Board Size, Firm Type, and Stock Return Volatility[¶]

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Abstract

We document a negative and robust association between board size and firm risk, which is amplified in high-growth but not in complex firms. Contrary to prior literature, our evidence suggests that board size affects risk for different reasons. Across all firms and for complex ones, we find evidence of better monitoring when boards become larger, which suggests they prevent unnecessary risks. In high-growth firms, however, the evidence points towards inefficiencies of large boards reducing the volatility. Overall, this supports the notion that different firm types benefit from different board structures with regard to firm risk.

JEL classification: G32, G34, M12

Keywords: Board size, volatility, firm types, monitoring, inefficiency

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Abstract

We document a negative and robust association between board size and firm risk, which is amplified in high-growth but not in complex firms. Contrary to prior literature, our evidence suggests that board size affects risk for different reasons. Across all firms and for complex ones, we find evidence of better monitoring when boards become larger, which suggests they prevent unnecessary risks. In high-growth firms, however, the evidence points towards inefficiencies of large boards reducing the volatility. Overall, this supports the notion that different firm types benefit from different board structures with regard to firm risk.

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1 INTRODUCTION

The board of directors is the principal means with which shareholders can monitor managers (John and Senbet, 1998). Many prior studies have emphasized the role of board size, and the negative effect of large boards on firm performance is well researched.[1] Much less is known about the association of board size and firm risk.[2] Cheng (2008) and Wang (2012) show that larger boards are associated with a reduction in the variability of corporate performance, with Cheng (2008) providing evidence that increasing communication and coordination problems are the underlying cause. He argues that decisions made by large groups exhibit less variability and are less extreme, as individual errors and different abilities often lead to compromises (Sah and Stiglitz, 1986, 1991). We call this the *'board inefficiency explanation'*, because it implies that larger boards are less able to function properly, and that the reduced volatility is the result of less efficient decision-making. However, larger boards can also benefit firms, since they can possess a greater capacity for monitoring (e.g., Boone et al., 2007), and if that causes lower risk, then it would be a positive outcome for shareholders. Neither Cheng (2008) nor Wang (2012) consider that the reduced variability could be due to better monitoring leading to a reduction in unnecessary risk-taking, which we call the *'monitoring capacity explanation'*.

In this paper, we test the explanatory power of those two competing explanations for the association of board size and firm risk. The monitoring capacity explanation is not ruled out by the results reported by Cheng (2008), who finds that firms with larger boards, among other things, spend less on research and development (R&D) and capital expenditures. This could be caused by either increased communication and coordination problems, or by improved monitoring. The fact that increasing the board's size can improve its monitoring function is well established. According to Bhagat and Black (1999) and Boone et al. (2007), additional directors can provide new knowledge and

[1] See, for example, Yermack (1996), Eisenberg et al. (1998), Conyon and Peck (1998), Mak and Kusnadi (2005), and Cheng et al. (2008).

[2] The board characteristics whose relations to firm risk have been investigated are diversity (Bernile et al., 2018; Giannetti and Zhao, 2019), gender (Sila et al., 2016), director independence and connectedness (Christy et al., 2013), and authority concentration (Tran and Turkiela, 2020).

skills that become necessary as a firm ages. Moreover, tasks will likely be delegated to committees, and the more directors there are, the more efficiently the work can be spread among them (Klein, 2002). Finally, in contrast to theoretical arguments made by, for example, Jensen (1993), experimental literature shows that large groups can learn to work effectively and efficiently (Weber, 2006). Thus, having more directors could increase the board's capacity for properly monitoring managers and, if that prevents unnecessary risks, the volatility would go down.

Both explanations, therefore, predict a negative association between board size and firm risk, although it is only a positive outcome in the case of the monitoring capacity explanation. Distinguishing between them thus requires also looking at the association between board size and firm outcomes indicative of monitoring or efficiencies, respectively.[3] We can, nevertheless, formulate more direct expectations for the effect in different firm types, as previous studies have shown that certain firm characteristics determine the usefulness of additional directors for firm monitoring (e.g., Boone et al., 2007; Coles et al., 2008; Linck et al., 2008). The trade-off between increasing the monitoring capacity, and increasing inefficiencies is related to the need for additional, more varied expertise on the board. This is why, in addition to using the overall sample of firms, we also conduct our analyses for two distinct firm types. Based on the monitoring hypothesis by Boone et al. (2007), we select one type where we expect monitoring capacity reasons, and one where we expect inefficiency reasons to explain the association between board size and risk.

First, we analyze *complex firms*, defined according to size, scope of operations, and leverage (Coles et al., 2008), which have a greater need for specialized knowledge in different areas and therefore, tend to have larger boards. They require different types of expertise, and, when these firms have more directors, they actually perform better (Coles et al., 2008; Adams and Mehran, 2012), which is compatible with the result in Weber (2006). That is why we expect the association to be negative and the outcome of a positive development as it will indicate a reduction in unnecessary risks. How the reduction will compare to that in non-complex firms is difficult to predict. These firms may also experi-

[3] We will explain our proxies for each in Section 5.

ence a monitoring effect from adding directors to the board, which will probably dissipate quickly and might even turn into an inefficiency effect. Whether the negative association in non-complex firms is stronger, weaker, or of comparable magnitude cannot be gleaned from the theoretical or empirical papers. Regarding the monitoring outcomes, we expect larger boards to be associated with better monitoring in complex firms.[4] In other words, we expect the monitoring capacity explanation to be the main driver of the volatility reduction in complex firms.[5]

Second, we examine *high-growth firms*, defined by R&D expenditures[6], which have very high monitoring costs (Jensen, 1993), and so they tend to have smaller boards (Linck et al., 2008; Lehn et al., 2009). Formal models by, for instance, Raheja (2005) and Harris and Raviv (2006) support the notion that when monitoring is costly, large boards are more likely to be ineffective. Directors face high costs of acquiring knowledge about the firm. Thus, their job becomes more difficult and so does the coordination among board members, which causes inefficiencies. Moreover, high-growth firms do not necessarily require different types of expertise from a multitude of directors. Therefore, we expect these inefficiencies to manifest quickly at comparatively smaller board sizes in these firms, which will lead to a stronger reduction in volatility than in low-growth firms. With respect to the monitoring and efficiency proxies, however, we expect to find larger boards to be associated with greater inefficiency. That is, we believe the inefficiencies to be the main reason behind the volatility reduction in high-growth firms.

We test the two competing explanations on a sample of 2,230 U.S. firms for the period from 1996 to 2015. Our baseline regression results show that board size is associated with a statistically and economically significant reduction in firm risk, measured via the standard deviation of daily stock returns (i.e., the volatility), over all firms, which is compatible with both the inefficiency and the monitoring capacity explanation. We do,

4 Note that evidence of strong monitoring does not necessarily imply a strong volatility reduction. It only indicates that better monitoring is the likely reason for the volatility reduction.

5 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 et al. (2016). They show that such firms are less likely to end up in bankruptcy if they have larger boards.

6 Using R&D expenditures means our firm types are identical to the ones used in Coles et al. (2008). In the robustness section, we verify the results by using the market-to-book ratio.

however, find differential results for the two firm types. While board size in complex firms has no additional effect compared to non-complex firms, it reduces the volatility of high-growth firms significantly faster than it does for low-growth firms. This finding is compatible with the idea that larger boards can accomplish better monitoring in complex firms, yet quickly lead to inefficiencies in high-growth firms, which we will further corroborate with the monitoring and efficiency tests.

In accordance with prior literature, we use the natural logarithm of board size in our baseline analyses, which accounts for the non-linear relationship. To get a better understanding of the specific effects of different board sizes, we rerun the regressions with board size dummies representing different size categories. These are based on quartiles of the actual distributions of board sizes in our sample, with the *small* dummy covering boards from 4 to 8 directors, the *medium* dummy covering boards with 9 to 11 directors, and the *large* dummy covering boards with 12 to 22 directors.[7] Our results from the baseline regressions are confirmed, showing that increases in board size reduce the stock return volatility. While we, again, see no significant effect of board size between non-complex and complex firms, we do find one for high-growth firms, where medium boards reduce the volatility to a much greater degree than for low-growth firms. For large boards, the effect is again indistinguishable, supporting our expectation that the magnitude of the effect is already realized at medium-sized boards. In other words, the effect sets in fully sooner in high-growth firms, which is in line with the conjecture of inefficiencies in this firm type.

As an additional test, we replace the overall volatility with the idiosyncratic volatility, calculated from the residuals of Fama-French three-factor model estimations. Overall volatility may be driven by market-wide factors that are beyond the influence of internal governance mechanisms, which is why the idiosyncratic volatility may be more informative about the effect of the board of directors. We repeat our baseline regressions and the results remain unchanged. For other sensitivity tests, we define high-growth firms

[7] We take the two middle quartiles together as the medium category, so that the small and large categories represent the extremes of our sample.

according to the market-to-book ratio; add dual-class firms back into the sample; use six instead of three size categories; include additional control variables (e.g., compensation vega or board co-option); and, we replace some of our control variables with alternative proxies. The association of board size and firm risk remains robust, including for the two different firm types.

