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The Effect of Board Independence on Information Asymmetry

Abstract

Boards have an important role in ensuring that investors' interests are protected. Our paper first examines whether the independence of a firm's board affects information asymmetry among investors. We provide evidence that greater board independence leads to lower information asymmetry. Next, we provide evidence that more voluntary disclosure and greater analyst coverage are two underlying mechanisms via which greater board independence reduces information asymmetry. Of the two mechanisms, we find that analyst coverage is more significant in influencing how board independence affects information asymmetry. Overall, our paper contributes to a better understanding of the effect of board independence on information asymmetry.

Keywords: Corporate governance, board independence, management forecasts, analysts, information asymmetry.

JEL Classifications: D82, G34, M41

1. Introduction

We examine the effect of board independence on a firm's information asymmetry among investors, and how this relationship is mediated by the firm's information environment. Firms and their various stakeholders (e.g., shareholders and regulators) often have a common response to problems associated with the lack of transparency: they push for greater board independence. Such a response indicates an underlying belief that greater board independence would lead to an improvement in transparency. For example, in its 2002 annual report, General Electric (GE) states its rationale for having an independent board as follows: "At the core of corporate governance, of course, is the role of the board in overseeing how management serves the long-term interests of share owners and other stakeholders. An active, informed, independent and involved board is essential for ensuring GE's integrity, transparency and long-term strength." Hence, an important empirical question is whether greater board independence indeed leads to an improvement in information asymmetry among investors.

Our study is in line with a growing literature that examines how board independence affects a firm's information environment and information asymmetry among investors (e.g., Klein, 2002; Anderson *et al*., 2004; Ahmed and Duellman, 2007; Petra 2007; Chung *et al*., 2010; Ferreira *et al*., 2011; Armstrong *et al*., 2014; Chen *et al*., 2014). These studies generally document positive relations between the proportion of independent directors and accounting quality, earnings informativeness, timely loss recognition, and proxies for the firm's information environment and asymmetry. However, Armstrong *et al*. (2014) note that this conclusion is premature because board independence can be endogenously determined by firm characteristics. For instance, studies have shown that firms with high information asymmetry choose to have relatively few independent directors (e.g., Linck *et al*., 2008; Lehn *et al*., 2009), raising concerns of potential reverse causality. The authors then exploit regulations issued in 2003 by the NYSE and NASDAQ as an exogenous event that significantly altered the proportion of independent directors for some firms' boards to observe whether and how these firms' information environments change in response to this shock. They find that the information asymmetry component of the bid-ask spread decreases in response to an exogenous increase in the proportion of independent directors. In a similar vein, Chen *et al*. (2014) take advantage of the 2003 NYSE and NASDAQ regulations to examine how board independence affects earnings management. These recent findings suggest the need for more research examining the (causal) relation between board independence and information asymmetry and the channels mediating this relation.

We first examine whether greater board independence leads to lower information asymmetry, proxied by the probability of informed-based trading (PIN) and bid-ask spread. Our empirical results indicate that greater board independence leads to lower information asymmetry among investors based on these proxies. To identify the causal effect of board independence, we employ a two-stage least squares (2SLS) instrumental variable approach and utilize two instruments — (1) the fraction of directors who also sit on at least one other firm's board with above median proportion of independent directors during the year and (2) the proximity to a supply of independent directors, defined as the number of external directors located in the state where the firm's headquarters is located in the year.[1] In the 2SLS regression, we continue to find a negative relation between board independence and our proxies for information asymmetry.

[1] The intuition for the first instrument is based on the concept of director social networks (Adams and Ferreria, 2009). Briefly, when directors of a board sit on other boards with more independent directors, they know more independent directors whom they can persuade to join the board and/or are more open to having more independent directorships. The intuition for the second instrument is that when there are more external directors serving in firms in the nearby location, there is a greater supply of independent directors from which the firm can appoint its independent directors (Knyazeva *et al*. 2011). We discuss more about these instruments in Section 4.1.

Further diagnostic tests generally support the use of the 2SLS research design and the validity of board connections and board locations as good instruments for board independence. Overall, our results support the role of board independence in reducing information asymmetry among investors.

In the second part of this study, we explore whether and to what extent firm's information environment mediates the relation between board independence and information asymmetry among investors. This investigation is motivated by a stream of literature that argues that it is not only important to examine eventual outcomes; it is also important to understand the underlying mechanisms that results in those outcomes using techniques such as path analysis (e.g., Bushee and Noe, 2000; Barton and Mercer, 2005; Bhattacharya *et al*., 2012). For example, Bhattacharya *et al*. (2012) find both a direct path from earnings quality to the cost of equity, and an indirect path that is mediated by information asymmetry. As such, they validate information asymmetry as one mediator linking earnings quality to cost of capital, while still finding that earnings quality has a direct effect on cost of capital incremental to that via information asymmetry.

In the case of board independence, the presence of more independent directors *per se* is unlikely to have only a direct effect on information asymmetry among investors; it is more likely that the change in board structure also affects the information environment, which, in turn, affects information asymmetry. Hence, to better understand the role of transparency in the relation between board independence and information asymmetry, we examine how the transparency associated with the firm's information environment mediates the relation between board independence and information asymmetry among investors. In other words, we attempt to open up the "black box" linking board independence to information asymmetry. We focus on two sources of transparency relating to the firm's information environment: (1) corporate voluntary disclosure as proxied by management forecast frequency, and (2) information acquisition and dissemination by information intermediaries as proxied by analyst coverage. We argue that firms with higher management forecast frequency and analyst coverage are seen by investors as being more transparent.

