Is Small and Independent Board A Better Board? An Example of High-tech Firms

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Abstract

This paper examines board structure and the effect of board size and composition on firm value for firms in high technology industries for the period 1995-2008. I find that high-tech firms, generally characterized by asymmetric information and growth opportunities, have board sizes 2.9% smaller and a proportion of insiders 1.7% higher than non high-tech firms. Using Tobin's *Q* as a measure of firm value, I document that Tobin's *Q* is increasing in board size for high-tech firms. This result is consistent with the argument that transaction costs, such as political pressure from regulators and institutional investors, as well as listing requirements set by the SEC and major stock exchanges, may impede board upsizing for high-tech firms. My findings indicate that a uniform "one size fits all" reform of corporate boards may impair board effectiveness in some types of firms.

I. Introduction

Agency theory argues that managers tend to choose projects that are not always in the best interest of shareholders (Jensen, 1986). The board of directors of a corporation, performing its functions of advising and monitoring top management, is one of the internal governance mechanisms to control agency conflicts between managers and shareholders. Numerous studies in the field of corporate governance explore the structure and efficiency of boards and suggest that the size of the board and the level of board independence affect the board's ability to perform its important functions. Various characteristics of firms or the context in which they operate may affect the board structure (Linck, Netter and Yang, 2008; Coles, Daniel, and Naveen, 2008). Given the high-growth, high-risk nature of tech-intensive industries, one might wonder whether the board structure in high-tech firm differs from the board structure in non high-tech firms. I answer this question by exploring the board structure and the effect of board structure on firm performance for firms in high-technology industries.

I answer this question for three reasons. First, though conventional wisdom suggests that smaller boards are more effective because large boards suffer coordination and free-rider problems (Jensen, 1993; Lipton and Lorsch, 1992), we still observe large boards. Apparently, no single board structure fits all firms optimally (Hermalin, 1994; Kole, 1997; Hermalin and Wallace, 2001). This study shows that the industry type could affect the size of the board.

Second, I respond to the on-going controversy among academics, practitioners and regulators on board independence. Independence boards can better curtail agency conflicts because outside directors are better monitors than inside directors. Along this line, Weisbach (1988) finds that CEO turnover is more sensitive to firm performance than it is in firms with less independent boards. Klein (2002) and Petra (2007) show that independent directors improve earnings quality.

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In practice, SEC requires firms to maintain board independence and Sarbanes-Oxley Act of 2002 requires that audit committees of boards have a majority of independent directors. Despite the widespread call for board reform, firms persist in having boards with a higher proportion of insiders. I show that technology-intensive industries, characterized by severe information asymmetry, may prefer a board with fewer outsiders. Taken together, results suggest that industry type affect the board composition including the size and the level of independence of a board.

Third, although prior studies document the relation between firm performance and board structure, studies on the relation between firm value and board independence generate mixed results. I investigate whether the relation between firm value and board composition can be explained by industry characteristics with regard to tech-intensity[1]. I find that increases in board size for high-tech firms result in increases in firm value, measured by Tobin's *Q*.

High-tech industries such as pharmaceuticals, computers, and electronics have emerged as leaders in the economy through their extreme competition and potential for future growth. Prior research has indicated that more than half of the total GDP in the wealthy economies of the world is based on high-tech industries (Kohers and Kohers, 2000). High-tech firms exhibit a high level of asymmetric information and growth opportunities (Francis and Schipper, 1999). These firm characteristics are associated with higher costs to verify the quality of projects for outsiders (Smith and Watts, 1992; Gaver and Gaver, 1993). The costs of information loss in having more outsiders may outweigh the benefits of having more outsiders to efficiently monitor management actions and give valuable advice; and therefore, high-tech firms should have smaller boards. Harris and Raviv (2008) argue that higher number of inside directors encourages CEOs to share information with outsiders, reducing the costs of information share. Therefore, boards in firms where information possessed only by insiders should have few outsiders. Taken together, I posit that smaller boards and a higher percentage of insiders are optimal for high-tech firms.

Using a sample of 14,131 firm-year observations over the period of 1995-2008, I find that high-tech firms have a board size 2.9% smaller and a proportion of insiders 1.7% higher than non high-tech firms. A closer look reveals that high-tech firms have a smaller number of both insiders and outsiders. For example, the coefficient estimates indicate that the number of insiders and the number of outsiders is 5.7% and 2.5% smaller for high-tech firms compared to non high-tech firms, respectively. These estimates are consistent with the findings of Denis and Sarin (1999) in that firms with greater growth opportunities have smaller boards with a smaller percentage of outsiders.

Next, I explore the relation firm value and board composition in high-tech industries. Any deviation from optimal board size may reduce firm value (see Coles et al., 2008). High-tech firms are likely to be younger firms and smaller in size relative to non high-tech firms. As firms grow, board size grows accordingly. However, transaction costs, such as political pressure from listing requirements set by the SEC and major national stock exchanges, as well as pressures from regulators and institutional investors, are likely to impede board upsizing. Therefore, high-tech firms tend to have smaller boards than optimal. Empirically, I should find increases in board size for high-tech firms result in increases in Tobin's *Q*.

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[1] Using a sample of 435 European firms, Andres and Rodriquez (2011) find that larger and less independent boards may enhance firm performance in high-tech industries.

Using Tobin's *Q* as a measure for firm value, I document that Tobin's *Q* is increasing with board size for high-tech firms. Moreover, adding insiders to the board has an even stronger positive effect on Tobin's Q than adding outsiders. Therefore, the previously documented negative relation between Tobin's *Q* and board size does not hold for high-tech firms. These results are consistent with the argument that, due to transaction costs, high-tech firms are likely to have smaller board sizes, measured by both insiders and outsiders, than the sizes that maximize firm value.

This paper complements and extends recent studies in several ways. First, I document that board size and composition in high-tech firms are significantly different from non high-tech firms in that high-tech firms have smaller boards with significantly fewer outside directors and significantly more insiders. These results are consistent with the argument that board size and composition vary across firms depending on the costs and benefits of the monitoring and advising roles of the boards (Denis and Sarin, 1999; Gillan, Hartzell, and Starks, 2003; Lehn, Patro, and Zhao, 2004; Boone, Field, Karpoff, and Raheja, 2007; Coles et al., 2008; Linck et al., 2008). Second, for high-tech firms, firm value is increasing with board size. Adding insiders has an even stronger positive effect on firm value than adding outsiders. This finding complements the results in Coles et al. (2008).[2]

My findings have important implications for policy makers regarding the reform of corporate boards. It appears that a generalized approach to board reform, such as specifying that all firms should have smaller and independent boards, may impair the effectiveness of boards for some firms. Advocates of smaller boards with larger numbers of outsiders appear to underestimate the information advantage of having a larger number of insiders on the board and the costs of having larger numbers of outsiders for firms with high growth opportunities and greater information asymmetry.

