494	0.000	0.000	1.000	1.000	1.000
CEO Tenure	19477	7.649	7.113	0.000	3.000	6.000	10.000	62.000
CEO Ownership (%)	19477	1.552	4.573	0.000	0.000	0.144	0.850	66.601
External Governance								
E Index	19477	3.093	1.430	0.000	2.000	3.000	4.000	6.000
Further Controls & Channels								
Total Assets	19477	7636.121	20130.756	16.767	712.887	1911.400	6061.880	479921.000
Book Leverage (%)	19477	23.296	18.137	0.000	8.521	22.857	34.552	292.514
ROA (%)	19477	4.117	12.860	-458.310	2.085	5.074	8.765	87.199
Cash Holdings (%)	19477	13.610	15.859	-0.161	2.225	7.321	19.436	94.988
R&D Expenditures (%)	19477	2.955	5.649	0.000	0.000	0.000	3.697	112.910
CAPEX/Sales (%)	19477	9.850	168.914	0.000	2.289	4.052	8.146	23398.992
Firm Age	19477	28.549	20.578	0.000	13.000	23.000	39.000	91.000
Acquisition Expenses (%)	19477	2.819	6.577	-17.398	0.000	0.000	2.259	79.176
Net Market Leverage (%)	19477	13.068	26.675	-490.286	-4.120	10.253	29.186	112.377
Business Segments	19477	2.456	1.747	1.000	1.000	2.000	3.000	15.000

This table shows summary statistics of the variables used throughout our analyses. The sample covers all firms in the ISS database from 1996 to 2015. Financial firms (Fama–French 49 industries 45–48) and dual-class firms are excluded. Data on daily stock returns, used to calculate stock return volatility and idiosyncratic volatility, are obtained from the CRSP. Idiosyncratic volatility is based on residuals from Fama–French three-factor model estimations. Our board size and independence variables, *CEO Duality* and *E Index*, are constructed using data from ISS. Data on CEOs and firm financials are from ExecuComp and Compustat, respectively, and *Firm Age* is the number of years since the first trade in the CRSP database. Detailed variable definitions can be found in Table A.1 in the Appendix.

Table 2 Board size and volatility

Panel A: Overall Volatility

	Industry Fixed Effects			Firm Fixed Effects		
	(1) Volatility	(2) Volatility	(3) Volatility	(4) Volatility	(5) Volatility	(6) Volatility
Small Board	2.2218***			1.1746***		
	(0.0000)			(0.0034)		
Medium Board		-0.9391***			-0.3994	
		(0.0007)			(0.1369)	
Large Board			-1.4060***			-0.6550*
			(0.0003)			(0.0621)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	No	No	No
Firm Fixed Effects	No	No	No	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.5808	0.5794	0.5794	0.5037	0.5032	0.5033

Panel B: Idiosyncratic Volatility

	Industry Fixed Effects			Firm Fixed Effects		
	(1) Idiosyncratic Volatility	(2) Idiosyncratic Volatility	(3) Idiosyncratic Volatility	(4) Idiosyncratic Volatility	(5) Idiosyncratic Volatility	(6) Idiosyncratic Volatility
Small Board	1.8877***			0.9466***		
	(0.0000)			(0.0050)		
Medium Board		-0.9049***			-0.3134	
		(0.0003)			(0.1720)	
Large Board			-0.9625***			-0.5464*
			(0.0063)			(0.0692)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	No	No	No
Firm Fixed Effects	No	No	No	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.5733	0.5721	0.5718	0.4656	0.4652	0.4653

This table presents the results of the regression on the relation between our three board size categories and (idiosyncratic) volatility, without conditioning on different types of firms. In both panels, Models (1) to (3) are estimated using industry and year fixed effects, while Models (4) to (6) include firm and year fixed effects. In Panels A and B, the dependent variable is stock return volatility and idiosyncratic volatility, respectively, based on residuals from Fama–French three-factor model estimations. *Small Board* is a dummy variable that is equal to one if the board size is between three and eight, *Medium Board* is a dummy variable that is equal to one if the board size is between nine and 11, and *Large Board* is a dummy variable that is equal to one if the board size is between 12 and 22. The controls include *Independence*, which is the fraction of independent directors on the board measured in percent, and *CEO Duality*, *CEO Ownership*, *Ln(1+CEO Tenure)*, *E Index*, *Ln(Total Assets)*, *Book Leverage*, *ROA*, *Cash Holdings*, *R&D Expenditures*, *CAPEX/Sales*, and *Firm Age*. Detailed variable definitions can be found in Table A.1 in the Appendix. The models also include a constant term. The p-values are based on clustered standard errors and are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 3 Effect on firm value and performance

	(1) Ln(Tobin's Q)	(2) Ln(Tobin's Q)	(3) Ln(Tobin's Q)	(4) ROA	(5) ROA	(6) ROA
Small Board	-0.0120			-0.1421		
	(0.2914)			(0.5363)		
Medium Board		-0.0004			0.1596	
		(0.9593)			(0.3659)	
Large Board			0.0196			-0.1260
			(0.1124)			(0.5749)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.4613	0.4612	0.4614	0.1783	0.1783	0.1782