Despite all of these robustness checks, there remains a possibility of endogeneity, which we address with two separate approaches. First, we use two-stage least squares (2SLS) regressions to address both simultaneity and omitted variable concerns. In accordance with several recent studies[8], we use industry-level measures to predict our potentially endogenous variable board size and relate it to the idiosyncratic volatility. Since industry-level board size is highly unlikely to affect a particular firm's *idiosyncratic* volatility, this approach should satisfy the exclusion condition. At the same time, the test statistics underscore the relevance of the instrument, which gives us confidence in this approach. The results support our baseline findings. Second, we employ a generalized method of moments (GMM) approach according to Wintoki et al. (2012). This procedure allows for a dynamic relation between board size and volatility, meaning that board size could affect volatility, but could also be affected by past volatility. Again, the results confirm our baseline findings for all firms and for the two firm types.

Next, we try to distinguish between our two explanations and investigate why exactly the risk goes down for firms that increase their board sizes. To that end, we test the association of board size and two kinds of firm outcomes. The first set of outcomes is indicative of monitoring, such as forced CEO turnover sensitivity to performance (e.g., Guo and Masulis, 2015), earnings management (e.g., Xie et al., 2003), dividend payouts (e.g., Chen et al., 2017), and leverage (e.g., Arping and Sautner, 2010). The other one focuses directly on (in)efficiencies in the innovation process, which is particularly relevant for high-growth firms. For the monitoring outcomes across all firms, we find that larger boards are associated with lower abnormal accruals, a higher likelihood of div-

[8] See, for example, Lin et al. (2011), Lin et al. (2011), Yang and Zhao (2014), Liu et al. (2015), and Tran and Turkiela (2020).

idend payments and larger payouts, as well as lower leverage. For complex firms, we find similar results with large boards being associated with higher payouts, a greater likelihood of payouts, and lower leverage than in non-complex firms. Additionally, large boards in complex firms are associated with a comparatively higher likelihood of forced CEO turnovers when firm performance is poor. They also appear to reduce incidences of earnings management when pre-managed earnings are lower than in the previous year, which is not the case in non-complex firms. For high-growth firms, conversely, we find that large boards are associated with greater abnormal accruals in those situations, while we find no additional effect on dividend payments or leverage beyond what exists for low-growth firms. Results support the monitoring explanation for complex firms, but not for high-growth firms.

To further substantiate the conjecture that larger boards lead to inefficiencies in high-growth firms, we investigate the association of board size and an area that is susceptible to inefficiencies, namely innovation. We use patent data from Kogan et al. (2017) for this test. While we find minimal to no effect over all firms and complex ones, which is not unexpected, the results for high-growth firms are highly significant. For those firms, the association of board size and the number, citations, and overall values of their patents is also positive. However, when putting the overall value of patents in relation to their R&D expenditures, the association with board size is negative. Additionally, the value per patent also goes down by economically significant margins as board size increases. Essentially, while the quantitative output increases, the quality per patent decreases, which is strongly indicative of inefficiencies resulting from larger boards in high-growth firms.

Our results contribute to the literature in two ways. First, we contribute to the aspect of fast-growing literature that analyzes the relation between board characteristics and firm risk. Bernile et al. (2018), for example, show that firms with more diverse boards, measured on a broad index, have lower stock return volatility, because the differences in backgrounds lead to more compromises, which, in turn, leads to more persistence in firm policies and thus, lower firm risk. Tran and Turkiela (2020) show that when decision-making power is more concentrated on a few people on the board, firms tend to experience more volatility. With respect to board size, Cheng (2008) has previously shown that larger boards lead to a lower variability in corporate performance, claiming that coordination and cooperation problems are the underlying cause. Wang (2012) shows that this result holds when controlling for the effects of incentive-based pay. Neither study, however, investigates the possibility that the reduction could be caused by improved monitoring. We provide evidence that, overall, increases in board size are associated with better firm monitoring, which leads to lower abnormal accruals, a greater chance of dividend payments, higher dividend payouts, and lower leverage and thus to lower firm risk.

Second, we extend the literature that investigates firm-type-specific effects of corporate governance on firm outcomes. Research on the determinants of board composition has revealed that different firm types benefit from different board sizes (e.g., Boone et al., 2007; Linck et al., 2008). Most importantly, Coles et al. (2008) show that complex firms benefit from larger boards in terms of firm performance, while R&D-intensive firms do not. Our paper is the first to analyze a firm-specific effect of board characteristics on firm risk. We show that increases in board size have different consequences for different firm types. In complex firms, our empirical evidence supports the notion that additional directors increase the monitoring capacity of the boards, which leads to a reduction in firm risk. In high-growth firms, smaller increases in board size reduce the volatility more strongly than in low-growth firms, and we do not find significant firm-specific effects on monitoring outcomes. Conversely, we find strong evidence that larger boards are associated with inefficiencies in the innovation process, as individual patents become less valuable and the overall value of all patents in relation to the R&D expenditures goes down as boards become larger.

The remainder of this paper is organized as follows. Section 2 contains a description of our data set and the firm type definitions, as well as the descriptive statistics. Our main results regarding the association of board size and firm risk are presented in Section 3, while Section 4 addresses endogeneity concerns. In Section 5 we investigate whether the reduction in firm risk is more like a result of increased monitoring capacities, or inefficiencies of large boards. Section 6 concludes the paper.

2 DATA SET AND DESCRIPTIVE STATISTICS

2.1 Data Set

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 (SIC codes 6000–6999) and all dual-class firms, whose corporate governance structures will likely differ significantly.[9] As in Cheng (2008), we also exclude nine observations from seven firms that have a board size of three, which is likely a data error in the ISS database. 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).

2.2 Defining firm types

We follow Coles et al. (2008) in identifying complex firms via a principal components analysis (PCA), in which we consider the scope of operations, firm size, and financial leverage as the three main complexity dimensions. We include one proxy for each of the dimensions in the PCA, namely, the number of business segments in different Fama-French 49 industries, the natural logarithm of sales, and book leverage. We then define a firm as complex when the factor score from the PCA of the particular firm-year is above the sample median.

High-growth firms have been defined by a variety of proxies in the literature. In our main analysis, we measure growth opportunities according to the ratio of R&D expenditures to the book value of assets, which makes our two firm types comparable to those used

[9] In Section 3.3 we briefly explain the results of two robustness checks in which we include dual-class firms or exclude utilities, respectively. These tests generally confirm our results.

in Coles et al. (2008). In the robustness section, we also use the market-to-book ratio as an alternative and get very similar results. We define firms as high-growth firms when that ratio is above the 75th percentile value. In accordance with prior literature (e.g., Coles et al., 2008; Bernile et al., 2018), we set missing values to zero. 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 (high-growth) firms, only 1,270 fall into both categories.

2.3 Variables and descriptive statistics

Our main dependent variable of interest is stock return volatility, which we calculate as the annualized standard deviation of daily stock returns for every firm's fiscal year. In addition, we also calculate the idiosyncratic volatility as the standard deviation of the residuals from Fama-French three-factor model estimations and apply this as the dependent variable in an additional analysis presented in Section 3.2.[10] Our main explanatory variable of interest is board size, for which we use both the natural log of the number of directors as well as board size categories based on the actual distribution in our sample. The latter approach allows us to analyze in which size category the effects occur. Table 1 provides an overview of the board size variables, including the categories, for all firms as well as for the different firm types.

[*Insert Table 1 about here.*]

The mean (median) board size is 9.24 (9), which makes this variable comparable to that observed by Cheng (2008). Consistent with prior literature, we see that complex firms have larger boards with a mean (median) of 10.27 (10), while high-growth firms have smaller boards with a mean (median) of 8.38 (8). To construct our board size dummy variables, we use the 25th percentile, which is eight directors, and the 75th percentile, which is 11, as the thresholds for the three categories small, medium, and large. We

[10] 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).

always sort firms that have 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.[11] The fact that a board size of eight directors is the threshold between small and medium boards is very telling, as Jensen (1993) argues that problems start to set in when boards go beyond that value in terms of their size.

In our models, we also control for several other board and CEO characteristics that we expect to be related to stock return volatility, such as board independence, CEO-chair duality, CEO tenure, and CEO ownership. In addition, we control for external governance by using the entrenchment index (E index) of Bebchuk et al. (2009). As firm controls, we include measures for firm size, book leverage, operating performance, cash holdings, R&D expenditures, and growth opportunities, which we measure as capital expenditures over sales, unless these variables are used to identify the firm type. All of the inputs are obtained from Compustat. Finally, we control for firm age 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 2 provides summary statistics for the volatility measures, as well as for governance and firm characteristics.

[*Insert Table 2 about here.*]

For the 19,476 observations (2,230 firms) in our data set, it can be observed 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.

[11] 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, which lie directly on the threshold with the medium category. In Section 3.3, we address this issue and classify boards of eight directors as medium sized. Our results remain qualitatively the same.

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 observed that several variables exhibit extreme values. Firm size, as measured by total assets, ranges from \$6 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 (ROA), cash holdings, R&D expenditures, and our measure for growth opportunities. To alleviate concerns about these extreme values affecting our results, we winsorize these variables at the 1% and 99% levels.