II. Literature review

A. Board size and high-tech firms

One of the main internal corporate governance mechanisms is board of directors and this mechanism has received vast attention from researchers. Literature documented two main roles of board of directors: monitoring and advising the management (see, for example, Adams and Ferreira, 2007). The monitoring role of boards can be compared to watchdog as directors monitor managers' action to ensure that manager is acting in the best interest of shareholders (Fama, 1980; Hermalin and Weisbach, 1998). In the advising role, boards take a more hands-off process by depending upon the expertise of its members to counsel management on the firm's strategic direction (Fama and Jensen, 1983).

The existing literature indicates that corporate board size is determined by the trade-off between the costs and benefits associated with the monitoring and advising roles of directors (Raheja, 2005; Adams and Ferreira, 2007; Boone et al., 2007; Coles et al., 2008; Linck et al., 2008, Harris and Raviv, 2008). The net benefits of monitoring increase with managers' opportunities to

[2] Coles et al. (2008) note that there is a positive relation between the proportion of insiders on the boards and firm value for firms with high R&D expenditures.

consume private benefits but decrease with the cost of monitoring. Managers on boards are better informed concerning the quality of projects, and outsiders must use managers' private information to monitor them. In noisy environments, managers may be reluctant to share information with outsiders because the more information outsiders have the more intensively they will monitor managers (Demsetz and Lehn, 1985; Gillan et al., 2003; Linck et al., 2008).

High-tech firms exhibit a high degree of asymmetric information between managers and shareholders (Benou, Gleason, and Madura, 2007). The technologies in high-tech firms are unique and not readily understandable to persons without highly specialized knowledge, thereby leading to greater levels of information asymmetry. High-tech firms also have more growth opportunities, and the cost of verifying the quality of the projects increases with the level of growth opportunities (Smith and Watts, 1992; Gaver and Gaver, 1993; Lehn et al., 2004). Therefore, the cost of monitoring is higher for high-tech firms relative to non high-tech firms. To the extent that the cost of monitoring of having a large board outweighs the benefits, high-tech firms should have smaller boards. Lastly, high-tech firms tend to operate in more volatile business environments with frequent technological changes and unstable market valuation. Managers need to manage their assets aggressively in order to keep pace with technological change. Therefore, high-tech firms desire corporate board structures that facilitate rapid decision-making. As the cost of altering corporate strategy is inversely related to board size,[3] high-tech firms should have smaller boards.

H_1. High-tech firms are associated with smaller boards than non high-tech firms.

B. Board composition and high-tech firms

Board composition has been at the core of numerous studies in the field of corporate governance. Scholars and regulators agree that a board is independent when the board has more outside directors. Fahlenbrach, Low, and Stulz (2010) note that in a large number of countries, laws or regulations require a fraction of the corporate board to be composed of independent outside directors based on the assumption that the interests of independent outside directors are better aligned with those of minority shareholders than the interests of inside directors. Outside directors are considered to be the crucial corporate governance mechanism for monitoring managers (Bhagat, Bolton and Romano, 2008). Prior studies show that having outside directors on the boards improves monitoring and advising functions of boards as outside directors on the board increases the independence of the board. Similarly, the major stock exchanges either mandate or highly recommend that the three principal monitoring committees (audit, compensation, and nominating) be entirely staffed with independent directors, while Section 301 of the Sarbanes-Oxley Act of 2002 (SOX) requires the same for the audit committee (Faleye, Hoitash, and Hoitash, 2011). Both the New York Stock Exchange (NYSE, since 1978) and NASDAQ (since 1989) require companies whose stock is traded on their exchanges to have at least two independent directors on their boards (Coles et al., 2008). Fama and Jensen (1983) argue that outside directors tend to be more effective monitors than inside directors as generally they are the key decision makers at other organizations who are concerned with their reputations in the managerial labor-market.

[3] Kole and Lehn (1999) report that board sizes of airline firms declined after industry deregulation in 1978, supporting this argument as deregulation leads to a more volatile business environment. Similarly, Frye and Smith (2003) find that regulated firms increase their board sizes more than unregulated firms following initial public offerings.

Evaluating the CEO and replacing him if his performance is poor is one of the main functions of board (Coles et al., 2008). Hermalin and Weisbach (1998) offer on board-specific model where they focus on two primary monitoring duties of the corporate boards: the hiring and the firing of the management. Weisbach (1988) reveal that CEO turnover is more sensitive to firm performance when boards are dominated by outside directors. He attributes this evidence to the fact that it can be costly for inside directors to challenge the CEO to whom their careers are tied. In UK, Cadbury Committee issued the Code of Best Practice in 1992 which recommends that boards of U.K. firms include at least three outside directors on their boards. Dahya, McConnell, and Travlos (2002) find that UK Firms that adopted the recommendations show a greater sensitivity of CEO turnover to performance than non-adopting firms. These studies consistenly point out that outside directors have an incentive to be effective monitors to signal to shareholders and labor markets their value as directors (Fama, 1980; Fama and Jensen, 1983).
Brickley, Coles, and Terry (1994) examine the impact of the board on the decision to adopt a poison pill. Brickley et al. (1994) find that the average stock market reaction to poison pills is positive when the board includes a majority of independent directors and negative when it does not. They conclude that outside directors serve the interests of shareholders based on this empirical finding. Cotter, Shivdasani, and Zenner (1997) analyze the role of the target firm's independent outside directors during takeover attempts by tender offer. Cotter et al. (1997) report that when a target's board includes a majority of outside independent directors, the target receives a return approximately 20 percentage points higher than that of a similar firm without a majority of outside independent directors on the board. Marciukaityte, Szewczyk, and Varma (2009) find that independent directors increase the likelihood of voluntary restatements and the stock performance following restatements recovers fast with the presence of independent boards. Uzun, Szewczyk, and Varma (2004) examine how different characteristics of the board of directors affect the occurrence of U.S. corporate fraud in the 1978-2001 period. They find that as the number of independent outside directors increases on a board, the likelihood of corporate wrongdoing decreases. In sum, these studies suggest that market view independent directors as an internal governance mechanism to overcome agency conflicts. Insiders on boards are better informed of the value of the potential projects. Therefore, larger numbers of insiders on the board can lead to more effective decision-making. Outsiders on the board need to use insiders' private information to monitor mangers' decisions. However, the more information outsiders have, the more intensively they will monitor managers. To insiders, the decision on whether to share information with outsiders depends on the trade-off between the benefits and costs associated with sharing information. To avoid intensive monitoring, they may choose not to share information, resulting in a higher cost of monitoring and advising (see Adams and Ferreira, 2007).