This table presents the results of the regression on the relation between our three board size categories and firm value and performance, without conditioning on different types of firms. In Models (1) to (3), the dependent variable is the natural logarithm of *Tobin's Q*, and, in Models (4) to (6), *ROA* is regressed on our set of independent variables. The variable *Small Board* is a dummy variable that is equal to one if the board size is between three and eight, *Medium Board* is a dummy variable that is equal to one if the board size is between nine and 11, and *Large Board* is a dummy variable that is equal to one if the board size is between 12 and 22. The controls include *Independence*, which is the fraction of independent directors on the board measured in percent, and *CEO Duality*, *CEO Ownership*, *Ln(1+CEO Tenure)*, *E Index*, *Ln(Total Assets)*, *Book Leverage*, *ROA*, *Cash Holdings*, *R&D Expenditures*, *CAPEX/Sales*, and *Firm Age*. In Models (3) to (6), *ROA* is excluded from the set of controls. Detailed variable definitions can be found in Table A.1 in the Appendix. Industry and year fixed effects are included in all the models, as well as a constant term. The *p*-values are based on clustered standard errors and are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 4 Board size and volatility by firm type

	Complex Firms			R&D-Heavy Firms		
	(1) Volatility	(2) Volatility	(3) Volatility	(4) Volatility	(5) Volatility	(6) Volatility
Small Board	3.4195***			1.8622***		
	(0.0000)			(0.0000)		
Medium Board		-2.3048***			-0.4955*	
		(0.0000)			(0.0953)	
Large Board			-4.6783***			-1.4087***
			(0.0000)			(0.0007)
Small Board × *Firm Type*	0.8813			1.5495**		
	(0.1865)			(0.0436)		
Medium Board × *Firm Type*		1.9769***			-2.1128***	
		(0.0004)			(0.0034)	
Large Board × *Firm Type*			1.6726*			0.0185
			(0.0697)			(0.9835)
Firm Type	-3.1366***	-4.5139***	-3.3665***	1.8577***	3.4362***	2.6305***
	(0.0000)	(0.0000)	(0.0000)	(0.0047)	(0.0000)	(0.0000)
Independence	-0.0390***	-0.0426***	-0.0475***	-0.0338***	-0.0349***	-0.0380***
	(0.0023)	(0.0010)	(0.0002)	(0.0070)	(0.0058)	(0.0027)
CEO Duality	-0.3531	-0.3413	-0.3138	0.1768	0.2389	0.2520
	(0.2982)	(0.3197)	(0.3579)	(0.5970)	(0.4749)	(0.4509)
Ln(1+CEO Tenure)	-0.1853	-0.1242	-0.0440	-0.3301	-0.3089	-0.2460
	(0.3804)	(0.5599)	(0.8347)	(0.1140)	(0.1389)	(0.2365)
CEO Ownership	0.0166	0.0314	0.0280	-0.0288	-0.0252	-0.0263
	(0.6889)	(0.4531)	(0.4897)	(0.4657)	(0.5193)	(0.5014)
E Index	-0.4022***	-0.4626***	-0.4734***	-0.6451***	-0.6999***	-0.7141***
	(0.0062)	(0.0020)	(0.0013)	(0.0000)	(0.0000)	(0.0000)
Ln(Total Assets)				-2.4108***	-2.6485***	-2.5830***
				(0.0000)	(0.0000)	(0.0000)
Book Leverage				0.0482***	0.0486***	0.0464***
				(0.0001)	(0.0001)	(0.0002)
ROA	-0.7203***	-0.7294***	-0.7246***	-0.6742***	-0.6754***	-0.6785***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Cash Holdings	0.1452***	0.1514***	0.1537***	0.1343***	0.1387***	0.1426***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
R&D Expenditures	0.2132***	0.2123***	0.2266***			
	(0.0003)	(0.0004)	(0.0001)			
CAPEX/Sales	0.0939***	0.0951***	0.0978***	0.1119***	0.1150***	0.1156***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Firm Age	-0.0999***	-0.1151***	-0.1086***	-0.0698***	-0.0754***	-0.0739***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.5674	0.5627	0.5645	0.5812	0.5799	0.5794

This table presents the results of the regression on the relation between our three board size categories and volatility, distinguishing between complex and non-complex firms (Models (1) to (3)), as well as between R&D-heavy firms and their non–R&D-heavy counterparts (Models (4) to (6)). The dependent variable is stock return volatility. The variable *Firm Type* is either our *Complex* dummy, which is equal to one if the firm's complexity score, derived from PCA, is above the median, or our *R&D-Heavy* dummy, which is equal to one if the firm's ratio of R&D expenditures to assets is greater than the 75th percentile. The variable *Small Board* is a dummy variable that is equal to one if the board size is between three and eight, *Medium Board* is a dummy variable that is equal to one if the board size is between nine and 11, and *Large Board* is a dummy variable that is equal to one if the board size is between 12 and 22. Detailed variable definitions can be found in Table A.1 in the Appendix. Industry and year fixed effects are included in all the models, as well as a constant term. The p-values are based on clustered standard errors and are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 5 Effect on firm value and performance by firm type