3 BOARD SIZE AND FIRM RISK

3.1 Baseline regressions

We start our empirical analysis by investigating the association of board size and volatility. Just as for all the analyses presented in the following, we do this once for the overall sample and for each of the two firm types separately. Our baseline model looks as follows:

$$\begin{aligned} Volatility_{i,t} = \; & \beta_0 + \beta_1 \, Ln(Board\,Size)_{i,t} \\ & + \beta_2 \, Ln(Board\,Size)_{i,t} \times Firm\,Type_{i,t} \\ & + \beta_3 \, Firm\,Type_{i,t} + \gamma \, Controls_{i,t} + \lambda_j + \phi_t + \epsilon_{i,t} \end{aligned} \tag{1}$$

where $Volatility_{i,t}$ is the overall stock return volatility. $Firm\,Type_{i,t}$ is a dummy variable that indicates the two different firm types, and which is interacted with our board size variable. In the case where we analyze the overall sample, this dummy is zero so that the two respective terms drop out of the equation. $Controls_{i,t}$ is a vector containing the control variables as described in the previous section, and defined in Table A.1 in the appendix. Whenever we estimate models for the firm types, we exclude the control variables that are part of or closely related to the firm identifier. For example, when we analyze complex firms, we drop *LN(Total Assets)* and *Book Leverage*, since they are already part of the PCA to define the *complex* dummy. λ_j and ϕ_t represent industry fixed effects, to control for unobserved heterogeneity in a firm's competitive environment, and time fixed effects. Throughout our estimations we always cluster standard errors at the firm level.

Table 3 illustrates the results of the estimations of the model from Equation (1).

[*Insert Table 3 about here.*]

The highly statistically significant negative coefficient on board size in Column (1) shows that the finding from our sample comports with the ones previously reported by Cheng (2008), and supports our general prediction of a negative association. Additionally, the estimates for the control variables show the expected signs, with the exception of cash holdings. Based on the coefficient estimates, an increase in board size by one standard deviation (2.30) at the median (9 directors), would lead to a decrease in volatility by roughly 1.53 percentage points. As stated earlier, this result is compatible with both the inefficiency and the monitoring explanation and requires further analysis in Section 5.

In Column (2), we can see that the association between board size and volatility is not different for complex firms, when compared to their non-complex counterparts, as the interaction term is insignificant. Contrarily, we find that the negative association is much stronger for high-growth firms than for low-growth firms, as the interaction term is highly significant, both statistically and economically. While high-growth firms have a higher volatility on average, as one would expect, increases in board size lead to a faster reduction than in low-growth firms. This is also borne out by the coefficient estimates. In complex firms, increasing the median board with 10 directors by one standard deviation (2.19) is associated with a volatility reduction of 2.18 percentage points. For high-growth firms, the reduction amounts to 2.64 percentage points at a median board of 8 and a standard deviation of 2.20. In comparison, the same increase in board size would yield a volatility reduction of only 1.45 percentage points in low-growth firms.

The different findings for complex and high-growth firms serve as an initial indication that there is a difference in the association based on the firm type. Given that theoretical models predict that monitoring is costlier in high-growth firms, the results are in line with our supposition that the reduction in volatility might be due to inefficiencies in the decision-making process. Furthermore, the fact that volatility does not decline faster for larger boards in complex firms, than it does in non-complex firms, is also in line with the conjecture that these firms do not necessarily see large(r) reductions in risk for increases at smaller board sizes, but only realize the full monitoring effect at relatively large boards. We will investigate this further in Section 5.

Since these results provide an indication of the overall effect across the whole range of board sizes, we next investigate how the effect differs between different board size categories. This helps us to isolate in which size category the effect occurs the strongest, and whether the effect of a particular board category is distinct for one of the firm types. To that end, we separate firms into three groups, namely those with small, medium, and large boards. The categorization is based on the actual distribution of boards in our sample and has been detailed in Section 2. We replace our board size variable in Equation (1) by the medium and large category dummies, while the small category serves as the benchmark. We also interact these board categories with our firm type indicators so that the updated model looks as follows:

$$\begin{aligned} Volatility_{i,t} = \; & \beta_0 + \beta_1\, Medium\, Board_{i,t} + \beta_2\, Medium\, Board_{i,t} \times Firm\, Type_{i,t} \\ & + \beta_3\, Large\, Board_{i,t} + \beta_4\, Large\, Board_{i,t} \times Firm\, Type_{i,t} \\ & + \beta_5\, Firm\, Type_{i,t} + \gamma\, Controls_{i,t} + \lambda_j + \phi_t + \epsilon_{i,t} \end{aligned} \tag{2}$$

where $Medium\, Board_{i,t}$ and $Large\, Board_{i,t}$ are dummy variables indicating boards with 9 to 11 and 12 to 22 directors, respectively. The remaining variables are the same as in Equation (1). Table 4 presents the results of the estimations of the model from Equation (2).

[*Insert Table 4 about here.*]

First, for Models (1) and (2) the initial finding is confirmed: the larger the board is, the lower is the volatility. Over all firms, a move from a small board to a medium board is associated with a volatility reduction of 2.32 percentage points, while a move to a large board is related to a reduction of 3.54 percentage points. For complex firms in Column (2), we see that there is no significant difference of the board size effect between complex and non-complex firms, neither for medium nor for large boards. For high-growth firms in Column (3), on the other hand, we see that a move from a small to a medium board seems to reduce the volatility significantly faster than it does in low-growth firms. While for low-growth firms, a move to a medium-sized board is associated with a reduction in the volatility of 1.76 percentage points, high-growth firms experience almost twice that, as the total reduction amounts to 3.56 percentage points when the two coefficients are added up. For large boards, there is no significant difference between the two groups, and the total reduction in volatility is 3.07 percentage points, which is less than the reduction for medium boards in high-growth firms.

To investigate how significant this apparent increase in volatility is for large boards, we rerun Equation (1) with an included squared term of board size, which we interact with the high-growth indicator. Both $LN(Board\ Size)$ and $LN(Board\ Size)^2$ are insignificant, whereas the interaction terms with the high-growth indicator are highly statistically significant. However, the increase in volatility beyond the calculated minimum of 9.7 directors is hardly economically meaningful.[12] Moreover, the adjusted R^2 is nearly identical to that of Model (3) in Table 3, suggesting that this approach does not model the relation any better than our baseline model does. Therefore, the combined evidence from the model with the squared term and the dummy variables suggests that there is no distinct economic meaningful difference in the effect of large boards in high-growth and low-growth firms.

Taken together, the results from the tests with the board size categories suggest two things. First, the overall negative association between board size and firm risk is supported. Second, we again see that for the two firm types, the effect of board size is different. We see no added decrease in firm risk in complex firms, at either medium or

[12] A move from 10 to 12 directors is associated with an increase in volatility of about half a percentage point. Detailed results from the quadratic regression are available upon request.

large boards, compared to non-complex firms. For high-growth firms, on the other hand, the reduction is amplified for medium-sized boards, but not large boards. This is in line with our inefficiency prediction for this firm type, which says that the effect would manifest at comparatively smaller boards. We will provide further evidence in support of this interpretation in Section 5.

3.2 Idiosyncratic firm risk

The analyses so far have relied on the overall volatility, which, potentially, might be driven to a large extent by influences outside managerial control. In that case, board structure may only have a small effect on it, or no effect at all. Idiosyncratic volatility, on the other hand, may be more informative about a firm's actions and thus be of interest when we analyze the effects of board size on volatility. As pointed out in Section 2.3, we calculate the idiosyncratic volatility as the standard deviation of the residuals from Fama-French three-factor model estimations. Results for the board size counter variable are depicted in Panel A, and for the size categories in Panel B of Table 5. Control variables are included but not reported for brevity.

[*Insert Table 5 about here.*]

In general, these regressions confirm our previous findings. The only notable difference compared to the results for overall volatility, is that complex firms exhibit lower idiosyncratic volatility than non-complex ones at medium boards, which is significant at the ten percent level. Since the idiosyncratic volatility is still lower, but not different to that of non-complex firms when they have large boards, this result is in line with our expectations.

Thus, our first set of analyses confirms previous results for all firms (i.e., larger boards are associated with lower volatility), but also establishes that the effect depends on the type of firm. Our results show that larger boards reduce the volatility faster in high-growth than in low-growth firms, while in complex firms there is no discernible effect beyond what can already be observed for non-complex firms. To analyze whether the effects stem from monitoring or inefficiencies, we will investigate monitoring and efficiency outcomes in Section 5.

3.3 Robustness Checks

To further corroborate our findings for the association between board size and volatility, we conduct the following tests.[13] First, we re-estimate our models with dual-class firms, which we have previously excluded. This increases the sample size to 21,209 observations, yet the results of our main analysis remain unchanged.

Second, in addition to the financial firms that we exclude in our main analyses, we now also exclude utilities (SIC codes 4900–4999) from the sample, because they operate in regulated industries. This reduces the sample size to 17,836 observations. While the results for the board size counter models remain basically unchanged, the ones for the board size categories exhibit one notable difference to the baseline results, that is that complex firms show significantly lower volatility than non-complex firms when they have a medium board. Since complex firms still appear to have the lowest volatility when they have large boards, our inferences remain unchanged.

Third, since there is a debate in the literature about what the best proxy for growth opportunities is (e.g, Adam and Goyal, 2008), we use the market-to-book ratio to define high-growth firms and rerun our regressions. In doing so, we confirm our baseline results.

Fourth, risk-taking incentives provided to the CEO have been shown to drive firm risk (Coles et al., 2006). Therefore, we rerun our analyses, but including the sensitivity of CEO wealth to stock return volatility (vega) as a further control variable. At the same time we also include board co-option, as it has been shown to affect how well board members work together (Coles et al., 2014).[14] Again, the results are virtually unchanged.

[13] Results, when untabulated, are available upon request from the authors.

[14] We thank Lalitha Naveen for providing the data on vega and co-option online. However, since those data end in 2014 and are not available for all of firm-years in our sample, which would reduce the sample size by about 2,900 observations, we only include those two variables in this robustness check.