Raheja (2005) and Harris and Raviv (2008) model board structure as a trade-off between agency costs of greater insider information and coordination costs of greater outsider representation. A higher number of inside directors encourages insiders to share information with outsiders, who use information to give advice. The quality of the advice depends on the quality of information outsiders receive from insiders. In cases when insiders have important information relative to that of outsiders, a greater proportion of outside directors on the boards may reduce the private information of insiders to be shared with outsiders. This loss of information increases the coordination costs of the boards, which are likely to be more costly than the agency costs associated with a less independent board. Empirically, Lehn et al. (2004), Linck et al. (2008), and Boone et al. (2007) show that high-growth firms with greater information asymmetry have smaller boards with a high proportion of inside directors because the costs of information share is higher than the agency costs. Coles et al. (2008) find that the proportion of insiders is positively related to the firm's research and development expenditures. I propose, for firms with high information asymmetry, such as high-tech firms, it is optimal to have a higher fraction of insiders on the board because insiders' information brings more value to firms than could be achieved with an independent board.

H_2. High-tech firms are associated with a higher proportion of inside directors on the boards than non high-tech firms.

C. The effect of board size and composition on firm performance in high-tech firms

Previous studies document a negative relation between board size and firm performance. Yermack (1996) and Eisenberg, Sundgern, and Wells (1998) find that smaller boards are associated with higher firm performance. Using a sample of Malaysian and Singapore firms, Mak and Kusnadi (2005) find the inverse relationship between board size and firm value in both countries. However, studies on the relation between firm performance and board composition find mixed results. Rosenstein and Wyatt (1990) find that on average there is a statistically significant 0.2 percent increase in stock prices in response to the announcement of adding outside directors' to the board. Byrd and Hickman (1992) find that bidding firms in which at least 50 percent of the directors are independent outside directors exhibit significantly higher announcement-date abnormal returns than other bidders. This result indicates that the market identifies firms with independent outside directors as making better acquisitions (Hermalin and Weisbach, 2003). Weisbach (1988), Brickley et al. (1994), and Cotter et al. (1997) document that a higher level of board independence increases firm value in some circumstances. Hermalin and Weisbach (1991), Mehran (1995), Klein (1998), and Bhagat and Black (2001) find no relation between the proportion of outside directors on the board and firm value, as measured by Tobin's *Q*. Yermack (1996) and Agrawal and Knoeber (1996) report a significant negative relation between proportion of independent directors and Tobin's *Q*. Barnhart and Rosenstein (1998) document an inverted-U relation between Tobin's *Q* and proportion of independent directors, implying that Tobin's *Q* is lower for firms with either less or highly independent directors.

A fundamental issue in the studies of the effect of corporate board on firm value is whether the empirical findings are driven by the endogeneity of board structure and/or the causality problems. Studies argue that the attributes of boards are endogenously determined by firm characteristics in ways consistent with value maximization (Boone et al., 2007; Coles et al., 2008; Linck et al., 2008). When transaction costs of re-contracting are small, firms and managers contract optimally, and corporate governance mechanisms are set at or near the value-maximizing level, on average (Demsetz and Lehn, 1985; Coles, Lemmon, and Meschke, 2006). Hence, any observed relation between corporate board structure and firm value arises because the firm's environment is inadequately captured. Furthermore, Hermalin and Weisbach (1998) indicate that it is the poor performance leading to increases in board independence rather than board independence decreasing firm value. Therefore, empirically, one could find a negative association or no association at all between board independence and firm value even though board independence actually increases firm value.

When examining the relation of firm value and managerial ownership, Core and Larcker (2002) propose the transaction cost theory. They argue that it is inappropriate to implicitly assume that adjustment costs are so small that firms can continuously re-contract. Likewise, Coles et al. (2008) posit transaction cost impedes the adjustment of board size and composition towards their optimum in both firms with high R&D expenditures and firms with greater complexity. Applying the same reasoning to the case of firms in the high-tech industries, I argue that high-tech firms can only periodically re-optimize board size and composition when they deviate from the optimal level, and any deviations may result in a reduction in firm value.

Studies find that there is an inverted-U relation between board size and Tobin's *Q* (Lipton and Lorsch, 1992; Coles et al., 2008). Applying their study to high-tech industries, I assume that there is an inverted-U relation between Tobin's *Q* and board size. On the one hand, in a case involving sub-optimal board size that is below optimal, increasing board size leads to higher firm value. On the other hand, when sub-optimal board size is above the optimal level, increasing board size leads to lower firm value. Empirically, Coles et al. (2008) find that firms cannot adjust their board structure quickly enough to be optimal, and Tobin's *Q* increases with the proportion of insiders on boards for high R&D-intensive firms.

Because of the transaction costs, board size deviates from its optimal. If deviations from optimal board sizes are random, that is, board sizes can be either smaller or larger than the optimal, I would detect no relation, a positive relation, or a negative relation between Tobin's *Q* and board size. Suppose that deviations from optimal board sizes are not random, however. More specifically, if high-tech firms tend to have smaller boards than optimal, I would observe only the part of the inverted-U relation that is to the left side of the optimum. Empirically, I should find a positive relation between Tobin's *Q* and board size for high-tech firms.

The question now turns to why high-tech firms tend to have smaller boards than optimal. First, boards grow slowly in response to the increasing net benefits of monitoring and advising functions by board members (Lehn et al., 2004). High-tech firms are likely to be younger firms and smaller in size relative to non high-tech firms. In my sample, the mean (median) log of total assets is 7.25 (6.99) for high-tech firms, while it is 7.61 (7.43) for non high-tech firms, with the difference statistically significant at the 1% level. Second, transaction costs of adding board members potentially impede upsizing. A good example of transaction costs would be political pressure from a variety of sources, including listing requirements promulgated by the SEC and major stock exchanges, the press, regulators, institutional investors, business groups such as the Conference Board and Business Roundtable, and even academia (Coles et al., 2008). For instance, Wu (2004) attributes the reduction in board size in the 1990s to institutional pressure. Lipton and Lorsch (1992) and Jensen (1993) argue that smaller boards are likely to dominate larger boards because of the coordination and director free-rider problems associated with larger boards. Another example of transaction cost would be the dollar cost associated with adding a board member. Yermack (2004) finds that directors' wealth increases approximately 11 cents per each $1,000 increase in firm value and about $285,000 for a 1 standard deviation change in firm value. Taken altogether, the various constraints are likely to prevent board structure of high-tech firms from adjusting to its optimal. This argument leads to the following hypothesis.

H_3. Tobin's Q is positively related to board size for high-tech firms.