Panel A: Complex Firms	(1) Ln(Tobin's Q)	(2) Ln(Tobin's Q)	(3) Ln(Tobin's Q)	(4) ROA	(5) ROA	(6) ROA
Small Board	-0.0187			-0.5999*		
	(0.2096)			(0.0532)		
Small Board × Complex	0.0137			-1.1849***		
	(0.4996)			(0.0085)		
Medium Board		0.0059			0.2497	
		(0.6692)			(0.4042)	
Medium Board × Complex		-0.0122			0.0429	
		(0.4641)			(0.9059)	
Large Board			0.0593**			1.3716***
			(0.0290)			(0.0034)
Large Board × Complex			-0.0466			-0.3116
			(0.1040)			(0.5442)
Complex	0.0150	0.0288*	0.0243**	-1.1013***	-1.3286***	-1.4076***
	(0.2408)	(0.0567)	(0.0461)	(0.0000)	(0.0001)	(0.0000)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.4613	0.4611	0.4615	0.1192	0.1163	0.1178

Panel B: R&D-Heavy Firms	(1) Ln(Tobin's Q)	(2) Ln(Tobin's Q)	(3) Ln(Tobin's Q)	(4) ROA	(5) ROA	(6) ROA
Small Board	-0.0043			0.5242**		
	(0.7369)			(0.0307)		
Small Board × R&D-Heavy	-0.0171			-2.9945***		
	(0.5041)			(0.0000)		
Medium Board		-0.0066			-0.0868	
		(0.4722)			(0.6165)	
Medium Board × R&D-Heavy		0.0138			1.5701***	
		(0.5578)			(0.0040)	
Large Board			0.0179			-0.7194***
			(0.1746)			(0.0018)
Large Board × R&D-Heavy			0.0220			3.6657***
			(0.5331)			(0.0000)
R&D-Heavy	0.1666***	0.1528***	0.1554***	-0.6026	-2.6816***	-2.4771***
	(0.0000)	(0.0000)	(0.0000)	(0.2859)	(0.0000)	(0.0000)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.4481	0.4480	0.4482	0.1494	0.1462	0.1474

This table presents the results of regression on the relation between our three board size categories and firm value and performance, distinguishing between complex and non-complex firms (Panel A), as well as between R&D-heavy ones and their non–R&D-heavy counterparts (Panel B). In both panels, the dependent variable of Models (1) to (3) is the natural logarithm of *Tobin's Q*, and, in Models (4) to (6), *ROA*. The variable *Complex* is a dummy that is equal to one if a firm's complexity score, derived from PCA, is above the median. The variable *R&D-Heavy* is a dummy that is equal to one if a firm's ratio of R&D expenditures to assets is greater than the 75th percentile. The variable *Small Board* is a dummy variable that is equal to one if the board size is between three and eight, *Medium Board* is a dummy variable that is equal to one if the board size is between nine and 11, and *Large Board* is a dummy variable that is equal to one if the board size is between 12 and 22. The controls include *Independence*, which is the fraction of independent directors on the board measured in percent, and *CEO Duality*, *CEO Ownership*, *Ln(1+CEO Tenure)*, *E Index*, *Ln(Total Assets)*, *Book Leverage*, *ROA*, *Cash Holdings*, *R&D Expenditures*, *CAPEX/Sales*, and *Firm Age*. In Models (3) to (6), *ROA* is excluded from the set of controls. Detailed variable definitions can be found in Table A.1 in the Appendix. Industry and year fixed effects are included in all the models, as well as a constant term. The *p*-values are based on clustered standard errors and are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 6 Six board size categories

Panel A: Complex Firms	(1) Volatility	(2) Volatility	(3) Volatility	(4) Volatility	(5) Volatility	(6) Volatility
Extra-Small Board	4.0657***					
	(0.0000)					
Extra-Small Board × Complex	1.9334					
	(0.1673)					
Small Board		0.8021*				
		(0.0529)				
Small Board × Complex		2.5529***				
		(0.0001)				
Medium-Small Board			-1.2233***			
			(0.0090)			
Medium-Small Board × Complex			1.7737***			
			(0.0035)			
Medium-Large Board				-2.3317***		
				(0.0000)		
Medium-Large Board × Complex				1.6271***		
				(0.0087)		
Large Board					-4.4661***	
					(0.0000)	
Large Board × Complex					2.2284**	
					(0.0158)	
Extra-Large Board						-4.3793*
						(0.0521)
Extra-Large Board × Complex						1.2126
						(0.5911)
Complex	-3.4475***	-4.1070***	-4.0414***	-3.9615***	-3.5779***	-3.5500***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.5651	0.5633	0.5616	0.5623	0.5632	0.5622