Fifth, even though we base the definition of our board size categories on the empirical distribution of board size, it still remains a discretionary choice to, for example, sort the observations that fall directly on the thresholds (8 or 11 directors, respectively) into the respective lower category. That is why we also test alternative specifications, three of which we discuss here. (i) We sort observations with a board size of eight into the medium board category, which affects a total of 2,973 observations (15.3 % of the sample). This creates a much more extreme benchmark group of small boards, which is reflected in generally higher coefficient estimates for the different board size variables. The complex dummy becomes insignificant, which is most likely due to the fact that we have a lot fewer observations of complex firms in the benchmark group so that the 'complexity effect' is fully absorbed in the interaction terms. Compared to the new extreme small-board group, complex firms on average exhibit an additional negative effect for medium boards, but large boards still provide the greatest volatility reduction in these firms, which is in line with our expectations. The models for the overall sample and for high-growth firms also confirm our earlier findings. (ii) We include boards with 11 directors (2,309 observations or 11,9 % of the sample) into the large category. This generates a less extreme large group, which consequently results in slightly smaller coefficient estimates for medium and large boards. Except for that, our results are confirmed. (iii) We re-estimate our models including more granular board categories, that is, we include separate dummy variables for each of the most prevalent board sizes (8 to 11) of our sample and one for boards with more than 11 directors. This analysis reveals each board size's average difference in volatility compared to small boards of four to seven directors. Thus, it provides an indication of the average effect each additional director adds. Table 6 presents the estimations.

[*Insert Table 6 about here.*]

The results generally confirm the negative board size-volatility relation and provide further support for the fact that adding an additional director does not have the same effect across all board sizes. For example, increasing the board size from eight to nine directors is associated with a larger reduction in volatility than an increase from 10 to 11. Moreover, results confirm our finding that the volatility reduction sets in at comparatively lower board sizes for high-growth firms, and that complex firms do not seem to be affected differently compared to non-complex ones.

Lastly, 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*, with the *Market-to-Book* ratio. The results are essentially unchanged.

We also perform all of these robustness checks for the idiosyncratic volatility and basically find results that confirm the ones presented in Section 3.2. The only exception is that in a few tests the firm-specific effect of medium boards in high-growth firms does not hold on a ten percent level anymore.

In total, the robustness checks presented in this section predominantly confirm our earlier findings, so we remain confident that our results are not driven by some discretionary choices made during the analyses.

4 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 for board size studies. Nakano and 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 U.S. sample, the first-stage test statistics reveal free float to be a weak instrument. Besides including industry fixed effects in our models to control for unobserved heterogeneity, we rely on two approaches that have been used in the literature to mitigate these concerns.

4.1 Two-stage least squares estimation

First, we conduct two-stage least squares (2SLS) estimations that address both simultaneity and omitted variable concerns. We follow a number of recent studies that use industry-level measures of their potentially endogenous variable of interest as the instrument.[15] A firm's competitive environment, such as levels of information asymmetry, will likely influence its choice of board structure, including the size of the board (e.g., Boone et al., 2007; Lehn et al., 2009). Therefore, it stands to reason that the median industry-level board size will be highly correlated with the firm's board size. At the same time, it is highly unlikely that the industry median board structure will affect any particular firm's *idiosyncratic* volatility. In other words, industry board size should only affect firm-level idiosyncratic volatility through its effect on the firm's board size, which satisfies the exclusion restriction.

We begin by identifying the industry median of board size for each year and use it as the instrument for the firm-level board size in the first-stage regression. For the estimations by firm type, the industry median board size is also interacted with our firm type dummies in the first stage to provide instruments for the respective interaction terms in the second stage. The predicted values are then used in the second stage to re-estimate our main models. Likewise, we also conduct 2SLS estimations for the board category models. In those cases, we instrument each board category by their industry mean of the particular year. Since our categories are defined as dummy variables, the instruments represent the fraction of firms in the same industry that have boards in the respective category.

Panel A of Table 7 illustrates two examples of the first-stage results for the cases without firm type differentiation and for high growth firms. The model for complex firms is estimated accordingly. The highly significant first-stage F-statistics of the excluded instruments and the highly significant coefficient estimates of the industry median (mean) board size variables and interaction terms indicate that we do not face a weak instrument

[15] See, for example, Lin et al. (2011), Lin et al. (2011), Kim et al. (2014), Yang and Zhao (2014), Liu et al. (2015), and Tran and Turkiela (2020).

problem. This also holds for all other untabulated first-stage regressions and provides support for the relevance of our instrument choice.

[*Insert Table 7 about here.*]

Panel B and C of Table 7 contain the results based on the board size counter and categorical variables, respectively. The results clearly support our earlier findings in that board size negatively affects volatility and that this effect is especially strong in high-growth firms, where medium boards lead to a significantly stronger reduction in volatility than in low-growth firms, while large boards do not. In an unreported analysis, we also conduct 2SLS regressions similar to the ones presented by Wang (2012), in which we use the second and third lags of our board variables as instruments. The results are largely the same. However, it is hard to argue that the lagged values of board size really meet the exclusion condition.

4.2 Dynamic panel GMM estimation

Second, we follow the methodology suggested by Wintoki et al. (2012) and re-estimate our models using the dynamic panel GMM estimator developed by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and 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 could not only affect volatility but could also 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. Second and third lagged values of the explanatory variables—including the board size variables—are then utilized as instruments in the estimation procedure.

To verify the validity of the approach, we provide the standard test statistics. Throughout the models presented in Table 8, the null hypothesis of the Hansen test of overidentification cannot be rejected at the ten percent level, which supports the validity of the instruments. Furthermore, the test statistics show that second-order serial correlation is not an issue.

[*Insert Table 8 about here.*]

The results presented in Table 8 reveal similar patterns as our baseline analyses. Across all firms, board size is still negatively associated with volatility. While complex firms do not differ in this regard from non-complex ones, the effect is again particularly strong in high-growth firms. In Model (3) of Panel A, the interaction term fully absorbs the negative effect. The fact that the coefficient on the non-interacted board size becomes insignificant in this model is one notable difference to earlier analyses. Furthermore, the results in Panel B provide additional support for our conjecture that in high-growth firms the reduction in volatility sets in at comparatively smaller board sizes already. Surprisingly, and different to the results in our main analysis, we find a positive coefficient on the interaction term between complex firms and medium boards. Overall, the tests in this section mitigate endogeneity concerns and corroborate our earlier findings.

5 TESTING THE MONITORING CAPACITY AND INEFFICIENCY EXPLANATIONS

Even though we have some initial indication with the two firm types, the results of the association between board size and firm risk can, for the most part, be explained by both monitoring capacity and inefficiency reasons. To ascertain which is more likely to be the underlying cause, we focus on the relation between board size and several firm outcomes that are indicative of (i) monitoring activities and (ii) innovation, which is highly susceptible to inefficiencies in corporate boards (e.g., Belloc, 2012; Balsmeier et al., 2017).

5.1 Evidence of board monitoring

We begin the analysis with firm outcomes that are commonly associated with better monitoring, namely forced CEO turnovers, earnings management, dividend payments, and leverage. The first is arguably the most important monitoring task a board has, and that is deciding when to fire or retain the CEO (Hermalin and Weisbach, 2003; Guo and Masulis, 2015; Jenter and Kanaan, 2015). If an increase in board size is associated with inefficiencies, one would not expect forced CEO turnover to be higher after poor performance, while that would be the case if board size is associated with better monitoring. We use data on forced CEO turnovers from Peters and Wagner (2014) and Jenter and Kanaan (2015) and investigate whether board size is related to the likelihood of the CEO being released, while conditioning on firm performance.[16] The second indicator we use is earnings management. Board monitoring should reduce earnings management, leading to a more truthful reporting of firm performance (Xie et al., 2003; Peasnell et al., 2005). Our proxy for earnings management is *Abnormal Accruals*, which we estimate using the modified Jones (1991)-model according to Dechow et al. (1995). Since the incentive to manage earnings upwards is particularly high if the firm misses its earnings targets, we follow Peasnell et al. (2005) and also interact our board size categories with the dummy variable *PME Below*, which takes the value of one if pre-managed earnings (PME) are below last year's earnings. We use cash flows from operating activities as a proxy for pre-managed earnings (Peasnell et al., 2005). Next, we check if firms with large boards have a higher likelihood to pay dividends and if they pay higher dividends. Distributing cash to shareholders reduces the free-cash flow problem and results in firms being exposed to the scrutiny of financial markets when they acquire external financing (Easterbrook, 1984; Jiraporn et al., 2011; Chen et al., 2017). Finally, we investigate if board size can affect leverage, which in itself can be a monitoring tool that is often used when internal

[16] We thank Florian Peters for sharing that data with us.

corporate governance is weak (Arping and Sautner, 2010; Jiraporn et al., 2012). So, if boards increase their monitoring, we expect leverage to go down.

We use Equation (1), but replace the dependent variable with the above-mentioned proxies for monitoring. Results for all firms are presented in Panel A, for complex firms in Panel B, and for high-growth firms in Panel C of Table 9. For brevity, we do not report the control variables.

[*Insert Table 9 about here.*]

Across all firms, we find no evidence of an association between board size and forced CEO turnover. For earnings management, however, we do find an indication for a monitoring effect. Board size on its own does not appear to have an effect. However, in situations when there is a special incentive for earnings management, that is, when the pre-managed earnings are below last year's earnings, abnormal accruals go down when boards become larger. This is indicative of the monitoring capacity explanation and could be due to more directors with specialized skills to prevent earnings management. The other proxies point in the same direction. Firms with larger boards have a significantly higher likelihood of paying dividends and they pay higher dividends than firms with smaller boards. In other words, they reduce the free cash flow problem, which also makes it more likely that they will have to raise external capital to finance investments. Lastly, firms with larger boards tend to have lower leverage. Since leverage is an external control mechanism, this could suggest, that when boards increase in size, these firms are no longer in need of that external control. All in all, these results are supportive of our monitoring capacity explanation, which supposes that firm risk goes down because of better monitoring and not inefficiencies.