Board reform proposed by regulators has increased independent director representation on board. Due to the substantial transaction cost, firms are reluctant to let go of directors. To increase the board independence, firms choose to add more outside directors rather than firing existing inside directors (Dahya et al., 2002; Linck et al., 2005). Consequently, the percentage of independent directors is likely to be less than its optimum. As firms in high-tech industries are associated with greater information asymmetry, adding more outside directors are more likely to lead to unbalanced power between insiders and outsiders, resulting in poor information-sharing for directors to perform both monitoring and advising functions. Moreover, the insiders are likely to be engineers or experts in their field in high-tech firms, thus, they can provide CEOs with more valuable insights on firm strategic planning. As such, I propose, although it is optimal for high-tech firms to have more insiders on the boards than non high-tech firms, this is less likely to be the case. Hence, adding more insiders to the board should increase firm value.

H_4. Tobin's Q is positively related to the number of insiders on the boards for high-tech firms.

III. Sample selection and data

A. Sample selection

My initial sample includes all firms in Compustat during the sample period 1995-2008. This sample is merged with Risk Metrics and Equilar to obtain board of director data. CEO characteristics, such as age, stock incentives, and year of tenure, are from Execucomp. Stock return data is from CRSP (Center for Research on Security Prices). All the observations with missing value for key variables are excluded. The full sample, including both high-tech firms and non high-tech firms, includes 14,131 firm-year observations.[4] When examining the relation between Tobin's *Q* and board structure for high-tech firms, I restrict the sample by including only high-tech firms, resulting in a sub-sample of 2,828 firm-year observations.

B. High-tech industries

Following Francis and Schipper (1999), I classify high-tech firms as firms having significant unrecorded intangible assets. Specifically, high-tech firms operate in such industries as pharmaceuticals, computer and electronics manufacturing, telecommunications, and software. Table I reports the three-digit SIC codes and names of the industries for high-tech firms.

[4] Excluding financial firms (SIC Codes 6000 to 6999) and utilities firms (SIC Codes 4000 to 4999) does not alter my results.

Table I: Classification of High-tech Industries

High-Technology Industries	
283	Drugs
357	Computer and Office Equipment
360	Electrical Machinery and Equipment, Excluding Computers
361	Electrical Transmissions and Distribution Equipment
362	Electrical Industrial Apparatus
363	Household Appliances
364	Electrical Lighting and Wiring Equipment
365	Household Audio, Video Equipment, Audio Receiving
366	Communication Equipment
367	Electronic Components, Semiconductors
368	Computer Hardware (Including Mini, Micro, Mainframes, Terminals, Discs, Tape Drivers, Scanners, Graphics Systems, Peripherals, and Equipment)
481	Telephone Communications
737	Computer Programming, Software, Data Processing
873	Research, Development, Testing Services

C. Variable construction

Board structure is measured by size and composition. Board size is measured by the number of directors (including both insiders and outsiders), and board composition is measured by the proportion of insiders on the board. Following the existing literature, I classify all directors who are employees of the firm as inside directors, and outsiders are board size minus insiders (Borokhovich, Parrino, and Trapani, 1996; Huson, Parrino, and Starks, 2001; Lehn et al., 2004; Coles et al., 2008; Linck et al., 2008). The proportion of insiders is the number of insiders scaled by the board size.

Firm value is measured by Tobin's *Q*, which is computed as book assets minus book equity plus market value of equity, all scaled by book assets. Hermalin and Weisbach (1998) suggest that board independence decreases with the CEO's bargaining power. To the extent that the CEO's bargaining power increases through operating performance and CEO tenure, board independence should decrease with operating performance and CEO tenure. Raheja (2005) argues that the number of outsiders increases as the CEO's influence increases. I use CEO age to proxy for the CEO's influence (Hermalin and Weisbach, 1998, Linck et al., 2008). Studies indicate that costs of monitoring increase with growth opportunities and the level of asymmetric information. Growth opportunities are proxied by intangible assets. Fama and Jensen (1983) indicate that firms with high stock return volatility are more likely to have private information unknown to outsiders. Accordingly, I use the standard deviation of monthly stock returns over the past three years to proxy for the level of asymmetric information. The benefits of advising increase with the complexity of firms in that highly complex firms benefit more from outsiders with a range of expertise (Coles et al., 2008; Linck et al., 2008). I use firm age and leverage to measure the complexity of firms' operating environment (Fama and Jensen, 1983; Booth and Deli, 1999; Boone et al., 2007; Coles et al., 2008; Linck et al., 2008). The benefits of monitoring increase with the level of private benefits available to managers (Raheja, 2005; Adams and Ferreira, 2007), and therefore I use free cash flow to proxy for private benefits (Jensen, 1986). Appendix A provides more detailed definitions of the variables.

D. Descriptive statistics

Table II presents descriptive statistics for all sample firms on key variables. Results are comparable with those reported in the existing literature, with some small differences due to different sample periods and sample selection methods. The mean (median) number of board members is 9.4 (9), compared to the observation of 10-12 in other studies (Bhagat and Black, 2001; Huson et al., 2001; Yermack, 1996; Coles et al., 2008). The mean (median) proportion of insiders on the board is 32.31% (30%), which is consistent with Linck et al. (2008) who observed an average insider fraction of 34.3%. Both the mean and the median number of insiders on the board are 3, and the mean (median) number of outsiders is 6.4 (6).

Table II: Descriptive Statistics

			Percentiles				
	Mean	Standard Deviation	Min	p25	Median	p75	Max
Board characteristics							
Board size	9.4388	2.5321	3.0000	8.0000	9.0000	11.0000	39.0000
Percentage of insiders	0.3231	0.1724	0.0000	0.1818	0.3000	0.4286	1.0000
Insiders	3.0203	1.8653	0.0000	2.0000	3.0000	4.0000	31.0000
Outsiders	6.4468	2.3947	0.0000	5.0000	6.0000	8.0000	23.0000
CEO characteristics							
CEO tenure	8.4134	7.3478	0.0000	3.0000	6.0000	11.0000	58.0000
CEO age	55.9914	7.3410	34.0000	51.0000	56.0000	61.0000	92.0000
CEO PPS	1.4139	12.5741	0.0000	0.0871	0.2425	0.6829	709.8297
Firm characteristics							
Tobin's *Q*	2.0220	1.5628	0.4037	1.2108	1.5616	2.2311	39.1199
Intangible assets	0.6898	0.2335	0.0297	0.5386	0.7525	0.8750	1.0000
R&D expenditure	0.0487	0.3725	0.0000	0.0000	0.0000	0.0305	29.7258
Capital expenditure	0.0837	0.1443	-0.0429	0.0242	0.0438	0.0863	4.2829
Leverage	0.2375	0.1763	0.0000	0.0949	0.2325	0.3488	1.7433
Firm age	34.3900	19.9251	1.0000	18.0000	29.0000	43.0000	85.0000
Firm risk	0.3854	0.1967	0.0842	0.2492	0.3392	0.4683	2.2125
ROA	0.1424	0.0967	-1.1705	0.0937	0.1363	0.1889	0.9651
Free cash flow	0.0832	0.0782	-1.3302	0.0488	0.0824	0.1181	0.6024