Panel B: R&D-Heavy Firms	(1) Volatility	(2) Volatility	(3) Volatility	(4) Volatility	(5) Volatility	(6) Volatility
Extra-Small Board	1.4906*					
	(0.0615)					
Extra-Small Board × R&D-Heavy	3.4401***					
	(0.0041)					
Small Board		1.1641***				
		(0.0021)				
Small Board × R&D-Heavy		-1.3149*				
		(0.0623)				
Medium-Small Board			-0.3086			
			(0.3641)			
Medium-Small Board × R&D-Heavy			-1.9893**			
			(0.0134)			
Medium-Large Board				-0.3441		
				(0.2552)		
Medium-Large Board × R&D-Heavy				-1.4330*		
				(0.0727)		
Large Board					-1.0891***	
					(0.0066)	
Large Board × R&D-Heavy					-0.7396	
					(0.4436)	
Extra-Large Board						-1.3875**
						(0.0436)
Extra-Large Board × R&D-Heavy						2.3296*
						(0.0608)
R&D-Heavy	2.1295***	3.0790***	2.9710***	2.9064***	2.6851***	2.5501***
	(0.0003)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.5812	0.5794	0.5794	0.5792	0.5793	0.5791

This table presents the results of the regression on the relation between board size and volatility when defining six board size categories, instead of three. Panels A and B illustrate the results for complex and R&D-heavy firms, respectively. The dependent variable is stock return volatility. The term *Extra-Small Board* is a dummy variable that is equal to one if the board size is smaller than seven, *Small Board* is a dummy variable that is equal to one if the board size is seven or eight, *Medium-Small Board* is a dummy variable that is equal to one if the board size is nine, *Medium-Large Board* is a dummy variable that is equal to one if the board size is 10 or 11, *Large Board* is a dummy variable that is equal to one if the board size is 12 or 13, and *Extra-Large Board* is a dummy variable that is equal to one if the board size is larger than 13. Controls as well as industry and year fixed effects are included, as in earlier analyses. Detailed variable definitions can be found in Table A.1 in the Appendix. The models also include a constant term. The p-values are based on clustered standard errors and are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 7 Effect in periods of high market uncertainty

	All Firms			Complex Firms			R&D-Heavy Firms		
	(1) Volatility	(2) Volatility	(3) Volatility	(4) Volatility	(5) Volatility	(6) Volatility	(7) Volatility	(8) Volatility	(9) Volatility
Small Board	0.0740			1.6591***			0.1003		
	(0.8254)			(0.0002)			(0.7795)		
Small Board × *Firm Type*				0.5800			0.9839		
				(0.3570)			(0.1372)		
Small Board × High VIX	4.3470***			3.4973***			3.6029***		
	(0.0000)			(0.0000)			(0.0000)		
Small Board × *Firm Type* × High VIX				0.8108			0.9202		
				(0.4304)			(0.3781)		
Medium Board		0.3161			-0.8175*			0.3501	
		(0.2275)			(0.0632)			(0.2185)	
Medium Board × *Firm Type*					0.8165			-1.0759*	
					(0.1306)			(0.0825)	
Medium Board × High VIX		-2.5336***			-2.9207***			-1.7839***	
		(0.0000)			(0.0000)			(0.0002)	
Medium Board × *Firm Type* × High VIX					2.1528**			-1.7500*	
					(0.0127)			(0.0929)	
Large Board			0.1377			-3.2495***			-0.1832
			(0.7010)			(0.0000)			(0.6347)
Large Board × *Firm Type*						1.3734			0.6812
						(0.1106)			(0.4008)
Large Board × High VIX			-2.9035***			-2.7251**			-2.2337***
			(0.0000)			(0.0300)			(0.0001)
Large Board × *Firm Type* × High VIX						0.6964			-1.4825
						(0.6071)			(0.2416)
Firm Type × High VIX				-1.1502**	-2.9925***	-1.9320***	2.6439***	4.3069***	3.9971***
				(0.0380)	(0.0000)	(0.0001)	(0.0001)	(0.0000)	(0.0000)
Firm Type				-2.6023***	-2.9906***	-2.4348***	0.6360	1.2346*	0.6836
				(0.0000)	(0.0000)	(0.0000)	(0.2904)	(0.0593)	(0.2530)
High VIX	4.2573***	7.1388***	6.4903***	5.0993***	8.2214***	7.3304***	3.6718***	5.7740***	5.3374***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.5859	0.5827	0.5824	0.5724	0.5665	0.5680	0.5874	0.5848	0.5841