For complex firms, which are presented in Panel B, we find a negative coefficient estimate on the triple interaction term, which indicates that the likelihood of forced CEO turnovers increases with board size when firm performance is poor. This result clearly points toward a monitoring effect of board size in complex firms. In addition, the results for earnings management show that abnormal accruals go down with board size. The significant positive coefficient on the interaction term between board size and our complexity dummy seems to suggest that in such firms, earnings management increases. However, an F test for joint significance reveals that the two coefficients together are not significantly different from zero, suggesting that board size itself has neither a positive nor negative effect on earnings management in complex firms. When we examine the triple interaction term, on the other hand, we see that it is significantly negative, which says that when these firms have an incentive to manipulate their earnings, large boards appear to reduce that effect significantly. Additionally, the likelihood of paying a dividend increases more strongly in complex firms than in non-complex firms when board size increases, and complex firms also pay higher dividends, whereas we find no effect in non-complex firms. Finally, while leverage goes up with board size in non-complex firms, it actually goes down in complex ones. Taken together, this again supports our expectation that increases in board size in complex firms increase the monitoring capacity of the board, which is in line with reduced firm risk due to better monitoring.

Results for high growth firms, presented in Panel C, look somewhat different. With respect to forced turnover, we find no significant effect. For earnings management, the results are somewhat unintuitive. Larger boards appear to reduce general earnings management in high-growth firms compared to low-growth firms. However, when pre-managed earnings are down compared to last year, that is, when there is a stronger incentive to manage earnings, abnormal accruals actually increase with board size in high-growth firms compared to low-growth firms. This does not support a monitoring effect. With respect to the likelihood of paying a dividend at all and the question of higher payouts, we find no additional board size effect in high-growth firms beyond what is already observed in low-growth firms. No effect can be detected for leverage, neither for high-growth nor for low-growth firms. Taken together, we find no direct evidence supporting a monitoring effect in high-growth firms, and we find some evidence that opportunistic earnings management does increase. While these results do point toward a negative effect of larger boards in high-growth firms, they are not clearly suggesting inefficiencies. That is why we further investigate this as a possible explanation in an area that is of particular importance to high growth firms, namely innovation, in the next section

5.2 Board size and innovation inefficiency

Innovation has a special importance for high-growth firms (Audretsch et al., 2014) and board structure can have a tremendous effect on the success of innovation (Balsmeier et al., 2017; Kang et al., 2018; Nguyen et al., 2020). That is why we analyze the association of board size and patents to find further evidence for our two explanations. We use the extended patent dataset from Kogan et al. (2017), who not only have the number of patents and their citations, but also calculate a dollar value for each patent.[17] That allows us to specifically test for inefficiencies, as we relate board size not just to the overall number of patents, their citations, and overall value, but also to the overall value per R&D expenditures and the value of each individual patent. Results for those analyses are presented in Table 10.

[*Insert Table 10 about here.*]

For all firms we only find weak evidence in Column (5) that the value per patent goes down when board size increases, whereas all the other relations are not significant. In Panel B, we can see that board size does not have a specific effect in complex firms beyond what can be observed in non-complex firms. Interestingly, we can see that firms with larger boards have more patents (Column (1)) with more citations (Column (2)) that have a higher total value (Column (3)). Moreover, since the patent value in relation to R&D expenditures (Column (4)) and the value of each patent (Column (5)) go up, we surmise that the innovation process also becomes more efficient as boards grow in size. The fact that the interaction terms with the complexity dummy are not significant can be interpreted as complex firms not being significantly different from non-complex firms in this respect. Nevertheless, since all values are positive, the findings again support our monitoring capacity explanation.

[17] We thank Kogan et al. (2017) for providing their data online.

For high-growth firms, the interpretation does not hold. The results in Columns (1) through (3) seem to suggest that these firms benefit as well from larger boards, since they produce a significantly higher number of patents that have more citations and a higher combined value. However, the results in Columns (4) and (5) reveal that the opposite is true. Both the patent value in relation to R&D expenditures as well as the average value per patent go down when boards increase in size, indicating that those firms pay significantly more to produce patents with lower quality. Both results provide a clear sign of inefficiencies in high-growth firms with large boards.

This effect is not only statistically significant, but also economically meaningful. For example, based on the coefficient estimate of -0.7542 in Model (5), an increase in board size by one standard deviation (2.30) at the median (9) would be associated with a comparably lower value per patent in high-growth firms of 19.27%. Considering that the median (mean) value per patent in our sample is \$15.96 (\$41.60) million, this implies that each patent produced by high-growth firms would be worth \$3.08 (\$8.02) million less than the ones produced by other firms.

These results, taken together with the ones from the previous section, provide strong evidence that an improved monitoring capacity of large boards can explain the reduction of firm risk in complex firms, as well as that inefficiencies in large groups can explain the reduction of firm risk in high-growth firms. As initially suspected, the reason for the reduction in firm risk appears to depend on the particular firm type. In complex firms, the lower risk seems to be mostly driven by an increased monitoring capacity of large boards, which would indicate that volatility is lower because of boards preventing unnecessary risk-taking. For high-growth firms, on the other hand, we find little evidence of a monitoring effect for larger boards, which could be explained by the higher monitoring costs these firms face. As expected, our evidence suggests that these firms quickly begin to face inefficiencies when their boards grow. When we analyze the effects across the whole universe of firms without distinguishing a certain type, the monitoring capacity appears to have the greatest explanatory power.

6 CONCLUSION

This paper investigates the association between board size and firm risk for a sample of U.S. firms from 1996 to 2015, with a special focus on different firm types. We find that stock return volatility goes down across all firms when boards become larger and this effect is amplified in high-growth firms but not in complex ones. This result is robust to alternative measures of board size, a variety of additional control variables, and tests for endogeneity.

We consider and test two competing explanations for this finding. While previous studies ascribe the reduction in volatility to communication and coordination problems of large boards that lead to inefficiencies and thus lower variability, we consider that larger boards can have a greater capacity for monitoring. Our results show that, across all firms and complex ones, larger boards are associated with a higher propensity to pay dividends, paying higher dividends, reduced earnings management, especially in situations where there is an incentive to increase abnormal accruals, and lower leverage. In addition, they are associated with a higher likelihood of forced CEO turnovers after poor performance in complex firms. For high-growth firms, however, we find that earnings management increases when there is an incentive to manage earnings upward, while we find no evidence of better monitoring when it comes to dividends or leverage compared to low-growth firms. With respect to innovation, though, which is of crucial importance to high-growth firms, we find strong evidence that larger boards are associated with a reduction in the value of individual patents and the value of patents in relation to R&D-expenditures.

These results are supportive of our conjecture that larger boards overall lead to better monitoring, which means that the reduction in firm risk is actually positive as it most likely comes from avoiding unnecessary risks. This is particularly true for complex firms, where theory predicts that they would benefit from larger boards. At the same time, the results for high-growth firms support the inefficiency explanation, especially with respect to the innovation processes.

Our findings provide strong evidence that, unlike suggested by previous studies, larger boards can have beneficial effects when it comes to firm risk, as they can enable better monitoring. However, this effect on risk is not uniform across all firms and different firm types can benefit from different board structures when they want to affect their stock price risk. This is important to consider when evaluating a firm's board. Conceivably, other aspects of board structure (e.g., diversity or independence) may likewise vary in their effect in different firm types. We leave this research to future studies.