The mean (median) years for CEO tenure is 8.4 (6), consistent with Linck et al. (2008). The mean (median) CEO age is 55.99 (56), which is consistent with Faleye (2007), Fee and Hadlock (2004), and Linck et al (2008). All three studies report a mean CEO age of 55. CEO pay performance sensitivity (PPS) is measured as the dollar change in CEO wealth for a percentage change in firm value, divided by 100,000. On average, a CEO has a PPS of 1.42. The mean (median) value of Tobin's *Q* is 2.02 (1.56), which is very close to the observation in Linck et al. (2008), who report that Tobin's *Q* has a mean value of 2.29 and median value of 1.47. The mean (median) firm age is 34.39 (29), which is less than the same measures for the sample firms used by Lehn et al. (2004), and greater than the same measures for the sample firms used by Boone et al. (2007).

IV. Univariate analysis

Panel A of table III presents the differences in board, CEO, and firm characteristics between high-tech firms and non high-tech firms. The average board size is 8.49 for high-tech firms and 9.68 for non high-tech firms. On average, high-tech firms have board size significantly smaller than non high-tecg firms by 1.19, a difference significant at the 1% level. The difference in board size is the result of the lower number of both insiders and outsiders on the board of high-tech firms relative to non high-tech firms. High-tech firms have a slightly higher proportion of insiders than non high-tech firms (32.81% versus 32.25%) and the difference is significant at the 10% level. Taken together, these results are consistent with hypothesis 1 and 2 that high-tech firms have higher monitoring costs and therefore, require smaller boards with a higher proportion of insiders.

CEOs in high-tech firms have longer years in tenure, suggesting that CEOs have stronger bargaining power. High-tech firms spend significantly more on intangible assets and research and development as percentages of total sales than non high-tech firms. For example, the proportion of intangible assets of total assets is 14.36% higher for high-tech firms than for non high-tech firms. On average, high-tech firms invest 17.97% of total assets in R&D compared to 1.57% for non high-tech firms, difference significant at the 1% level. Higher intangible assets and R&D expenditures indicate a higher level of asymmetric information and growth opportunities, thereby suggesting high-tech firms require smaller and less independent boards.

Table III: Univariate Results: Panel A

	Mean			Median		
	[I] High-tech firms	[II] Other firms	[I]-[II] (t-statistics)	[I] High-tech firms	[II] other firms	[I]-[II] (Z-value)
Board size	8.4894	9.6777	-1.1883***	8.0000	9.0000	-1.0000***
			(-22.70)			(24.57)
Percentage of insiders	0.3281	0.3225	0.0056*	0.3000	0.2857	0.0143*
			(1.83)			(1.63)
Outsiders	5.7740	6.6104	-0.8363***	5.0000	7.0000	-2.000***
			(-16.74)			(17.98)
Insiders	2.7341	3.0979	-0.3638***	2.0000	3.0000	-1.000***
			(-9.29)			(9.28)
CEO tenure	8.7815	8.3088	0.4727***	6.0000	6.0000	0.0000***
			(3.06)			(2.80)
CEO age	54.0916	56.4603	-2.3687***	54.0000	56.0000	-2.0000***
			(-15.47)			(-14.99)
Intangible assets	0.8050	0.6614	0.1436***	0.8421	0.7198	0.1224***
			(30.17)			(-28.22)
R&D expenditures	0.1797	0.0157	0.1640***	0.0954	0.0000	0.0954***
			(21.36)			(64.39)
Firm risk	0.5194	0.3518	0.1677***	0.4710	0.3201	0.1509***
			(43.19)			(35.42)
Firm age	28.3052	35.9381	-7.6329***	24.0000	37.0000	7.0000***
			(-18.43)			(-18.98)

Panel B presents the relation between Tobin's *Q* and board structures for high-tech firms. High-tech firms are sorted based on whether they have a board size above the sample median (large board) or below the sample median (small board), whether they have a proportion of insiders above the sample median (high insider proportion) or below the sample median (low insider proportion), whether they have a number of insiders above the sample median (high number of insiders) or below the sample median (low number of insiders), and whether they have a number of outsiders above the sample median (high number of outsiders) or below the sample median (low number of insiders). On average, firms with large boards have a Tobin's *Q* of 2.9, while firms with small boards have Tobin's *Q* of 2.75, the difference between these two values is statistically significant at the 10% level. Tobin's *Q* is higher for firms with a higher proportion of insiders on the boards (3.01) compared with those with a lower proportion of insiders (2.67). The difference is statistically significant at the 1% level. Tobin's *Q* is higher for firms with a higher number of insiders than those with lower number of insiders, and for firms with a lower number of outsiders than those with a higher number of outsiders. In both cases, the differences are statistically significant at the 1% level. Similar results can be obtained when the median value of Tobin's *Q* is examined. The results from Panel B are consistent with the hypotheses that Tobin's *Q* is positively related to firm size and the number of insiders on the board for high-tech firms.

Table III: Univariate Results: Panel B

Mean		[I]-[II] (t-statistics)	Median		[I]-[II] (Z-value)
[I] Small board	[II] Large board		[I] Small board	[II] Large board	
2.7528	2.9009	-0.1480* (-1.63)	2.0697	2.1310	-0.0613 (-0.60)
[I] Low insider proportion	[II] High insider proportion		[I] Low insider proportion	[II] High insider proportion	
2.6693	3.0082	-0.3389*** (-3.75)	2.0357	2.1868	-0.1511*** (-3.14)
[I] Low number of insiders	[II] High number of insiders		[I] Low number of insiders	[II] High number of insiders	
2.6662	3.0384	-0.3722*** (-4.11)	1.9993	3.5719	-1.5726*** (-5.32)
[I] Low number of outsiders	[II] High number of outsiders		[I] Low number of outsiders	[II] High number of outsiders	
2.9840	2.6833	0.3007*** (3.32)	2.1468	2.0667	0.0801** (2.02)

V. Multivariate analysis

The multivariate specifications are estimated using both ordinary least squares (OLS) regressions and median regression for each regression model to eliminate potential biases from the skewness of the variables (Gompers, Ishii, and Metrick, 2003; Coles et al., 2008). Specifically, the median regression uses the least absolute deviation criterion, rather than least squares, with respect to deviations from the median to obtain coefficient estimates. A fixed effect model might not be appropriate in this study because board structure is relatively persistent, and the lack of within variation of the year-to-year firm-level observations may bias the results of the regression. Firms in the same industries face similar market conditions, and the regression residuals are likely to be cross-sectionally correlated. To account for the biases from the contemporaneous correlation in the regression residuals across firms, I include both year and industry dummy variables, which are classified by two-digit standard industrial classification (SIC). For the OLS regressions, the standard errors are adjusted by clustering observations within firms and the covariance matrix is estimated using White's (1980) estimator. This methodology allows me to use panel data yet still control for the time series correlation in the time series observations for each firm.