Our empirical results indicate that both corporate voluntary disclosure and information acquisition and dissemination by information intermediaries mediate the relation between board independence and information asymmetry. Specifically, we first document that greater board independence is associated with more frequent management forecasts and greater analyst coverage, which suggests that board independence leads to greater transparency in the firm's information environment. We then find that greater board independence is still significantly associated with lower information asymmetry, when we include the information quality variables—voluntary disclosure and analyst coverage—as additional controls in our regressions. Our results are also robust to using an alternate measure of PIN based on the information component of PIN (Duarte and Young, 2009), and using two alternative approaches to deal with cross-correlation in the error terms. Overall, these results suggest that the board independence has both a direct effect on information asymmetry, as well as an indirect effect on information asymmetry through increased transparency in the information environment.

In our investigation of how the information environment mediates the relation between board independence and information asymmetry among investors using path analysis, we find that analyst coverage is the more important mediating variable, compared to forecast frequency. Specifically, between 55.5 and 96.9 percent of the mediated path effect from board independence to information asymmetry is attributable to analyst coverage. Hence, the results suggest analysts are attracted to firms with a more independent board. Consequently, this significantly affects how board independence affects information asymmetry among investors, possibly because of the important role that analysts play as information intermediaries (Roulstone, 2003; Frankel and Li, 2004).

We contribute to the extensive literature on board structure in several ways. First, we identify the causal effect of board independence on the firm's information asymmetry. This identification is important because actions by regulators and firms are based on the belief that greater board independence can improve transparency. Prior studies that examine this issue suffer from significant endogeneity concerns; we propose an approach to mitigate these concerns based on an instrumental variable research design. Second, we attempt to shed light on the black box between board independence and information asymmetry among investors by showing that management forecast frequency and analyst coverage are important mediating mechanisms. We also provide a comparative analysis that measures the relative importance of each of these mediating variables in reducing the information asymmetry among investors.

Our paper complements Armstrong *et al*. (2014) who also examine the effect of board independence on the firm's information environment. There are two key differences between both papers. First, we rely on board networks and board locations as instruments to identify the effect of board independence, while they rely on the 2003 NYSE and NASDAQ requirement of majority independent directors as an exogenous event shock.[2] Second, we examine the underlying mechanisms between board independence and information asymmetry, whereas they examine how this relation varies cross-sectionally with information processing costs. As

[2] There are key differences between both approaches. First, the instrumental variable approach can typically be applied to any time period. In contrast, the use of an exogenous event shock, by construction, requires the empirical analyses to be at a single time point. Second, an exogenous event shock offers a cleaner identification to the extent that it satisfies the requirement that no other confounding events and that it causes a spike in board independence. Instrument variables often face significant validity threats due to imperfect exogeneity (Larcker and Rusticus, 2010). Given the differences in the identification techniques, similar findings help strengthen the conclusion that more board independence leads to an improvement to the information environment.

discussed earlier, one objective of studying underlying mechanisms is to validate arguments relating two concepts such as board independence and information asymmetry among investors. The objective of examining how relations vary cross-sectionally is to understand the conditions (e.g., different information processing costs) under which certain relations are stronger/weaker.[3] Hence, both papers take different approaches to understand an important relation.

The next section develops our conceptual framework linking board independence and information asymmetry. Section 3 describes the sample and empirical measures. Section 4 discusses the test results and Section 5 concludes.

2. Framework linking board independence and information asymmetry

2.1 The effect of board independence on the information asymmetry among investors

More independent boards are more likely to act in the interests of investors, who typically demand greater transparency from the firms that they invest in. Independent directors have incentives to promote greater corporate disclosure to enhance shareholder value via increased stock liquidity and reduced cost of capital (e.g., Ajinkya *et al*., 2005; Karamanou and Vafeas, 2005).[4] Furthermore, in order to better fulfill their fiduciary duties toward shareholders, independent directors seek better and more information to aid their monitoring activities and thus have the incentive to increase the transparency of the information environment by encouraging greater disclosure made by corporate managers (e.g., Linck *et al*., 2008; Armstrong *et al*., 2010).

Hence, we argue that greater board independence is expected to be associated with lower information asymmetry to the extent that i) more independent boards lead to firms being more

[3] In terms of the language used in path analyses, information processing cost has a *moderating* (as opposed to *mediating*) effect on the effect of board independence on the information environment.

[4] Bushman and Smith (2003) also highlight other channels through which financial accounting information can affect economic performance: 1) better identification of good vs. bad projects by managers and investors and; 2) discipline on project selection and expropriation by managers.

transparent and ii) there is less information asymmetry among the investors of more transparent firms (Welker, 1995; Leuz and Verrecchia, 2000). This argument is also consistent with that of Chung *et al*. (2010), who examine the relation between internal corporate governance and information asymmetry. Chung *et al*. (2010) measure internal corporate governance using a governance index that consists of 24 governance attributes. With this index, they show that firms with better corporate governance are associated with lower information asymmetry. Apart from these, other studies have also examined the relation between the external corporate governance of a firm and information asymmetry (e.g., Bacidore and Sofianos, 2002; Brockman and Chung, 2003). These papers generally find that external corporate governance mechanisms (e.g., legal and regulatory environments) that increase shareholder protection are associated with reduced information asymmetry. Hence, our first hypothesis, stated in the alternative form, is:

H1: Greater board independence reduces the information asymmetry among investors.