Appendix

Table A.1 Variable definitions

Variable	Definition	Data Source
Volatility Measures		
Volatility (%)	Annualized standard deviation of daily stock returns for the firm's fiscal year.	*CRSP*
Idiosyncratic Volatility (%)	Annualized standard deviation of daily residuals, obtained from Fama-French three-factor model estimations, for the firm's fiscal year. The factor model is estimated on a yearly basis using data from Kenneth R. French's data library.	*CRSP, French's data library*
Firm Type Indicators		
Complex	Dummy variable equal to one if the firm's complexity score, derived from PCA and based on the number of business segments, the natural logarithm of sales, and book leverage, is above the sample median; zero otherwise.	*Compustat*
High Growth	Dummy variable equal to one if the firms ratio of R&D expenditures to the book value of assets is above the 75th percentile; zero otherwise.	*Compustat*
Board Governance & CEO		
Board Size	Number of directors on the board.	*ISS Directors*
Small Board	Dummy variable equal to one, if the board consists of 4 to 8 directors; zero otherwise.	*ISS Directors*
Medium Board	Dummy variable equal to one, if the board consists of 9 to 11 directors; zero otherwise.	*ISS Directors*
Large Board	Dummy variable equal to one, if the board consists of 12 to 22 directors; zero otherwise.	*ISS Directors*
Independence (%)	Number of independent directors divided by the total number of directors on the board.	*ISS Directors*
CEO Duality	Dummy variable equal to one, if the CEO is also the chairperson of the board; zero otherwise.	*ISS Directors*
CEO Ownership (%)	Percentage of a company's shares owned by the CEO, options excluded.	*ExecuComp*
CEO Tenure	Years since the CEO took over office.	*ExecuComp*
External Governance		
E Index	Entrenchment index introduced by Bebchuk et al. (2009).	*ISS Governance*
Further		
Total Assets	Book value of assets.	*Compustat*
Book Leverage (%)	Sum of long-term debt and current liabilities divided by the book value of total assets.	*Compustat*
ROA (%)	Return on assets. Net income divided by the book value of assets.	*Compustat*
Cash/Assets (%)	Cash and short-term investments divided by the book value of assets.	*Compustat*
R&D/Assets (%)	R&D expenditures divided by the book value of assets.	*Compustat*
CAPEX/Sales (%)	Capital expenditures divided by sales.	*Compustat*
Firm Age	Number of years since the first trading on CRSP, with 1925 being the earliest year possible.	*CRSP*
Forced Turnover	Dummy variable equal to one if the firm experiences a forced turnover in the current fiscal year; zero otherwise. Forced turnovers are determined using the updated dataset from Peters and Wagner (2014) and Jenter and Kanaan (2015).	*Florian Peters*
Abnormal Accruals	Abnormal accruals based on the modified Jones (1991)-model from Dechow et al. (1995).	*Compustat*
Pays Dividend	Dummy variable equal to one if the firm pays dividends in the current fiscal year; zero otherwise.	*Compustat*
Dividend/Equity	Dividends paid divided by the book value of equity.	*Compustat*
Market Leverage (%)	Sum of long-term debt and current liabilities divided by the sum of market equity and book debt.	*Compustat*
Number of Patents	Number of patents filed (and eventually granted) during the firm's fiscal year, based on the updated Kogan et al. (2017) dataset.	*Stoffman's website*
Number of Citations	Number of forward citations received by the patents filed (and eventually granted) during the firm's fiscal year, based on the updated Kogan et al. (2017) dataset.	*Stoffman's website*
Total Value of Patents	Total dollar value (in millions) of all patents filed (and eventually granted) during the firm's fiscal year, based on the updated Kogan et al. (2017) dataset.	*Stoffman's website*
Total Value of Patents/R&D	Total dollar value (in millions) of all patents filed (and eventually granted) during the firm's fiscal year divided by R&D expenditures, based on the updated Kogan et al. (2017) dataset.	*Stoffman's website; Compustat*
Value/Patent	Mean value of the patents filed (and eventually granted) during the firm's fiscal year, based on the updated Kogan et al. (2017) dataset.	*Stoffman's website*

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

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Tables

Table 1 Board size overview

Panel A: Board Size Counter		**All**	**Complex**	**High Growth**
Board Size	*Mean*	9.24	10.27	8.38
	Median	9	10	8
	Min.	4	4	4
	Max.	22	22	19
	Std. Dev.	2.30	2.19	2.20

Panel B: Board Size Categories		**All**		**Complex**		**High Growth**	
	Definition	*Obs.*	*% of sample*	*Obs.*	*% of sample*	*Obs.*	*% of sample*
Small Board	4-8	7,632	39.2%	1,928	9.9%	2,791	14.3%
Medium Board	9-11	8,752	44.9%	5,225	26.8%	1,627	8.4%
Large Board	12-22	3,092	15.9%	2,585	13.3%	451	2.3%
		19,476	100.0%	9,738	50.0%	4,869	25.0%

This table presents an overview of the distribution of board size. Panel A provides descriptive statistics for the board size variable that counts the number of directors on the board, while Panel B illustrates the definition as well as the distribution of the three board size categories that we define based on the empirical distribution of the number of directors on the board. In both panels the respective statistics are presented across all firms as well as for the two firm types, complex and high-growth firms.

Table 2 Summary statistics

	Obs.	Mean	Std. Dev.	Min.	25th Pct.	Median	75th Pct.	Max.
Volatility Measures								
Volatility (%)	19476	40.376	20.214	7.317	26.479	35.548	48.927	224.052
Idiosyncratic Volatility (%)	19476	33.583	17.942	6.938	21.376	29.370	40.918	219.554
Board Governance & CEO								
Board Size	19476	9.243	2.297	4.000	8.000	9.000	11.000	22.000
Independence (%)	19476	73.473	15.490	0.000	66.667	77.778	85.714	100.000
CEO Duality	19476	0.577	0.494	0.000	0.000	1.000	1.000	1.000
CEO Tenure	19476	7.649	7.113	0.000	3.000	6.000	10.000	62.000
CEO Ownership (%)	19476	1.552	4.573	0.000	0.000	0.144	0.850	66.601
External Governance								
E Index	19476	3.093	1.430	0.000	2.000	3.000	4.000	6.000
Further Controls								
Total Assets	19476	7640.877	20138.949	6.268	712.995	1911.599	6063.991	479921.000
Book Leverage (%)	19476	23.298	18.136	0.000	8.522	22.857	34.556	292.514
ROA (%)	19476	4.127	12.832	-458.310	2.085	5.074	8.765	87.199
Cash/Assets (%)	19476	13.616	15.877	-0.161	2.225	7.322	19.437	100.000
R&D/Assets (%)	19476	2.952	5.637	0.000	0.000	0.000	3.697	112.910
CAPEX/Sales (%)	19476	9.852	168.919	0.000	2.289	4.052	8.146	23398.992
Firm Age	19476	28.550	20.577	0.000	13.000	23.000	39.000	91.000

Note. 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 (SIC codes 6000–6999) and dual-class firms are excluded. Data on daily stock returns, used to calculate stock return volatility and idiosyncratic volatility, are obtained from CRSP. Idiosyncratic volatility is based on residuals from Fama–French three-factor model estimations. All variables are defined in Table A.1 in the appendix.

Table 3 Board size and volatility

	All	Complex	High Growth
	(1)	(2)	(3)
	Volatility	Volatility	Volatility
Ln(Board Size)	-5.9790***	-9.9490***	-5.2740***
	(0.0000)	(0.0000)	(0.0000)
Ln(Board Size) × *Firm Type*		-0.2703	-4.3189***
		(0.8495)	(0.0077)
Firm Type		-1.7119	11.8637***
		(0.5888)	(0.0010)
Independence	-0.0355***	-0.0388***	-0.0376***
	(0.0048)	(0.0024)	(0.0030)
CEO Duality	0.1121	-0.4523	0.0734
	(0.7373)	(0.1812)	(0.8288)
Ln(1+CEO Tenure)	-0.2873	-0.1733	-0.2773
	(0.1706)	(0.4157)	(0.1887)
CEO Ownership	-0.0463	-0.0145	-0.0441
	(0.2576)	(0.7324)	(0.2709)
E Index	-0.6208***	-0.3708**	-0.6048***
	(0.0000)	(0.0108)	(0.0000)
Ln(Total Assets)	-2.2028***		-2.1542***
	(0.0000)		(0.0000)
Book Leverage	0.0465***		0.0523***
	(0.0002)		(0.0000)
ROA	-0.6625***	-0.7105***	-0.6758***
	(0.0000)	(0.0000)	(0.0000)
Cash/Assets	0.1370***	0.1405***	0.1293***
	(0.0000)	(0.0000)	(0.0000)
R&D/Assets	0.2159***	0.2059***	
	(0.0003)	(0.0006)	
CAPEX/Sales	0.1088***	0.0937***	
	(0.0000)	(0.0000)	
Firm Age	-0.0662***	-0.0899***	-0.0713***
	(0.0000)	(0.0000)	(0.0000)
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476
Adj. R-Squared	0.5790	0.5685	0.5770

Note. This table presents the results of regressions on the relation between the board size counter variable and volatility across all firms (Model (1)) as well as for the two firm types complex (Model (2)) and high-growth firms (Model (3)). In each model, the dependent variable is stock return volatility. *Ln(Board Size)* is the natural logarithm of the number of directors on the board. The firm type indicators are the dummy variables *Complex*, which is equal to one if the firm's complexity score is above the median, and *High Growth*, which is equal to one if the firm's ratio of R&D expenditures to assets is greater than the 75th percentile. The remaining variables are defined in Table A.1 in the appendix. All models include industry and year fixed effects, as well as a constant term. The p-values are based on standard errors clustered at the firm-level and are reported in parentheses. *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

Table 4 Board size and volatility by board categories

	All	Complex	High Growth
	(1) Volatility	(2) Volatility	(3) Volatility
Medium Board	-2.3163***	-2.8340***	-1.7638***
	(0.0000)	(0.0000)	(0.0000)
Medium Board × *Firm Type*		-1.1619	-1.7969**
		(0.1132)	(0.0267)
Large Board	-3.5422***	-5.7278***	-3.0697***
	(0.0000)	(0.0000)	(0.0000)
Large Board × *Firm Type*		-0.4661	-0.5465
		(0.6797)	(0.6027)
Firm Type		-1.7490***	3.3814***
		(0.0066)	(0.0000)
Independence	-0.0172	-0.0253*	-0.0402***
	(0.2419)	(0.0791)	(0.0016)
CEO Duality	0.0160	-0.4104	0.1586
	(0.9630)	(0.2311)	(0.6391)
Ln(1+CEO Tenure)	-0.0032	0.0522	-0.2704
	(0.9899)	(0.8274)	(0.1966)
CEO Ownership	0.0073	0.0350	-0.0359
	(0.8861)	(0.4660)	(0.3628)
E Index	-0.4776***	-0.3023**	-0.6348***
	(0.0028)	(0.0451)	(0.0000)
Ln(Total Assets)	-1.9646***		-2.3143***
	(0.0000)		(0.0000)
Book Leverage	0.0511***		0.0533***
	(0.0001)		(0.0000)
ROA	-0.6578***	-0.7078***	-0.6791***
	(0.0000)	(0.0000)	(0.0000)
Cash/Assets	0.1502***	0.1520***	0.1359***
	(0.0000)	(0.0000)	(0.0000)
R&D/Assets	0.2489***	0.2324***	
	(0.0001)	(0.0001)	
CAPEX/Sales	0.1130***	0.0994***	
	(0.0000)	(0.0000)	
Firm Age	-0.0703***	-0.0920***	-0.0729***
	(0.0000)	(0.0000)	(0.0000)
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476
Adj. R-Squared	0.9137	0.9120	0.5758