This table presents the results of an analysis set up to examine the effect of our three board size categories on volatility in periods of high market uncertainty. Models (1) to (3) illustrate the results for all firm, and Models (4) to (6) ((7)–(9)) focus on complex (R&D-heavy) ones. The dependent variable is stock return volatility. The variable *High VIX* is a dummy variable that is equal to one in a specific year if the average VIX in that year exceeds its median in our sample period. The variable *Firm Type* is either our *Complex* dummy, which is equal to one if a firm's complexity score, derived from PCA, is above the median, or our *R&D-Heavy* dummy, which is equal to one if a firm's ratio of R&D expenditures to assets is greater than the 75th percentile. The variable *Small Board* is a dummy variable that is equal to one if the board size is between three and eight, *Medium Board* is a dummy variable that is equal to one if the board size is between nine and 11, and *Large Board* is a dummy variable that is equal to one if the board size is between 12 and 22. Detailed variable definitions can be found in Table A.1 in the Appendix. Industry and year fixed effects are included in all the models, as well as a constant term. The *p*-values are based on clustered standard errors and are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 8 Channels

	(1) R&D Expenditures	(2) R&D Expenditures	(3) Acquisition Expenses	(4) Acquisition Expenses	(5) Net Market Leverage	(6) Net Market Leverage	(7) Ln(Business Segments)	(8) Ln(Business Segments)
Panel A: All Firms								
Small Board	0.1521		0.5342***		0.3924		-0.0369*	
	(0.1527)		(0.0000)		(0.4553)		(0.0850)	
Large Board		0.1676		-0.4095***		-2.0546***		-0.0122
		(0.1014)		(0.0008)		(0.0012)		(0.6540)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.5889	0.5888	0.0887	0.0879	0.6323	0.6330	0.2132	0.2127
Panel B: Complex Firms	(1) R&D Expenditures	(2) R&D Expenditures	(3) Acquisition Expenses	(4) Acquisition Expenses	(5) Net Market Leverage	(6) Net Market Leverage	(7) Ln(Business Segments)	(8) Ln(Business Segments)
Small Board	0.3682**		0.4569***		-1.0598*		-0.0261	
	(0.0126)		(0.0016)		(0.0501)		(0.3002)	
Small Board × Complex	-0.5325***		0.5481**		4.3922***		0.0213	
	(0.0033)		(0.0224)		(0.0000)		(0.5708)	
Large Board		-0.1314		-0.8033***		0.4316		-0.0464
		(0.5306)		(0.0007)		(0.6453)		(0.3362)
Large Board × Complex		0.3633		0.1989		-2.9615***		0.0349
		(0.1088)		(0.4662)		(0.0085)		(0.5243)
Complex	-0.3057**	-0.5866***	0.3120**	0.4248***	11.8070***	13.7603***	0.3427***	0.3533***
	(0.0100)	(0.0000)	(0.0278)	(0.0019)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.5874	0.5869	0.0790	0.0777	0.6655	0.6649	0.2498	0.2497
Panel C: R&D-Heavy Firms	(1) R&D Expenditures	(2) R&D Expenditures	(3) Acquisition Expenses	(4) Acquisition Expenses	(5) Net Market Leverage	(6) Net Market Leverage	(7) Ln(Business Segments)	(8) Ln(Business Segments)
Small Board	-0.3229***		0.6061***		-0.1631		-0.0032	
	(0.0000)		(0.0000)		(0.7926)		(0.8956)	
Small Board × R&D-Heavy	1.8714***		-0.2702		1.9070**		-0.1353***	
	(0.0000)		(0.2972)		(0.0415)		(0.0036)	
Medium Board		0.1347***		-0.2574**		0.9920**		0.0080
		(0.0001)		(0.0169)		(0.0381)		(0.6677)
Medium Board × R&D-Heavy		-1.2372***		0.2742		-1.2374		0.1123***
		(0.0000)		(0.2628)		(0.1334)		(0.0065)
R&D-Heavy	6.0138***	7.4116***	0.1850	-0.0594	-6.1287***	-4.6933***	0.0802*	-0.0297
	(0.0000)	(0.0000)	(0.4468)	(0.8023)	(0.0000)	(0.0000)	(0.0874)	(0.4664)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	19,477	19,477	19,477	19,477	19,477	19,477	19,477	19,477
Adj. R-Squared	0.7578	0.7543	0.0887	0.0876	0.6326	0.6326	0.2146	0.2141

This table presents the results of the regression on the relation between our board size categories and possible channels through which board size could affect stock return volatility. For brevity, we only report the coefficients for the two extreme categories in Panels A and B, and those for firms with small and medium boards in Panel C. Panel A comprises the results across all firms, while Panel B (C) differentiates between complex (R&D-heavy) firms and non-complex (non–R&D-heavy) ones. In each of the three panels, Models (1) and (2) focus on the channel of R&D expenditures, Models (3) and (4) on acquisition expenses, Models (5) and (6) on net market leverage, and Models (7) and (8) on the natural logarithm of the number of business segments. The variable *Complex* is a dummy that is equal to one if a firm's complexity score, derived from PCA, is above the median. The variable *R&D-Heavy* is a dummy that is equal to one if a firm's ratio of R&D expenditures to assets is greater than the 75th percentile. The variable *Small Board* is a dummy variable that is equal to one if the board size is between three and eight, and *Large Board* is a dummy variable that is equal to one if the board size is between 12 and 22. The controls are the same as in earlier analyses. Highly collinear control variables or controls that are used as the dependent variable are excluded when necessary. Detailed variable definitions can be found in Table A.1 in the Appendix. Industry and year fixed effects are included in all the models, as well as a constant term. The *p*-values are based on clustered standard errors and are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 9 Further evidence of monitoring