2.2 Mediation via voluntary disclosure and information intermediation

In this paper, we also propose that board independence could influence information asymmetry through its effect on transparency of the firm's information environment. Theory generally predicts that better disclosure and increased transparency is likely to reduce information asymmetry (e.g., Verrecchia, 2001). Consistent with this theory, many empirical studies provide evidence indicating that better disclosure and increased transparency is associated with lower information asymmetry (e.g., Welker, 1995; Coller and Yohn, 1997; Leuz and Verrecchia, 2000; Verrecchia and Weber, 2006; Brown and Hillegeist, 2007).

Following Bushman *et al*. (2004), we conceptualize and characterize the transparency of the information environment by: 1) corporate voluntary disclosures made by the firm and; 2) information acquisition and dissemination by information intermediaries. Corporate voluntary disclosure refers to the non-mandatory periodic disclosure made by the firm to outside stakeholders (such as shareholders, creditors, government agencies, etc.). Information acquisition and dissemination by information intermediaries refer to the collection, interpretation, and dissemination of information by financial intermediaries for other market participants. Hence, in this paper, we examine the effect of board independence on a firm's information environment through voluntary corporate disclosure, and information acquisition and dissemination by information intermediaries.

Of the various forms of corporate voluntary disclosure, management forecast has been extensively studied in the literature (Hirst *et al*., 2008). Recent studies support the notion that firms with more independent boards are likely to engage in more voluntary disclosure. For example, Ajinkya *et al*. (2005) show that managers of firms with more outside directors and greater institutional ownership are more likely to both issue a forecast and forecast more frequently. Similarly, Karamanou and Vafeas (2005) show that firms with more effective boards and audit committees are more likely to issue and update a forecast. Hence, our next hypothesis, stated in the alternative form, is:

H2a: Greater board independence increases the quantity of corporate voluntary disclosure in terms of the frequency of management earnings forecasts.

Armstrong *et al*. (2010) argue that independent directors have incentives to attract more information acquisition and dissemination by information intermediaries. To carry out their monitoring activities, independent directors are unlikely to rely solely on information supplied by, and filtered through, managers because managers are not likely to share information that is detrimental to their own interests (Jensen, 1993; Verrecchia, 2001). Given this concern, independent directors are likely to seek and facilitate (e.g., via information sharing) other channels that aid their monitoring activities. Information intermediaries such as analysts play an important role in processing and interpreting financial disclosures made by the firm and in acquiring additional information to determine the future financial prospects of the firm. They themselves might be attracted to firms that are inherently better monitored because of the greater reliability of the information they use in their work. Hence, we expect firms with more independent directors to attract more analyst following. Our hypothesis, stated in the alternative form, is:

H2b: Greater board independence increases the amount of information acquisition and dissemination by information intermediaries in terms of analyst coverage.

Finally, we compare and contrast the roles and relative importance of management forecast and analyst coverage in mediating the relation between board independence and information asymmetry. What appears to be missing in the literature is a within-sample joint analysis of the relation between board independence, the firm's information environment mechanisms, and information asymmetry among investors. By conducting such an analysis, we are able to better understand the underlying mechanisms linking board independence to information asymmetry in the capital markets. Stated differently, it allows us to evaluate the extent to which certain aspects of the information environment, specifically, management forecasts and analyst coverage, can explain the effect of board independence on information asymmetry. In particular, we test the following related hypothesis:

H2c: Management forecast frequency and analyst coverage mediate the effect of board independence on information asymmetry among investors.

The information environment variables in our study constitute a small subset of the characteristics that capture the degree of transparency in a firm's information environment. The choice of these characteristics is driven by their measurability, as well as the extensive literature that has studied them. In practice, it is likely that there are other mediating mechanisms through which board independence affects information asymmetry.[5] Hence, our study should be regarded as an attempt to partially open up the "black box" between board independence and information asymmetry among investors.

3. Research design

3.1 Sample construction

We measure the variables used in our empirical analyses with data from the Trade and Quotes (TAQ), RiskMetrics, CDA/Spectrum, First Call, I/B/E/S, CRSP, and Compustat databases. These databases are available from Wharton Research Data Services (WRDS). First Call provides information on management forecasts (our proxy for voluntary disclosure). We collect our data from 1996 onwards because data coverage is incomplete and only becomes more extensive after the Private Securities Litigation Reform Act of 1995. We impose a one-year lag for the independent variables, to mitigate reverse causality concerns. For example, the stock liquidity of a firm in 2005 is matched with the firm's corporate governance, voluntary disclosure, analyst coverage and information asymmetry in 2004. Our sample period is between 1997 and 2006.

[5] For example, there could be public disclosures that are not (directly) related to earnings but which could reduce information asymmetry, such as discussions about the future direction of the firm in the annual reports, press releases, and conference presentations. Board independence could also affect mechanisms other than public disclosures. For example, with better oversight by independent directors, there might be less private communication between managers and selected stakeholders and less private-information-based insider trading.

Table 1 panel A reports our sample construction. Our initial sample comprises all firms in the Riskmetrics database for which *Board independence* can be computed. We remove 1,380 observations for which the *G-index* is unavailable. We then link our dataset to the CRSP database via CUSIP. We retain firms which have ordinary shares listed on the NYSE, AMEX, or NASDAQ stock exchanges. We also remove observations for which *PIN*, *Spread*, *Forecast frequency, Analyst coverage*, and our set of control variables are unavailable. Our final sample comprises 10,744 firm-year observations.