Note. This table presents the results of regressions on the relation between our board size category variables and volatility across all firms (Model (1)) as well as for the two firm types complex (Model (2)) and high-growth firms (Model (3)). In each model, the dependent variable is stock return volatility. *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 firm type indicators are the dummy variables *Complex*, which is equal to one if the firm's complexity score is above the median, and *High Growth*, which is equal to one if the firm's ratio of R&D expenditures to assets is greater than the 75th percentile. The remaining variables are defined in Table A.1 in the appendix. All models include industry and year fixed effects, as well as a constant term. The *p*-values are based on standard errors clustered at the firm-level and are reported in parentheses. *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

Table 5 Board size and idiosyncratic volatility

Panel A: Board Size Counter	All	Complex	High Growth
	(1) Idiosyncratic Volatility	(2) Idiosyncratic Volatility	(3) Idiosyncratic Volatility
Ln(Board Size)	-4.9972***	-9.5586***	-4.4186***
	(0.0000)	(0.0000)	(0.0000)
Ln(Board Size) × *Firm Type*		-0.6200	-3.4250**
		(0.6329)	(0.0172)
Firm Type		-1.0331	9.6227***
		(0.7209)	(0.0029)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476
Adj. R-Squared	0.5707	0.5521	0.5694

Panel B: Board Size Categories	All	Complex	High Growth
	(1) Idiosyncratic Volatility	(2) Idiosyncratic Volatility	(3) Idiosyncratic Volatility
Medium Board	-2.0364***	-2.7205***	-1.5663***
	(0.0000)	(0.0000)	(0.0000)
Medium Board × *Firm Type*		-1.2866*	-1.2837*
		(0.0611)	(0.0687)
Large Board	-2.8793***	-5.3099***	-2.4122***
	(0.0000)	(0.0000)	(0.0000)
Large Board × *Firm Type*		-0.7818	-0.3123
		(0.4572)	(0.7370)
Firm Type		-1.7473***	2.8207***
		(0.0042)	(0.0001)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476
Adj. R-Squared	0.9019	0.8984	0.5682

Note. This table presents the results of regressions on the relation between board size and idiosyncratic volatility across all firms (Model (1)) as well as for the two firm types complex (Model (2)) and high-growth firms (Model (3)). Panel A includes the board size counter variable, whereas in Panel B board size is measured in categories. In each model, the dependent variable is idiosyncratic volatility, which is based on Fama–French three-factor model estimations. The firm type indicators are the dummy variables *Complex*, which is equal to one if the firm's complexity score is above the median, and *High Growth*, which is equal to one if the firm's ratio of R&D expenditures to assets is greater than the 75th percentile. The (omitted) controls are the same as in previous analyses. Variable definitions can be found in Table A.1 in the appendix. All models include industry and year fixed effects, as well as a constant term. The *p*-values are based on standard errors clustered at the firm-level and are reported in parentheses. *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively..

Table 6 Board size and volatility by six board size categories

	All	Complex	High Growth
	(1) Volatility	(2) Volatility	(3) Volatility
Board Size=8	-1.4874***	-2.1290***	-0.6597
	(0.0010)	(0.0000)	(0.2254)
Board Size=8 × *Firm Type*		-0.6104	-2.5690***
		(0.5202)	(0.0074)
Board Size=9	-2.5922***	-3.2701***	-1.8735***
	(0.0000)	(0.0000)	(0.0006)
Board Size=9 × *Firm Type*		-1.1993	-2.7942***
		(0.2139)	(0.0085)
Board Size=10	-2.8510***	-4.5313***	-2.2061***
	(0.0000)	(0.0000)	(0.0003)
Board Size=10 × *Firm Type*		-0.7344	-3.0760**
		(0.4812)	(0.0112)
Board Size=11	-2.9991***	-4.6713***	-2.5560***
	(0.0000)	(0.0000)	(0.0000)
Board Size=11 × *Firm Type*		-1.3888	-1.7095
		(0.2095)	(0.1775)
Board Size>11	-3.8950***	-7.1335***	-3.5465***
	(0.0000)	(0.0000)	(0.0000)
Board Size>11 × *Firm Type*		-0.4104	-1.4137
		(0.7321)	(0.2230)
Firm Type		-1.6312**	4.2434***
		(0.0432)	(0.0000)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476
Adj. R-Squared	0.5784	0.5673	0.5765

Note. This table presents the results of the regressions on the relation between board size and volatility, where board size is measured by six categories. In each model the dependent variable is stock return volatility. *Small Board*, *Medium Small Board*, *Medium Large Board*, *Large Board* are dummy variables that are equal to one if the board size is eight, nine, ten, or 11, respectively, and *Extra Large Board* is a dummy variable that is equal to one if board size is between 12 and 22. The firm type indicators are the dummy variables *Complex*, which is equal to one if the firm's complexity score is above the median, and *High Growth*, which is equal to one if the firm's ratio of R&D expenditures to assets is greater than the 75th percentile. The (omitted) controls are the same as in previous analyses. Variable definitions can be found in Table A.1 in the appendix. All models include industry and year fixed effects, as well as a constant term. The p-values are based on standard errors clustered at the firm-level and are reported in parentheses. *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

Table 7 Endogeneity - 2SLS

Panel A: Exemplary First Stage	All Firms	High Growth Firms	
	(1)	(2)	(3)
	Ln(Board Size)	Ln(Board Size)	Ln(Board Size) x High Growth
Ln(Industry Board Size)	0.4125***	0.4044***	-0.0446**
	(0.0000)	(0.0000)	(0.0421)
Ln(Industry Board Size) × High Growth		0.0550	0.6670***
		(0.4269)	(0.0000)
High Growth		-0.1138	0.7094***
		(0.4458)	(0.0000)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476
Adj. R-Squared	0.4560	0.4544	0.9850
F-Test of Excl. Instruments (p-value)	0.0000	0.0000	0.0000

Panel B: Board Size Counter (Second Stage)	All	Complex	High Growth
	(1)	(2)	(3)
	Idiosyncratic Volatility	Idiosyncratic Volatility	Idiosyncratic Volatility
Instr. Ln(Board Size)	-38.4429***	-42.2880***	-30.2894***
	(0.0000)	(0.0000)	(0.0000)
Instr. Ln(Board Size) × *Firm Type*		8.3215	-27.1374***
		(0.1827)	(0.0002)
Firm Type		-16.9169	60.6003***
		(0.2255)	(0.0001)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476
Adj. R-Squared	0.4484	0.4444	0.4383

(Continued)

Table 7 Continued

Panel C: Board Size Categories (Second Stage)	All	Complex	High Growth
	(1) Idiosyncratic Volatility	(2) Idiosyncratic Volatility	(3) Idiosyncratic Volatility
Instr. Medium Board	-12.3201***	-13.9241***	-7.9842***
	(0.0000)	(0.0000)	(0.0000)
Instr. Medium Board × *Firm Type*		3.4385	-23.0713***
		(0.2565)	(0.0000)
Instr. Large Board	-20.4158***	-22.8937***	-18.9520***
	(0.0000)	(0.0000)	(0.0000)
Instr. Large Board × *Firm Type*		3.8791	9.1848*
		(0.3944)	(0.0771)
Firm Type		-1.9847	10.5491***
		(0.3221)	(0.0000)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476
Adj. R-Squared	0.4863	0.4758	0.4053

This table presents the regression results for the 2SLS estimations using the industry median (mean) as instruments for our firm-level board size counter (category) variables. Panel A presents exemplary first-stage results across all firms and for high growth firms in which board size is measured as a counter variable. Panel B illustrates the second-stage results for the models including the board size counter variable and Panel C for those measuring board size in categories. The second-stage models are the same as in previous analyses, except the board variables and the interaction terms are based on their predicted values. The (omitted) controls are the same as in previous analyses. Variable definitions can be found in Table A.1 in the appendix. All models include industry and year fixed effects, as well as a constant term. The *p*-values are based on standard errors clustered at the firm-level and are reported in parentheses. *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

Table 8 Endogeneity - Dynamic panel GMM estimation

Panel A: Board Size Counter	(1) Volatility	(2) Volatility	(3) Volatility
L.Volatility	0.2839***	0.2769***	0.2983***
	(0.0000)	(0.0000)	(0.0000)
Ln(Board Size)	-15.0985*	-21.3047*	5.4623
	(0.0881)	(0.0805)	(0.7132)
Ln(Board Size) × *Firm Type*		15.1348	-81.9448**
		(0.2777)	(0.0182)
Firm Type		-33.3826	181.6434**
		(0.2779)	(0.0197)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	7,472	7,472	7,472
Wald χ^2 Statistic	32192.61	5875.44	5188.80
Number of Instruments	87	87	87
AR(1) p-value	0.0000	0.0000	0.0000
AR(2) p-value	0.5382	0.4525	0.1761
Hansen J Statistic (p-value)	0.3201	0.2456	0.1640