A. Board size of high-tech firms

Panel A of table IV reports the results from regressing the log of board size on the high-tech dummy as well as control variables[5] to test hypothesis H_1. The regressions include all the observations in the full sample. High-tech firms have higher asymmetric information and growth rate than non high-tech firms, and the associated higher monitoring costs should lead to smaller boards. I use a high-tech dummy, which takes a value of one if a firm belongs to a high-tech industry and zero otherwise, to capture the effect of being a high-tech firm on board size. Both OLS (model 1) and median regression (model 2) have estimated coefficients of the high-tech dummy significantly negative (at the 1% level). The parameter estimates suggest that the average board size is about 2.9% smaller for high-tech firms than for non high-tech firms, strongly supporting hypothesis H_1.

Table IV: Do High-tech Firms Have Smaller Boards? Panel A

	Model 1 OLS regression	Model 2 Median regression
	Log (board size)	Log (board size)
High-tech	-0.0289**	-0.0288***
	(-2.03)	(-3.15)
Log (CEO tenure)	-0.0167**	-0.0203***
	(-2.46)	(-5.81)
Log (CEO age)	0.0888**	0.0682***
	(2.23)	(3.21)
Risk	-0.4336***	-0.4551***
	(-13.60)	(-23.64)
ROA	0.0278	0.0007
	(0.36)	(0.85)
ROA_1	-0.1905***	-0.0020***
	(-4.84)	(-3.84)
Intangible assets	0.0160	0.0169
	(0.69)	(1.35)
Leverage	0.1621***	0.1598***
	(5.69)	(10.46)
Firm age	0.0035***	0.0036***
	(13.63)	(30.48)
Free cash flow	0.0208	-0.0055
	(0.22)	(-0.06)
Intercept	1.8799***	1.9834***
	(11.87)	(25.49)
Industry and year dummies	YES	YES
N	14,131	14,131
R^2 (Pseudo-R^2)	26.24%	14.74%

[5] I use a log (board size) to adjust the skewness of the data and to be consistent with current studies (Coles et al., 2008). I find similar results when board size is used instead.

Table IV: Do High-tech Firms Have Smaller Boards? Panel B

	Model 1 Log(insiders)	Model 2 Log(insiders)	Model 3 Log(outsiders)	Model 4 Log(outsiders)
High-tech	-0.0573***	-0.0552**	-0.0246*	-0.0141*
	(-2.73)	(-2.36)	(-1.84)	(-2.04)
Log (CEO tenure)	0.0469***	0.0401***	-0.0497***	-0.0487***
	(4.53)	(2.74)	(-6.19)	(-9.60)
Log (CEO age)	0.1266**	0.1154**	0.0485	0.0540***
	(2.23)	(2.06)	(0.98)	(2.84)
Risk	-0.1848***	-0.1273***	-0.4412***	-0.4567***
	(-4.04)	(-2.70)	(-11.73)	(-17.66)
ROA	0.2287**	0.1860	-0.0434	-0.0162
	(1.98)	(1.45)	(-0.52)	(-0.19)
ROA_1	-0.0121	0.0348	-0.2141***	-0.2941***
	(-0.20)	(0.53)	(-4.62)	(-4.76)
Intangible assets	0.0519	0.0095	-0.0309	-0.0172
	(1.40)	(0.65)	(-1.09)	(-1.13)
Leverage	0.0220	-0.0021	0.1554***	0.1590***
	(0.47)	(-0.08)	(4.53)	(8.68)
Firm age	-0.0020***	-0.0022***	0.0056***	0.0052***
	(-4.55)	(-2.84)	(17.83)	(28.10)
Free cash flow	-0.2107	-0.1170	0.0799	0.0347
	(-1.58)	(-1.03)	(0.79)	(0.37)
Intercept	0.5279**	0.6244***	1.9607***	1.9743***
	(2.36)	(2.78)	(10.06)	(24.49)
Industry and year dummies	YES	YES	YES	YES
N	14131	14131	14131	14131
R^2 (Pseudo-R^2)	15.58%	8.62%	0.2746	16.94%

The signs of coefficient estimate of control variables are consistent with existing literature. The relation between CEO tenure and board size is significantly negative (Coles et al., 2008). Both CEO age and firm age are positively and significantly related to board size (Denis and Sarin, 1999; Baker and Gompers, 2003; Coles et al., 2008). The standard deviation of stock returns is negatively and significantly related to board size (Coles et al, 2008; Linck et al., 2008). Investment opportunities, measured by intangible assets, appear to have no effect on board size (Coles et al., 2008; Linck et al., 2008).

I further examine what drives the smaller board sizes for high-tech firms relative to non high-tech firms. Specifically, I estimate regression models similar to those in panel A with dependent variables being log (insiders) and log (outsiders). Results are reported in panel B. The average smaller board size for high-tech firms reflects the fact that high-tech firms have both fewer insiders and fewer outsiders than non high-tech firms. The coefficient estimates indicate that the number of insiders is 5.7% smaller for high-tech firms compared to non high-tech firms, and the number of outsiders is 2.4% smaller for high-tech firms than for non high-tech firms.

B. Board composition of high-tech firms

The results in table V strongly support hypothesis H_2. The significantly positive coefficient estimates on the high-tech dummy in both OLS and median regressions indicate that high-tech firms are associated with a higher proportion of insiders on the boards. More specifically, the average (median) proportion of insiders for high-tech firms is 1.7% (2.6%) higher than for non high-tech firms. Consistent with the bargaining power hypothesis in Hermalin and Weisbach (1998), the proportion of insiders increases with CEO tenure and profitability, but is only weakly positively related to CEO age. Consistent with the argument that firms with high monitoring costs have less independent boards, the proportion of insiders increases with risk and intangible assets. As in Coles et al. (2008), I find that the standard deviation of stock returns is positively related to the proportion of insiders, supporting the monitoring cost hypothesis (Adams and Ferreira, 2007; Raheja, 2005). Firm age, a proxy for firm complexity, is negatively and significantly related to the proportion of insiders, supporting the argument that complex firms have high advising benefits and require more independent boards (Raheja, 2005; Coles et al., 2008).

Table V: Do High-tech Firms Have Larger Proportions of Insiders on the Board?