Table 1 panel B reports the distribution of our observations across our sample period. The mean (median) *Board independence* for our sample firms gradually increases from 60.2 (62.5) percent in 1997 to 72.8 (75.0) percent in 2006. The gradual increase in board independence over our sample period is consistent with other studies that have also documented a similar over-time increase in the mean board independence level (e.g., Armstrong *et al*., 2014; Chen *et al*., 2014). The increase is likely to be due to regulatory reforms and shareholder activism, especially in response to the accounting scandals involving prominent firms like Enron and WorldCom. For example, in 2003, the NYSE and NASDAQ mandated rules that require listed companies to have a majority of board members who are independent. NASDAQ (p. 1, 2003) emphasizes that this requirement is "part of NASDAQ's continuous commitment to restoring confidence in the markets through enhanced disclosure and transparency".

3.2 The effect of board independence on information asymmetry among investors

To test the effect of board independence on information asymmetry among investors (H1), we use the following ordinary least squares (OLS) regression specification:

$$Information\ asymmetry_{t+1} = \gamma_0 + \gamma_1 Board\ independence_t + \gamma_2 X_t + \varepsilon_{t+1}, \qquad (1)$$

where *Information asymmetry*$_{t+1}$ is proxied by either *PIN* or *Spread*. *Board independence*$_t$ is the proportion of board members who are independent. X_t is a vector of control variables: *Market cap*, *Book-to-market*, *ROA*, *Loss*, *Excess return*, *Return volatility, Stock turnover, G-index*, *Ext Board Seats*, *Board size*, as well as year and industry fixed effects. Appendix 2 includes the detailed definition of all variables.

Our first information asymmetry measure is *Spread*, which is the average of the daily relative effective bid-ask spreads of a stock. From an information asymmetry perspective, the spread measures the compensation that uninformed market participants such as market makers demand for the perceived information risk associated with trading with relatively more informed traders. We use the intra-day trades and quotes from the TAQ database to calculate spread. To ensure data integrity, we remove trades and quotes that are likely to be errors or outliers, as discussed in Appendix 1.A. The relative effective spread is based on the notion that trade is only costly to the investor to the extent that the trade price deviates from the true price, approximated by the bid-ask midpoint. To compute each effective spread, we match each intraday trade to an intraday quote using the standard Lee and Ready (1991) algorithm described in Appendix 1.B. This process attempts to remove quotes for which trades have not been executed and could potentially reduce the noise from the transaction cost estimation. For each trade-matched quote at time *s* for firm *i*, we compute the intraday relative effective spread, *IntraESpread*, as 2|*trade price* — mid-point of *bid price* and *ask price*| / *trade price*, where *ask price* (*bid price*) is the ask price (bid price) for the quote, and *trade price* is the price at which the trade is executed. We compute the daily relative effective spreads as the average of intraday relative effective spreads. *Spread* is the average of these daily spreads within the year; this average is multiplied by 100 to make spread a percentage.

Our second information asymmetry measure is the probability of informed-based trading (PIN). *PIN* is based on the market microstructure model specified in Easley *et al*. (1997), which depicts the trading behavior of informed investors. Details of the computation of *PIN* are provided in Appendix 1.C. Specifically, we use the TAQ data and the Lee and Ready (1991) algorithm to first estimate the daily number of buy and sell trades in the stock. *PIN* is then estimated by the numerical maximization of the likelihood function of the model.

We include an extensive number of control variables in our empirical model to mitigate the omitted correlated variables problem. We control for firm size (*Market cap*) and the book-to-market ratio (*Book-to-market*), as we expect there to be differences in information asymmetry between larger and smaller firms, and between firms with low growth opportunities and those with high growth opportunities. Loss firms have greater economic uncertainty compared with profitable firms. Hence, we control for firm performance using *ROA* and *Loss* because we expect the information uncertainty and asymmetry to differ based on firm performance. Prior research has shown that stock performance (*Excess return*), return volatility (*Return volatility*), and stock turnover (*Stock turnover*) could affect information asymmetry among investors (McInish and Wood, 1992; Chung *et al*., 1999; Stoll, 2000). Hence, we include these market characteristics as additional control variables. We also include several governance variables as additional controls. We use the Gompers *et al*. (2003) governance index as a proxy for the strength of the firm's other governance mechanisms. We control for the total number of external independent board seats held by the directors of the firm (*Ext Board Seats*) to control for busyness of the board that might influence the directors' ability to carry out their duties effectively (Adams and Ferreira, 2009). Finally, we control for number of directors on the board (*Board size*) because prior work suggests that board size affects firm performance (e.g., Yermack, 1996). For all our regression estimation, we use heteroskedasticity-robust standard errors clustered by firm.

3.3 *The effect of board independence on the information environment*

To test the effect of board independence on the information environment (H2a and H2b), we use the following ordinary least squares (OLS) regression specification:

$$Information\ environment_{t+1} = \gamma_0 + \gamma_1\ Board\ independence_t + \gamma_2 X_t + \varepsilon_{t+1}, \quad (2)$$

where $Information\ environment_{t+1}$ is proxied by either $Forecast\ frequency_{t+1}$ or $Analyst\ coverage_{t+1}$. *Forecast frequency* is the number of management forecasts of annual EPS in the year; these forecasts are obtained from the First Call Company Issued Guidelines database. *Analyst Coverage* is the average of the monthly number of analysts making forecasts of the annual EPS of the firm in each year; these forecasts are obtained from the I/B/E/S summary file.