Panel A: All Firms	Delta			Abnormal Accruals						Stock Price Crash Risk		
	(1) Delta	(2) Delta	(3) Delta	(4) Abnormal Accruals	(5) Abnormal Accruals	(6) Abnormal Accruals	(7) Abnormal Accruals	(8) Abnormal Accruals	(9) Abnormal Accruals	(10) Crash	(11) Crash	(12) Crash
Small Board	71.3548			0.2837*			0.1728			0.0765*		
	(0.9011)			(0.0948)			(0.3069)			(0.0916)		
Small Board × Below							0.9903*					
							(0.0707)					
Medium Board		160.6283			-0.1469			-0.0888			-0.0628	
		(0.5377)			(0.2431)			(0.4759)			(0.1088)	
Medium Board × Below								-0.3351				
								(0.5364)				
Large Board			-451.5900			-0.1203			-0.0566			0.0131
			(0.3991)			(0.4489)			(0.7145)			(0.8268)
Large Board × Below									-2.4006***			
									(0.0049)			
Below							9.1639***	9.8206***	9.8989***			
							(0.0000)	(0.0000)	(0.0000)			
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	17,185	17,185	17,185	19,181	19,181	19,181	19,181	19,181	19,181	19,477	19,477	19,477
Adj. (Pseudo) R-Squared	0.0480	0.0481	0.0482	0.2054	0.2053	0.2052	0.2787	0.2784	0.2788	0.0304	0.0304	0.0302

(Continued)

Table 9 Continued

Panel B: Complex Firms	(1) Delta	(2) Delta	(3) Delta	(4) Abnormal Accruals	(5) Abnormal Accruals	(6) Abnormal Accruals	(7) Abnormal Accruals	(8) Abnormal Accruals	(9) Abnormal Accruals	(10) Crash	(11) Crash	(12) Crash
Small Board	-1321.6588			0.8898***			0.6408***			0.0346		
	(0.1241)			(0.0000)			(0.0017)			(0.5365)		
Small Board × Complex	1133.0626			-0.9055***			-0.7831**			0.1934**		
	(0.2185)			(0.0038)			(0.0106)			(0.0186)		
Small Board × Below							1.1861					
							(0.1254)					
Small Board × Complex × Below							-1.1147					
							(0.3610)					
Medium Board		1173.5537			-0.6910***			-0.4641**			-0.0084	
		(0.1315)			(0.0005)			(0.0177)			(0.8802)	
Medium Board × Complex		-1571.6751*			0.9413***			0.6373***			-0.1271*	
		(0.0803)			(0.0001)			(0.0072)			(0.0945)	
Medium Board × Below								-1.2525				
								(0.1154)				
Medium Board × Complex × Below								2.4940**				
								(0.0254)				
Large Board			746.4697*			-0.9823***			-0.8426**			-0.0982
			(0.0745)			(0.0042)			(0.0143)			(0.4070)
Large Board × Complex			-104.2871			0.6777*			0.7324**			0.0807
			(0.8549)			(0.0643)			(0.0467)			(0.5448)
Large Board × Below									-0.6227			
									(0.7711)			
Large Board × Complex × Below									-1.9001			
									(0.4058)			
Complex × Below							0.0092	-1.8262**	-0.5392			
							(0.9908)	(0.0175)	(0.3689)			
Below							9.2879***	10.4733***	10.2099***			
							(0.0000)	(0.0000)	(0.0000)			
Complex	1533.9674**	2853.6939*	2039.8776**	0.4605***	-0.4154*	0.0195	0.4343**	-0.2056	0.0558	-0.1736***	-0.0596	-0.1297***
	(0.0335)	(0.0503)	(0.0458)	(0.0081)	(0.0587)	(0.9131)	(0.0118)	(0.3267)	(0.7460)	(0.0021)	(0.3010)	(0.0049)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	17,185	17,185	17,185	19,181	19,181	19,181	19,181	19,181	19,181	19,477	19,477	19,477
Adj. (Pseudo) R-Squared	0.0348	0.0346	0.0338	0.2035	0.2030	0.2024	0.2785	0.2783	0.2780	0.0303	0.0300	0.0297

(Continued)