	Model 1 Percentage of insiders	Model 2 Percentage of insiders
High-tech	0.0173**	0.0258***
	(2.04)	(4.85)
Log (CEO tenure)	0.0245***	0.0282***
	(6.18)	(6.83)
Log (CEO age)	0.0247	0.0273*
	(1.07)	(1.83)
Risk	0.0524***	0.0629***
	(2.99)	(4.70)
ROA	0.0706*	0.1154**
	(1.71)	(2.34)
ROA_1	0.0474*	0.0701**
	(1.93)	(2.35)
Intangible assets	0.0224	0.0148*
	(1.58)	(1.67)
Leverage	-0.0281	-0.0559***
	(-1.59)	(-4.39)
Firm age	-0.0018***	-0.0018***
	(-11.71)	(-20.22)
Free cash flow	-0.0750	-0.1380***
	(-1.55)	(-2.81)
Intercept	0.1003	0.0765
	(1.11)	(1.34)
Industry and year dummies	YES	YES
N	14131	14131
R^2 (Pseudo-R^2)	20.01%	11.27%

C. Tobin's Q and board structure

Next, I explore the relation between board size and Tobin's *Q*. Based on the literature on the determinants of Tobin's *Q*, I control CEO pay performance sensitivity, stock return volatility, current and past profitability, intangible assets, capital structure, and firm age in the regression model (Morck, Shleifer, Vishny, 1988; McConnell and Servaes, 1990; Yermack, 1996; Himmelberg, Hubbard, and Palia, 1999; Demsetz and Villalonga, 2001; Coles et al., 2008). Results are reported in table VI. The coefficient on board size is significantly positive in both the OLS regression (model 1) and the median regression (model 2). The parameter estimate in model (1) suggests that adding one board member increase Tobin's *Q* by 20% (0.5537/ (exp $^{(1)}$)×100%).

Note that I also control for the proportion of insiders in the regression models, and therefore the positive relation between board size and Tobin's *Q* is not the confounding effect of the proportion of insiders. These results are consistent with hypothesis H_3 that increasing board size leads to higher Tobin's *Q* for high-tech firms. The high transaction costs of adding board members prevent high-tech firms from upsizing board size to its optimal.

Table VI: The Relation between Tobin's *Q* and Board Size for High-tech Firms

	Model 1 Tobin's *Q*	Model 2 Tobin's *Q*
Log (board size)	0.5537*	0.2466***
	(1.85)	(3.10)
Percentage of insiders	-0.1997	0.1634
	(-0.45)	(1.00
CEO PPS	0.0154***	0.0182***
	(8.07)	(6.40)
Risk	1.1933***	0.9264***
	(3.35)	(9.72)
ROA	5.4586***	5.7253***
	(5.89)	(18.57)
ROA_1	-1.3369	0.4282
	(-1.56)	(1.07)
Intangible assets	1.9964***	1.2137***
	(3.87)	(9.77)
Leverage	-1.5126**	-1.2443***
	(-2.38)	(-8.08)
Firm age	-0.0113**	-0.0020
	(-2.43)	(-1.35)
Intercept	-1.2028	-0.3991
	(-1.29)	(-1.38)
Industry and year dummies	YES	YES
N	2828	2828
R^2 (Pseudo-R^2)	21.28%	14.25%

Coefficient on other control variables is generally significant in the expected direction. CEO pay performance sensitivity is positively related to Tobin's *Q* (Mehran, 1995; Core and Larker, 2002). Consistent with Yermack (2004) and Coles et al. (2008), current level of profitability, proxied by return on assets, has positive associations with Tobin's *Q*. Intangible assets, the measure for investment opportunities, have a significantly positive effect on Tobin's *Q*.

Table VII separately examines the effect of adding insiders and outsiders on Tobin's *Q*, controlling for the proportion of insiders. Note that when the proportion of insiders is held constant, any increase in the number of insiders (outsiders) requires a corresponding increase in the number of outsiders (insiders). The significant positive coefficient on log (insiders) in model (1) and (2) indicates that adding inside directors improve firm value, supporting H_4. The number of inside directors on board is less than its optimum for high-tech firms, and they will be better off by adding more inside directors. Furthermore, it appears that increasing the number of outsiders can also increase Tobin's *Q*, as indicated by the positive and significant coefficient on log (outsiders) in model (3) and (4). Taken as a whole, the results indicate that increasing board size, both by adding insiders and outsiders, increases firm value for high-tech firms.

Table VII: A Separate Examination of the Effect of Adding Insiders and Outsiders on Tobin's *Q* for High-tech Firms

	Tobin's *Q*	Tobin's *Q*	Tobin's *Q*	Tobin's *Q*
Log(insiders)	0.6480*	0.3069**		
	(1.93)	(2.24)		
Log(outsiders)			0.6734**	0.3009***
			(2.01)	(3.19)
Percentage of insiders	-1.5712**	-0.4925**	0.7640	0.6395**
	(-1.98)	(-2.09)	(1.12)	(2.09)
CEO PPS	0.0154***	0.0183***	0.0153***	0.0184***
	(8.01)	(6.75)	(8.06)	(9.43)
Risk	1.1422***	0.8722***	1.1848***	0.8848***
	(3.27)	(6.90)	(3.36)	(5.10)
ROA	5.4610***	5.7001***	5.4575***	5.6817***
	(5.89)	(12.10)	(5.88)	(11.82)
ROA_1	-1.3631	0.3771	-1.3557	0.3892
	(-1.60)	(1.02)	(-1.59)	(0.90)
Intangible assets	1.9732***	1.1778***	2.0126***	1.1938***
	(3.85)	(5.88)	(3.91)	(5.79)
Leverage	-1.4738**	-1.2522***	-1.5008**	-1.2625***
	(-2.36)	(-9.79)	(-2.37)	(-8.68)
Firm age	-0.0102**	-0.0015	-0.0114**	-0.0020
	(-2.29)	(-1.25)	(-2.47)	(-1.44)
Intercept	-0.3740	-0.2805	-1.6067	-0.8260***
	(-0.58)	(-1.35)	(-1.55)	(-2.78)
Industry and year dummies	YES	YES	YES	YES
N	2828	2828	2828	2828
R^2 (Pseudo-R^2)	21.25%	14.25%	21.31%	14.27%

VI. Robustness

A. Exploring endogeneity

The analysis above indicates that firm value increases with board size and the number of both insiders and outsiders for high-tech firms. However, I might interpret these findings in two ways: larger boards lead to better firm performance for high-tech firms, or firm value requires an adjustment of board structure by adding board members. If firms expand their boards after good performance or downsize their boards after poor performance, the contemporaneous relation between firm value and board size is subject to the concern that changes in firm value result in changes in board size. To address the causality issue, I regress Tobin's *Q* on lagged board size and board composition with other control variables (Hermalin and Weisbach, 1991). The results remain unchanged (results are not tabulated and available upon request).