X_t is the vector of control variables in equation (1) but further includes *Litigation risk*, *R&D*, *Tangibility*, *Information cost* and *Business segments* which have been documented to affect the firm's information environment. Appendix 2 includes the detailed definition of these variables. We control for *Litigation risk* using the Rogers and Stocken's (2005) litigation risk model because it might influence the firm's disclosure policy, financial reporting quality and the extent of analyst coverage (Francis *et al*., 1994; Rogers and Stocken, 2005). The difficulty in valuing firms with more research and development could increase the advantage of more informed investors, whereas the ease of valuing firms with relatively more tangible assets could reduce such an advantage (e.g., Aboody and Lev, 2000; Barth *et al*., 2001). Therefore, we also control for the information advantage of more informed investors using research and development intensity (*R&D*) and asset tangibility (*Tangibility*), which is measured based on

Berger *et al*. (1996) and Almeida and Campello (2007). The cost of acquiring information about a firm and the complexity of its business can affect the disclosures of the firm, as well as the effectiveness of information intermediaries. Hence, we add controls for information acquisition cost (*Information Cost*) and business complexity, based on the the number of business segments that it operates (*Business Segments*).

Finally, to test the mediating effect of information environment on the relationship between board independence and information asymmetry (H2c), we include proxies for *Information environment* in equation (1):

$$\textit{Information asymmetry}_{t+1} = \gamma_0 + \gamma_1 \textit{ Board independence}_t + \gamma_2 \textit{Information environment}_{t+1} + \gamma_3 X_t + \varepsilon_{t+1}, \quad (3)$$

In addition, we use path analysis to examine the relative importance of each mediating channel through which board independence affects information asymmetry.

3.4 Descriptive statistics

Table 2 provides the descriptive statistics of the variables used in our empirical tests. On average, 65.8 percent of the directors of the sample firms are independent. With regard to our information asymmetry variables, the mean probability of information-based trading in the stocks of our sample firms is 0.125 and the mean effective spread for our sample firms is 0.459.

Turning to our proxies for information environment, our sample firms make an average of about three management forecasts a year and are followed by an average of about ten analysts. Our sample firms have an average market cap of $7.8 billion and an average book-to-market ratio of 0.50. The average firm in our sample reported an ROA of 4.28 percent, and 13.2 percent of our firm-year observations reported a net loss. With regard to market characteristics, our sample firms have a monthly return of 0.005 in excess of the value-weighted market return and a mean daily return volatility of 0.104. The average of the monthly ratio of trading volume to shares outstanding for our sample is 0.149.

In terms of other governance characteristics, the mean G-index value for our sample is 9.24, the average number of independent board seats held by directors of each firm is 2.4, and the average board size is 9.6 directors. In terms of other attributes relating to the firm's information environment, the average estimate of our sample firms' litigation risk exposure is -2.52, based on the litigation risk model in Rogers and Stocken (2005). Our sample firms also have an average R&D expenses to total assets of 8.01 percent, and an average ratio of tangible assets to total assets of 0.47. Finally, the adjusted R^2 from regressing a firm's daily stock return on market return (information acquisition cost proxy) is 0.19, and an average number of business segments of 5.74.

Table 3 reports the Pearson correlations for the main variables used in the regressions. Consistent with our expectations, the Pearson correlation coefficients show that *Board independence* is negatively correlated with *PIN* (-0.156) and *Spread* (-0.177), and positively correlated with, *Forecast frequency* (0.140) and *Analyst coverage* (0.102). The aforementioned correlations are all statistically significant at the 1 percent level.

4. Empirical results

4.1 The effect of board independence on information asymmetry among investors

Table 4 Panel A presents the results of our OLS regressions that examine the effect of board independence on information asymmetry among investors, which we proxied using *PIN* and *Spread*. As predicted in H1, we find a negative and significant association between *Board* *independence* and *PIN*. Specifically, the coefficient on *Board independence* is -0.015 (t-stat = -3.01), significant at the 0.01 level. We obtain similar results similar results using *Spread* as the information asymmetry proxy. Specifically, the coefficient on *Board independence* is -0.097 (t-stat = -2.30).

While we find a significant association between board independence and information asymmetry, we are not able to infer whether this relation is causal or simply associative.[6] We attempt to address this issue by using instrumental variables approach in a two-stage least squares (2SLS) regression specification. We utilize two instruments for our 2SLS research design. The first instrument, *Board connections*, is based on social networks among directors and is defined as the fraction of the firm's directors who are also sitting on at least one other firm's board with above median proportion of independent directors of the year. Following Adams and Ferreira (2009), we consider board connections to be a potential instrument for a more independent board structure because of the notion that social networks among directors have a significant influence on the recruitment of independent directors (e.g., Koenig and Gogel, 1981; Simon and Warner, 1992; Robins and Alexander, 2004; Jackson and Rogers, 2007; Jackson, 2009; Hwang and Kim, 2009).[7,8] In particular, we argue that a firm's board is likely to have more independent directors if its directors are more socially connected to other independent directors whom they can introduce to the firm and/or whom they are more comfortable working with as

[6] Many studies have suggested that the findings on the relation between board independence and information environment suffer from endogeneity (e.g., Hermalin and Weisbach, 2003; Larcker *et al*., 2007; Armstrong *et al*., 2010, 2014; Larcker and Rusticus, 2010).