Table 9 Continued

Panel C: R&D-Heavy Firms	(1) Delta	(2) Delta	(3) Delta	(4) Abnormal Accruals	(5) Abnormal Accruals	(6) Abnormal Accruals	(7) Abnormal Accruals	(8) Abnormal Accruals	(9) Abnormal Accruals	(10) Crash	(11) Crash	(12) Crash
Small Board	461.8486			-0.1538			-0.1484			0.0670		
	(0.1682)			(0.4036)			(0.4233)			(0.1895)		
Small Board × R&D-Heavy	-1546.0720			1.6746***			1.2836***			0.0365		
	(0.4856)			(0.0000)			(0.0003)			(0.6802)		
Small Board × Below							0.1251					
							(0.8600)					
Small Board × R&D-Heavy × Below							1.2171					
							(0.3031)					
Medium Board		88.3292			0.1485			0.1218			-0.0541	
		(0.4522)			(0.2608)			(0.3570)			(0.2149)	
Medium Board × R&D-Heavy		365.8843			-1.2966***			-0.9638***			-0.0386	
		(0.7107)			(0.0001)			(0.0033)			(0.6719)	
Medium Board × Below								0.6885				
								(0.2909)				
Medium Board × R&D-Heavy × Below								-1.8382				
								(0.1238)				
Large Board			-852.4273			0.0407			0.0497			0.0138
			(0.1778)			(0.8050)			(0.7573)			(0.8237)
Large Board × R&D-Heavy			2707.6790			-1.1285**			-0.8497*			-0.0057
			(0.4415)			(0.0149)			(0.0603)			(0.9718)
Large Board × Below									-1.8830**			
									(0.0429)			
Large Board × R&D-Heavy × Below									-1.6103			
									(0.4592)			
R&D-Heavy × Below							-0.5602	1.0750	0.4144			
							(0.5568)	(0.1537)	(0.5304)			
Below							9.3475***	9.0469***	9.6014***			
							(0.0000)	(0.0000)	(0.0000)			
R&D-Heavy	1632.0511	737.8223	562.6743	-1.6184***	-0.2870	-0.6792**	-1.6257***	-0.6305**	-0.9190***	-0.0538	-0.0213	-0.0366
	(0.3240)	(0.1279)	(0.1115)	(0.0000)	(0.3706)	(0.0238)	(0.0000)	(0.0493)	(0.0024)	(0.4983)	(0.7745)	(0.5849)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample Size	17,185	17,185	17,185	19,181	19,181	19,181	19,181	19,181	19,181	19,477	19,477	19,477
Adj. (Pseudo) R-Squared	0.0491	0.0485	0.0494	0.2080	0.2070	0.2060	0.2794	0.2788	0.2783	0.0304	0.0304	0.0302

This table presents the results of the regression on the relation between our board size categories and proxies for monitoring. Panel A comprises the results across all firms, while Panel B (C) differentiates between complex (R&D-heavy) firms and non-complex (non–R&D-heavy) ones. In each of the three panels, Models (1) to (3) focus on CEO pay-performance sensitivity as in Coles et al. (2006), Models (4) to (9) on earnings management, while (7) to (9) also consider whether pre-managed earnings are below zero, and Models (10) to (12) on stock price crash risk. The variable *Complex* is a dummy that is equal to one if a firm's complexity score, derived from PCA, is above the median. The variable *R&D-Heavy* is a dummy that is equal to one if a firm's ratio of R&D expenditures to assets is greater than the 75th percentile. The variable *Small Board* is a dummy variable that is equal to one if the board size is between three and eight, and *Large Board* is a dummy variable that is equal to one if the board size is between 12 and 22. The controls are the same as in earlier analyses. Highly collinear control variables are excluded when necessary. Detailed variable definitions can be found in Table A.1 in the Appendix. Industry and year fixed effects are included in all the models, as well as a constant term. Models (10) to (12) are estimated using logit regressions. The *p*-values are based on clustered standard errors and are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 10 2SLS estimations

Panel A: First-Stage Results (Example)

	(1) Small Board	(2) Small Board x Complex
L2.Small Board	0.4595***	-0.0067***
	(0.0000)	(0.0000)
L3.Small Board	0.2114***	-0.0089***
	(0.0000)	(0.0000)
L2.Small Board × Complex	-0.0814***	0.3927***
	(0.0016)	(0.0000)
L3.Small Board × Complex	0.0199	0.2484***
	(0.4192)	(0.0000)
Complex	-0.0651***	0.0704***
	(0.0000)	(0.0000)
Controls	Yes	Yes
Year Fixed Effects	Yes	Yes
Industry Fixed Effects	Yes	Yes
Sample Size	13,475	13,475
Adj. R-Squared	0.5199	0.4490

Panel B: Second Stage (Complex Firms)

	(1) Volatility	(2) Volatility	(3) Volatility
Small Board	3.8447***		
	(0.0000)		
Small Board × Complex	3.8456***		
	(0.0021)		
Medium Board		-2.4510**	
		(0.0110)	
Medium Board × Complex		2.2685*	
		(0.0912)	
Large Board			-7.6865***
			(0.0000)
Large Board × Complex			1.2815
			(0.5114)
Complex	-3.4098***	-4.3575***	-2.5227***
	(0.0000)	(0.0000)	(0.0000)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	13,475	13,475	13,475
Adj. R-Squared	0.5566	0.5541	0.5538
1st-Stage F-Test (*p*-value)	0.0000	0.0000	0.0000
Hansen J-Statistic (p-value)	0.4863	0.5364	0.2192