Panel B: Board Size Categories	(1) Volatility	(2) Volatility	(3) Volatility
L.Volatility	0.2968***	0.2887***	0.3131***
	(0.0000)	(0.0000)	(0.0000)
Medium Board	-4.7010	-8.8319**	4.6290
	(0.1755)	(0.0214)	(0.3532)
Medium Board × *Firm Type*		15.5389**	-36.3530***
		(0.0340)	(0.0009)
Large Board	-8.5055**	-2.0658	-0.7952
	(0.0304)	(0.7358)	(0.8783)
Large Board × *Firm Type*		-0.0858	-22.4652*
		(0.9927)	(0.0753)
Firm Type		-8.8383	29.1142**
		(0.1115)	(0.0177)
Controls	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Sample Size	7,472	7,472	7,472
Wald χ^2 Statistic	5575.10	5789.18	24852.38
Number of Instruments	90	92	92
AR(1) p-value	0.0000	0.0000	0.0000
AR(2) p-value	0.5196	0.4214	0.2802
Hansen J Statistic (p-value)	0.2557	0.3334	0.3540

Note. This table presents the regression results for the GMM estimations according to Wintoki et al. (2012). This analysis uses only the even years of the original sample. Panel A includes the board size counter variable, whereas in Panel B board size is measured in categories. 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 an independent variable. The (omitted) controls are the same as in previous analyses. Variable definitions can be found in Table A.1 in the appendix. All models include industry and year fixed effects, 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. *, **, and *** indicating significance levels of 10%, 5%, and 1%, respectively.

Table 9 Board size and monitoring

Panel A: All	(1) Forced Turnover	(2) Abnormal Accruals	(3) Pays Dividend	(4) Dividend/ Equity	(5) Market Leverage
Ln(Board Size)	0.0106	-0.2837	0.7025***	224.5353***	-2.8100**
	(0.9248)	(0.4484)	(0.0000)	(0.0000)	(0.0159)
Ln(Board Size) × ROA	0.0007				
	(0.4554)				
Ln(Board Size) × PME Below		-1.2234*			
		(0.0699)			
ROA	-0.0283***	0.3551***	0.0287***	14.0446***	-0.7941***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
PME Below		9.0793***			
		(0.0000)			
Controls	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Sample Size	19,348	19,177	19,375	19,150	19,476
Adj. (Pseudo) R-Squared	0.1318	0.2839	0.3186	0.2747	0.5141

(Continued)

Table 9 Continued

Panel B: Complex	(1) Forced Turnover	(2) Abnormal Accruals	(3) Pays Dividend	(4) Dividend/ Equity	(5) Market Leverage
Ln(Board Size)	-0.0103	-2.0719***	0.7343***	46.0075	1.8781*
	(0.9359)	(0.0000)	(0.0000)	(0.2879)	(0.0954)
Ln(Board Size) × Complex	0.0886	2.5933***	0.4174**	269.2768***	-9.1834***
	(0.6396)	(0.0001)	(0.0472)	(0.0005)	(0.0000)
Ln(Board Size) × ROA	0.0024*				
	(0.0647)				
Ln(Board Size) × Complex × ROA	-0.0133**				
	(0.0220)				
Complex × ROA	0.0257**				
	(0.0496)				
Ln(Board Size) × PME Below		0.9697			
		(0.2951)			
Ln(Board Size) × Complex × PME Below		-3.7516**			
		(0.0190)			
Complex × PME Below		7.7947**			
		(0.0288)			
ROA	-0.0311***	0.3450***	0.0326***	11.4350***	-0.7179***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
PME Below		4.6950**			
		(0.0152)			
Complex	-0.2491	-5.3741***	-0.7048	-451.7719***	32.9412***
	(0.5556)	(0.0003)	(0.1279)	(0.0085)	(0.0000)
Controls	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Sample Size	19,348	19,177	19,375	19,150	19,476
Adj. (Pseudo) R-Squared	0.1335	0.2835	0.3136	0.2601	0.5567

(Continued)

Table 9 Continued

Panel C: High Growth

	(1) Forced Turnover	(2) Abnormal Accruals	(3) Pays Dividend	(4) Dividend/ Equity	(5) Market Leverage
Ln(Board Size)	-0.0554	0.7158*	0.7108***	229.2935***	-2.1760
	(0.6607)	(0.0720)	(0.0000)	(0.0000)	(0.1153)
Ln(Board Size) × High Growth	0.1791	-3.9470***	0.1088	13.1409	-2.1271
	(0.3358)	(0.0000)	(0.6793)	(0.8691)	(0.2209)
Ln(Board Size) × ROA	-0.0003				
	(0.7686)				
Ln(Board Size) × High Growth × ROA	-0.0056				
	(0.3000)				
High Growth × ROA	0.0177				
	(0.1006)				
Ln(Board Size) × PME Below		-2.4278***			
		(0.0016)			
Ln(Board Size) × High Growth × PME Below		3.3706**			
		(0.0223)			
High Growth × PME Below		-8.0190**			
		(0.0113)			
ROA	-0.0299***	0.3594***	0.0293***	13.6908***	-0.7545***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
PME Below		11.9585***			
		(0.0000)			
High Growth	-0.3611	7.7653***	-0.6625	23.4390	-1.8279
	(0.3783)	(0.0000)	(0.2526)	(0.8908)	(0.6292)
Controls	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Sample Size	19,348	19,177	19,375	19,150	19,476
Adj. (Pseudo) R-Squared	0.1343	0.2866	0.3160	0.2713	0.5100

This table presents the results of regressions on the relation between board size and a variety of firm outcomes that are related to monitoring activities. While Panel A illustrates the results across all firms, Panel B and C show the results for the two firm types complex and high-growth firms, respectively. The dependent variables comprise the dummy variable *Forced Turnover* that is equal to one if a firm experiences a forced turnover, *Abnormal Accruals*, the dummy variable *Pays Dividend*, the ratio *Dividend/Equity*, and *Market Leverage*. *PME Below* is a dummy variable that is equal to one if pre-managed earnings are below last year's earnings. The remaining variables, including the (omitted) controls, are the same as in previous analyses. Variable definitions can be found in Table A.1 in the appendix. All models include industry and year fixed effects, as well as a constant term. Models (1) and (3) are probit models. The *p*-values are based on standard errors clustered at the firm-level and are reported in parentheses. *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.

Table 10 Board size and innovation across all firms

Panel A: All	(1) Ln(1+Number of Patents)	(2) Ln(1+Number of Citations)	(3) Ln(1+Total Value of Patents)	(4) Total Value of Patents/R&D	(5) Ln(Value/ Patent)
Ln(Board Size)	0.1584	0.1302	0.2450	-163.7484	-0.1445*
	(0.1396)	(0.4093)	(0.1852)	(0.2490)	(0.0996)
Controls	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476	9,546	8,744
Adj. R-Squared	0.5952	0.5659	0.6049	0.2562	0.6628
Panel B: Complex	(1) Ln(1+Number of Patents)	(2) Ln(1+Number of Citations)	(3) Ln(1+Total Value of Patents)	(4) Total Value of Patents/R&D	(5) Ln(Value/ Patent)
Ln(Board Size)	1.2026***	1.4890***	2.1954***	350.6060**	1.1688***
	(0.0000)	(0.0000)	(0.0000)	(0.0101)	(0.0000)
Ln(Board Size) × Complex	0.0610	0.0500	0.3991	345.4001	-0.0538
	(0.7624)	(0.8634)	(0.2710)	(0.1425)	(0.7804)
Complex	0.3993	0.5950	0.2043	-544.9045	0.7754*
	(0.3816)	(0.3650)	(0.8020)	(0.2928)	(0.0708)
Controls	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476	9,546	8,744
Adj. R-Squared	0.5105	0.5014	0.4993	0.2144	0.4733
Panel C: High Growth	(1) Ln(1+Number of Patents)	(2) Ln(1+Number of Citations)	(3) Ln(1+Total Value of Patents)	(4) Total Value of Patents/R&D	(5) Ln(Value/ Patent)
Ln(Board Size)	-0.2890**	-0.3296*	-0.2065	198.9330	0.2087*
	(0.0162)	(0.0573)	(0.3170)	(0.2811)	(0.0604)
Ln(Board Size) × High Growth	1.6770***	1.6380***	1.7128***	-654.6353***	-0.7542***
	(0.0000)	(0.0000)	(0.0000)	(0.0053)	(0.0000)
High Growth	-2.3969***	-1.7950***	-1.9414***	1201.8198**	1.5887***
	(0.0000)	(0.0082)	(0.0092)	(0.0152)	(0.0000)
Controls	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes
Sample Size	19,476	19,476	19,476	9,546	8,744
Adj. R-Squared	0.6068	0.5729	0.6036	0.2587	0.6648

Note. This table presents the results of regressions on the relation between board size and a variety of innovation outcomes. While Panel A illustrates the results across all firms, Panel B and C show the results for the two firm types complex and high-growth firms, respectively. The dependent variables are based on the data from Kogan et al. (2017) and comprise *Ln(1+Number of Patents)*, *Ln(1+Number of Citations)*, *Ln(1+Total Value of Patents)*, the ratio *Total Value of Patents/R&D)*, and *Ln(Value/Patent)*. The remaining variables, including the (omitted) controls, are the same as in previous analyses. Variable definitions can be found in Table A.1 in the appendix. All models include industry and year fixed effects, as well as a constant term. The p-values are based on standard errors clustered at the firm-level and are reported in parentheses. *, **, and *** indicate significance levels of 10%, 5%, and 1%, respectively.