[7] To study how gender-diverse boards affect firm performance, Adams and Ferreira (2009) instrument gender-diverse boards (i.e., the fraction of female directors on the board) using board connections to female directors (i.e., the fraction of male directors on the board who sit on other boards that have female directors).

[8] For example, Jackson (2009) state "The fact that social networks are an important conduit of information about and access to jobs is evident to anyone who has ever looked for employment in almost any profession." In the case of the employment of independent directors to be on the firm's boards, social networks are likely to play an especially important role because there is a small pool of qualified directors to begin with. By definition, independent directors have to be from outside the firm. It is highly unlikely that a complete stranger would be added from the outside to the board because boards are typically quite small and individual board members can have significant influence on the board dynamics.

independent directors. These independent directors belong to an exclusive group of corporate elite and they help each other obtain outside independent directorships because they share similar background and feel committed to each other and to the network. This contention is supported by recent work that explores the economic value of social networks and finds that belonging to a social network has a significant impact on employment of directors (Ioannids and Loury, 2004; Kuhnen, 2009; Barnea and Guedj, 2009). For example, Barnea and Guedj (2009) find that well-connected independent directors (i.e., directors who have more direct links to other directors in the network) are more likely to be awarded more directorships in the future. Specifically, the probability of a connected independent director receiving one additional director seat the following year is 68% higher than that of an unconnected independent director.[9] In a similar vein, Kuhnen (2009) finds that mutual fund directors who are more connected are more likely to earn additional seats in the future when new funds are offered by management.

Similar to Adams and Ferreira (2009), we acknowledge that it is not possible to directly observe the social networks among board of directors. Instead, we argue that it is reasonable to assume that when directors of a firm are sitting on other board(s), especially those with a relatively higher proportion of independent directors, the firm is likely to be more networked with directors from outside the firm. We argue that social connections to other predominantly independent boards are unlikely to be correlated directly with a firm's information environment, as well as the information asymmetry among the firm's investors. In fact, a review of the literature did not reveal any study that suggests that such connections would have endogeneity effects. From a conceptual perspective, finding an instrument that the prior literature has not yet

[9] The unconditional probability of an independent director getting a new directorship the following year is 2.5%, while the same probability for a connected independent director is 4.2%.

considered to be an explanatory variable in the second stage regression helps to increase the likelihood that the instrument satisfies the exogeneity condition (Adams and Ferreira, 2009).[10]

The second instrument, *Board locations*, is based on the proximity to other firms' with similar corporate governance structure and is defined as the number of external directors located in the state where the firm's headquarters is located in the year.[11] The intuition for this instrument is that when there are more external directors in the nearby location of the firm's headquarters, there is a greater supply of independent directors from which the firm can appoint as its independent directors. From the independent directors' perspective, they are also more willing to accept additional directorships because serving as an independent director is time-consuming and thus being on firms' board that are in close proximity helps save travel time. Finally, there may be greater pressure from various stakeholders to increase board independence when a firm is located in close proximity with other firms with relatively more independent boards. On the other hand, it is difficult to argue that being in a location close to other firms with relatively more independent boards will directly influence a firm's information environment or the information asymmetry among the firm's investors. We use both variables as our instruments in our first-stage regression explaining board independence, and we conduct the tests suggested by Larcker and Rusticus (2010) and find that these two instruments are relevant and valid.

Table 4 Panel B presents the results of our 2SLS regressions that examine the effect of board independence on a firm's information asymmetry. The first column presents the results of the first stage regression with *Board independence* as the dependent variable. *Board connections*

[10] The prior literature has used the fraction of a board's directors who sit on at least one additional board as a proxy of "busy directors" (e.g., Fich and Shivdasani, 2006). Note that this proxy does not require the additional board(s) to have a majority of independent directors. Nevertheless, one might still view *Board connections* as potentially a proxy for busy directors. When directors sit on other boards, there are many outcomes such as i) they get to know more directors, ii) they are busier, and iii) they learn more from other directors and of other firms. While we focus on the first outcome (i.e., the social connections aspect), to the extent that the other outcomes are unlikely to have a direct effect on the information environment, *Board connections* remains a reasonable instrument.

[11] We thank an anonymous referee for suggesting this additional instrument.

is a very significant predictor of *Board independence* (t-stat = 16.78). The positive coefficient on *Board connections* indicates that the proportion of independent directors on a board is greater when the firm's board has a higher proportion of directors who also sit on at least one other firm's board with above median proportion of independent directors of the year. *Board locations* is also a significant predictor of *Board independence* (t-stat = 2.48), which suggests that the proportion of independent directors on a board is greater when the firm's headquarters is located in a state with greater number of external directors serving in firms in the year. Diagnostic tests of the relevance of *Board connections* and *Board locations* as instruments indicate that they are powerful: the partial R^2 is 0.08, suggesting that they add a reasonable amount of explanatory power to the regression. The null hypothesis that these are weak instruments is soundly rejected. The F-statistic is statistically significant (F-stat = 142.22) and is above the rule of thumb of 10 proposed by Staiger and Stock (1997). The F-statistic also satisfies the higher standard proposed by Stock *et al*. (2002): specifically, it is above the critical value of 11.59 based on the 2SLS size of the nominal 5% Wald test.