The above analysis assumes that the corporate structure is exogenous. Previous studies, however, indicate that board variables could be endogenous (Demsetz and Lehn, 1985; Hermalin and Weisbach, 1998; Bizjak, Brickley, and Coles, 1993; Bhagat and Black, 1999; Denis and Sarin, 1999; Coles, Lemmon and Meschke, 2006). Any observed relation between board structure and firm value may be attributable to I inadequately capture the contracting environment and my model specifications suffer omitted variable bias. To proxy for firm contracting environment, I include a one-year lagged value of Tobin's *Q* as a control variable in the regression models. The coefficient estimates on board size and the number of insiders and outsiders are smaller but remain significant. The robustness of the results is more consistent with the notion that Tobin's *Q* is increasing in board size (results are not tabulated and available upon request).

Finally, I address the endogeneity issue using three-stage least squares (3SLS) regressions. The dependent variables are Tobin's *Q*, logarithm of board size, and the proportion of insiders (see Bhagat and Black, 2001; Coles et al., 2008). The results are consistent with my hypotheses[6].

Table VIII: Effect of Board Structure on Tobin's *Q*: 3SLS Regressions

	Tobin's *Q*	Log (board size)	Percentage of insiders
Log (board size)	2.1775***		0.1616***
	(3.55)		(5.59)
Percentage of insiders	-7.6642**	-0.2329	
	(-2.57)	(-0.24)	
Risk	1.4706***	-0.1052***	0.0314
	(4.95)	(-3.49)	(1.36)
ROA	0.0548***	0.0086***	-0.0016
	(8.90)	(3.35)	(-1.15)
ROA_1	-0.0138**	-0.0029***	-0.0003
	(-2.24)	(-3.57)	(-0.71)
Intangible assets	2.8949***	0.0022	0.1279***
	(5.92)	(0.02)	(3.91)
Firm age	-0.0054	0.0023*	0.0009***
	(-1.02)	(1.78)	(2.92)
Tobin's *Q*		-0.0476**	-0.0127
		(-2.06)	(-1.36)
Free cash flow		-0.6403***	0.2832***
		(-3.49)	(2.87)
Log (CEO tenure)		-0.0059	-0.0198***
		(-0.26)	(-4.14)
Log (CEO age)		0.0358	0.0267
		(0.88)	(1.42)
Leverage	-1.7087***		-0.0233
	(-5.89)		(-0.90)
Firm Size		0.0917***	
		(7.91)	
CEO PPS	0.0129***		
	(6.08)		
Industry and year dummies	YES	YES	YES
N	2828	2828	2828

B. Are the assumptions for my hypotheses sound?

My hypotheses are developed based on the assumption that high-tech firms tend to have smaller boards and fewer insiders than their optimum. To test whether this is indeed the case, we estimate the regression with board size, board size squared, the interaction between board size and

[6] I extend the data of this table until 2013 and find similar results. Results are not tabulated but available upon request.

the high-tech dummy, the interaction between board size squared and the high-tech dummy, the proportion of insiders, and other control variables. The estimated coefficients on both interaction terms are significantly different from zero, indicating that board size has different effects on Tobin's *Q* for high-tech firms versus non high-tech firms. Furthermore, the tangible point is 9.4 and therefore, the optimal board size that maximizes firm value is 10. With the premise that board size and Tobin's Q have an inverted U-relation, there should be a positive relation between board size and Tobin's *Q* as long as board size is less 10. More than 75% of my sample firms have board sizes of less than 10. Therefore, the assumption that high-tech firms tend to have smaller boards than optimal appears to be valid in my sample.

Similarly, I replace board size with the number of insiders and the number of outsiders in the regressions. Results indicate that a large portion of my sample firms have less than optimal numbers of insiders and outsiders. These results provide further support for the hypotheses.

VII. Conclusions

There has been an active debate in the corporate governance literature about the optimal size and composition of a board. Prior literature finds evidence that smaller boards are associated with higher firm performance. However, studies on the relation between firm value and board composition find mixed results. Past studies look at all firms and industries in aggregate, and little research has been done to examine whether board structure vary by firm and industry characteristics. Some firms under specific industries may have characteristics that can result a non-conventional board structure.

This paper examines board structure and the effect of board size and composition on firm value for firms in the high technology industries. I argue that information asymmetry is severe in high-tech industries. Managers of high-tech firms may be unwilling to share information with outsiders because the outsiders will use the information to intensively monitor managers, resulting in higher costs of information share. Furthermore, managers in high-tech firms are likely to be experts in their field, leading to lower benefits of having a large board with outside expertise to provide advice. Therefore, high-tech firms are likely to have smaller boards with higher insider representation. Lipton and Lorsch (1992) suggest that there is an inverted-U relation between board size and firm value. The transaction costs of adding directors to the board impede board upsizing. Hence, high-tech firms tend to have smaller boards than optimal. Increases in board size should increase firm value.

I document a smaller board with a higher proportion of insiders for high-tech firms using a sample of 14,131 firm-year observations over the period of 1995-2008. The smaller board size appears to be driven by both smaller numbers of insiders and smaller numbers of outsiders. Using Tobin's *Q* as a measure for firm value, I document that Tobin's *Q* is increasing in board size for high-tech firms. While both adding insiders and outsiders increases firm value, the positive effect of adding insiders is stronger than that of adding outsiders. My results are robust to alternative model specifications that control for endogeneity and causality.

The findings in this study have important implications for any discussion on board reform. Board size and independence are shaped by firm-specific and managerial characteristics. Any attempt to impose regulations to ensure that all boards are small with a high level of independence may be ineffective in some cases. No single prescription for optimal board size will serve all firms and their stakeholders equally well.

VIII. Appendix A: Variable Definitions

The appendix defines the key variables employed in this study. Accounting data is taken from Compustat and are defined by their corresponding data item number in Compustat. Board data is from RiskMetrics and Equilar. CEO data is from Execucomp. Stock return data is from CRSP (Center for Research on Security Prices).

Tobin's Q= (data6+data199×data22-data60)/data6
Board size=Number of directors
Insiders=Number of employee directors
Outsiders=Board size-number of insiders
The proportion of insiders=Insiders/board size
CEO tenure = the number of years the CEO has been CEO
CEO PPS (CEO pay performance sensitivity) = the dollar change in total CEO wealth for a percentage change in firm value, divided by 1,000,000
Intangible assets=one minus the ratio of net property, plant, and equipment to book value of assets.
R& D expenditure =Max(0, data46)/data12
Capital expenditure =data128/data12
Leverage = (data0+data34)/data6
Firm age=the number of years since the first trading date on CRSP
Firm risk= standard deviation of monthly stock returns for previous 36 months
ROA= data13/data6
Free cash flow= (data308-data19-data21)/data6

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