Panel C: Second Stage (R&D-Heavy Firms)

	(1) Volatility	(2) Volatility	(3) Volatility
Small Board	2.7766***		
	(0.0003)		
Small Board × R&D-Heavy	1.9248		
	(0.1223)		
Medium Board		-0.1129	
		(0.8806)	
Medium Board × R&D-Heavy		-4.1503***	
		(0.0088)	
Large Board			-3.4708***
			(0.0002)
Large Board × R&D-Heavy			0.8551
			(0.6382)
R&D-Heavy	1.5846**	4.2583***	2.3732***
	(0.0443)	(0.0000)	(0.0011)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	13,475	13,475	13,475
Adj. R-Squared	0.5735	0.5732	0.5727
1st Stage F-Test (p-value)	0.0000	0.0000	0.0000
Hansen J-Statistic (p-value)	0.1008	0.2339	0.3811

This table presents the results of the regression for the 2SLS estimations using the second and third lags of the board categories as instruments. Panel A presents exemplary first-stage results for the case of complex firms with small boards, while the second-stage results for complex (R&D-heavy) firms are illustrated in Panel B (C). The second-stage models are the same as in earlier analysis, except the board categories and the interaction terms are based on their predicted values. Detailed variable definitions can be found in Table A.1 in the Appendix. Industry and year fixed effects are included in all the models, as well as a constant term. The *p*-values are based on clustered standard errors and are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 11 Dynamic GMM estimations

Panel A: All Firms	(1) Volatility	(2) Volatility	(3) Volatility
Small Board	17.7847**		
	(0.0190)		
Medium Board		-5.9813	
		(0.2120)	
Large Board			-15.9427**
			(0.0395)
L.Volatility	0.2982***	0.2970***	0.2844***
	(0.0000)	(0.0000)	(0.0000)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	7,474	7,474	7,474
Wald χ^2 Statistic	4961.57	5719.81	36442.50
Number of Instruments	80	80	80
AR(1) p-value	0.0000	0.0000	0.0000
AR(2) p-value	0.5625	0.7940	0.5024
Hansen J-Statistic (p-value)	0.3308	0.1710	0.2465

Panel B: Complex Firms	(1) Volatility	(2) Volatility	(3) Volatility
Small Board	19.4317***		
	(0.0090)		
Small Board × Complex	-14.7165		
	(0.2643)		
Medium Board		-18.0978***	
		(0.0080)	
Medium Board × Complex		21.7284***	
		(0.0081)	
Large Board			-17.5692**
			(0.0416)
Large Board × Complex			5.0511
			(0.6614)
Complex	5.8991	-11.8609**	-2.2887
	(0.3738)	(0.0214)	(0.4405)
L.Volatility	0.2874***	0.2829***	0.2730***
	(0.0000)	(0.0000)	(0.0000)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	7,474	7,474	7,474
Wald χ^2 Statistic	35059.40	31887.12	39455.05
Number of Instruments	80	80	80
AR(1) p-value	0.0000	0.0000	0.0000
AR(2) p-value	0.4006	0.5637	0.4760
Hansen J-Statistic (p-value)	0.1479	0.2668	0.3767

Panel C: R&D-Heavy Firms	(1) Volatility	(2) Volatility	(3) Volatility
Small Board	15.2926*		
	(0.0665)		
Small Board × R&D-Heavy	9.3046		
	(0.3910)		
Medium Board		-2.7976	
		(0.5909)	
Medium Board × R&D-Heavy		-17.4007	
		(0.1524)	
Large Board			-17.0041*
			(0.0582)
Large Board × R&D-Heavy			-18.6604
			(0.5164)
R&D-Heavy	1.0898	13.1870	7.4952
	(0.8692)	(0.1716)	(0.3934)
L.Volatility	0.3002***	0.3016***	0.2855***
	(0.0000)	(0.0000)	(0.0000)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	7,474	7,474	7,474
Wald χ^2 Statistic	5578.89	38065.97	39297.75
Number of Instruments	82	82	82
AR(1) p-value	0.0000	0.0000	0.0000
AR(2) p-value	0.4835	0.7425	0.3446
Hansen J-Statistic (p-value)	0.1979	0.0805	0.1872

This table presents the results of the regression for the estimations using the dynamic panel GMM estimator developed by Arellano & Bond (1991), Arellano & Bover (1995), and Blundell & Bond (1998). This analysis uses only the even years of the original sample. Panel A comprises the results across all firms, while Panel B (C) differentiates between complex (R&D-heavy) firms and non-complex (non–R&D-heavy) ones. Besides the respective board categories, the firm type dummies, and the relevant control variables, the models include the first lag of stock return volatility as a dependent variable. Detailed variable definitions can be found in Table A.1 in the Appendix. Industry and year fixed effects are included in all the models, as well as a constant term. The estimations are performed using Stata's *xtabond2* module, where we employ the *collapse* and *robust* options. The *p*-values are reported in parentheses, with *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.