In the remaining columns, we present the results of the second-stage regressions with *PIN* and *Spread* as the dependent variables. We continue to find a highly significant and negative association between *Board independence* and proxies for information asymmetry (t-stats = -7.79 and -7.43 for *PIN* and *Spread*, respectively). The panel beneath the regression results provides some diagnostic tests to ascertain the endogeneity of *Board independence*. The null hypothesis of each test is that there is no endogeneity; the test statistic is the F-statistic of Wooldridge's (1995) robust score. The tests indicate that there is an endogeneity issue with both *PIN* and *Spread* as the dependent variable in the second-stage regression; hence the use of the 2SLS research design is supported in this case. Although the J-statistics remain low (0.150 and 0.104, respectively), the result from the over-identification test of all instruments is statistically insignificant at conventional levels. This suggests that the instruments meet the commonly accepted threshold for validity and are correctly excluded in the second stage regression. Taken together, the results from the 2SLS regressions suggest that more independent boards lead to less information asymmetry among investors.

4.2 How the information environment mediates the effect of board independence on information asymmetry among investors

Table 5 Panel A presents the results of our OLS regressions that the association between a firm's board independence and its information environment. We proxy for the firm's information environment mechanisms using *Forecast frequency* and *Analyst coverage*. Consistent with H2a and H2b, we find board independence is positive and significantly associated with more frequent forecasts and greater analyst coverage (t-stat = 2.45 and 3.64, respectively). Turning to Panel B of Table 5, we find some evidence that more frequent management forecasts and greater analyst coverage are associated with lower information asymmetry. Specifically, using *PIN* (*Spread*) as the dependent variable, the coefficients on *Forecast frequency* and *Analyst coverage* are -0.000 (-0.001) and -0.003 (-0.016), respectively. All the coefficients, except *Forecast frequency* using *Spread* as the dependent variable, are significant at the 0.05 level or better. Therefore, consistent with H2c, we find that forecast frequency and analyst coverage mediate the association between board independence and information asymmetry.

We also observe that after adding the information environment variables — *Forecast frequency* and *Analyst coverage* — to the regressions in equation (1), the negative association between *PIN* and *Board independence* remains significant, while the negative association between and between *Spread* and *Board independence* becomes weakly significant. Specifically, the coefficient on *Board independence* using *PIN* as the dependent variable is -0.010 (t-stat = -2.12) and the coefficient on *Board independence* using *Spread* as the dependent variable is -0.066 (t-stat = -1.60). This result suggests that the board independence has both a direct effect on information asymmetry, as well as an indirect effect on information asymmetry through increased transparency in the information environment.

Taken together, the results in Table 5 suggest that board independence reduces information asymmetry among investors, and that the effect of board independence on information asymmetry is incremental to that reduction via increased forecast frequency and analyst coverage.

Next, we use path analysis to further explore the relative importance of each information environment variable in mediating the effect of board independence on information asymmetry. In path analysis, mediated pathways (those acting through a mediating variable, i.e., "Y," in the pathway $X \rightarrow Y \rightarrow Z$) can be examined. Path analysis formalizes these relations using a series of structural equations, which are then depicted diagrammatically for ease of conceptualization and clarity. In this study, an indirect effect refers to the role of board independence on information asymmetry that is expected to be mediated through the hypothesized mediating mechanisms of voluntary disclosure and analyst coverage. A direct effect is the effect of board independence on information asymmetry that is not mediated through any of the mechanisms.

We use path analysis to decompose the effect of board independence on information asymmetry into indirect and direct effects. Path analysis is commonly regarded as a special case of structural equation modeling.[12] It is a statistical technique that is used mainly to understand the comparative strengths of direct and indirect relationships among a set of variables (Ullman, 1996) and it has been used in studies such as Bushee and Noe (2000), Barton and Mercer (2005), and Bhattacharya *et al*. (2012). Specifically, we examine the indirect role of *Board independence* in influencing two distinct information quality variables, *Forecast frequency and Analyst coverage*, and we consequently test the relative impact of these mediating variables on our outcome variable, information asymmetry, as proxied by *PIN* and *Spread*. We also model the direct role of *Board independence* in influencing *PIN* and *Spread* to capture all unmodeled latent variables that could possibly explain the relation between board independence and information asymmetry.

Panels A and B of Table 6 present the path coefficients for the indirect and direct effects from board independence to information asymmetry. All the path coefficients are standardized for meaningful comparisons among the paths (Bushee and Noe, 2000). The path coefficients between board independence and information environment are obtained from regression results in Table 5 Panel A while the path coefficients between information environment and information asymmetry, and the direct path coefficient between board independence and information asymmetry, are obtained from regression results in Table 5 Panel B. To compare the strengths of the two mediated variables, we use the standard procedure in path analysis of multiplying the path coefficients across the respective pathways. For example, the relative impact linking *Board independence* to *PIN* through *Analyst coverage* is obtained by multiplying the mediating path coefficients 1.908 and -0.003, to arrive at -0.005.

[12] Unlike structural equation modeling, which deals with both measured and latent variables, path analysis is regarded as a special case of structural equation modeling in that the latent variables are explicitly specified.

In Table 6, Panel A, we observe that the total effect of *Board independence* on *PIN* is -0.019. Given that standardized coefficients are used, this result means that a one standard deviation increase in *Board independence* is associated with a 0.105 standard deviation decline in *PIN*, which translates to about 5.3% reduction in *PIN*.[13] The effects of *Board independence* on *PIN* through *Forecast frequency* and *Analyst coverage*, are -0.004 and -0.005, respectively.

Among the two mediating variables, the more economically significant mediated effect is the pathway through *Analyst coverage* (-0.005). The impact of board independence on information asymmetry through voluntary disclosure is relatively smaller: about 55.6% (0.005/0.009) of the total mediated effect is through analyst coverage. The results suggest that the role of independent boards in attracting more analysts to cover the firm has the greater relative impact in alleviating information asymmetry among investors. The role of independent boards in increasing voluntary disclosure appears to be relatively less important in reducing information asymmetry.

Turning to Table 6, Panel B, we observe that the total effect of *Board independence* on *Spread* is -0.098. Given that standardized coefficients are used, this result means that a one standard deviation increase in *Board independence* is associated with a 0.098 standard deviation decline in *Spread*, which translates to about 12.7% reduction in *Spread*. The results of the path analysis using *Spread* are similar to those using *PIN*. Specifically, the effects of *Board independence* on *Spread* through *Forecast frequency* and *Analyst coverage*, are -0.001 and -0.031, respectively. Likewise, we observe that the more economically significant mediated effect among the two mediating variables is through *Analyst coverage* (-0.031). The impact of *Board independence* on information asymmetry through voluntary disclosure is relatively smaller:

[13] One standard deviation in PIN is 0.0632, and hence the impact of 0.015 standard deviation decline in PIN is (0.0632 x 0.015) divided by 0.1247 (mean value of PIN) = 5.32%. The other comparative statics are computed analogously.

about 96.9% (0.031/0.032) of the total mediated effect is through analyst coverage. Overall, the results in Table 6 reveal that while voluntary disclosure and analyst coverage mediate the effect of board independence on information asymmetry among investors, the influence of analyst coverage is more dominant.

4.3 Alternate measure of PIN based on the information asymmetry component of PIN

In this paper, we use *PIN* as one of our proxy for information asymmetry. Duarte and Young (2009) find that *PIN* can be decomposed into two components: one related to information asymmetry and another related to illiquidity. Given that our paper focuses on whether board independence is related to information asymmetry specifically, in a robustness test, we re-run our analyses using the information asymmetry component of *PIN* (*Adj_PIN*) as our proxy of information asymmetry following Duarte and Young (2009). Our available data for *Adj_PIN* spans from 1997 – 2003, and the result is presented in Table 7.[14] As observed from this table, we still observe a negative and significant association between *Board independence* and *Adj_PIN*, both before and after controlling for information environment proxies. The result is also quantitatively similar to that documented using *PIN* as the proxy for information asymmetry in Table 4. In untabulated analyses, we find that this result is also robust to the use of the 2SLS regression technique in Table 4. This suggests that our inferences are unchanged using an alternate measure of *PIN* based on Duarte and Young (2009).

4.4 Alternative approaches to deal with cross-correlation in error terms

There are several approaches to estimating standard errors for regression coefficients that account for cross-sectional and/or time-series dependence in the error terms (Petersen, 2009,

[14] We thank the authors for sharing the data on *Adj_PIN* with us.

Gow *et al*., 2010). To examine the robustness of our results, we rerun the OLS regressions in Table 4 Panel A, Table 5 Panel A, and Table 5 Panel B using two approaches. Table 8 Panel A presents the results with two-way clustering of the standard errors by firm and by year. This approach allows for both cross-sectional and time-series dependence in the error terms. Panel B presents the results of using the Fama-MacBeth approach; the regressions are first run for each year and the average coefficients and corresponding t-statistics across the years are then computed. This approach is designed to address concerns about cross-sectional correlation and assumes that the yearly estimates of the coefficient are independent of each other. For parsimony, we report only the coefficients and the t-statistics of the key independent variables of each regression. As observed from both Panels A and B, the statistical significance of our test variables are quantitatively similar to those reported before and thus our inferences are unchanged using alternative approaches to deal with cross-correlation in the error terms.

5. Conclusion

In this paper, we examine whether greater board independence leads to an improvement in the information environment and reduced information asymmetry among investors. With bid-ask spreads and PIN as our proxies for information asymmetry among investors, we find that a more independent board leads to lower information asymmetry. With regard to the information environment, we show that greater board independence leads to greater management forecast frequency and broader analyst coverage. Not only that, we find that greater board independence is still significantly associated with lower information asymmetry when we include voluntary disclosure and analyst coverage as additional controls in our regressions. This result suggests that the board independence has both a direct effect on information asymmetry, as well as an indirect effect on information asymmetry through increased transparency in the information environment. To further examine the indirect effects, we develop a framework that lays out how the information environment could drive the relation between board independence and information asymmetry among investors. Using path analysis as an empirical tool to test this framework, we find that board independence affects information asymmetry though voluntary disclosure and analyst coverage. The more significant mediating mechanism driving the relation between board independence and information asymmetry appear to be analyst coverage. In contrast, the mediating effect through voluntary disclosure appears to be smaller.

Overall, our paper provides an incremental contribution to the existing corporate governance research by identifying the effect of board independence on the information environment. This identification is important because actions by regulators and firms are based on the belief that greater board independence can improve transparency. In addition, by studying the underlying mechanisms that link board independence to the firm's information environment, the paper addresses the question of *how* board independence could be associated with information asymmetry. In conducting our study, we utilize a parsimonious and empirically testable framework that links board independence to information asymmetry. We then make use of path analysis to analyze, *within sample*, the different paths through which we expect board independence to be associated with information asymmetry.

Appendix 1

1.A – Cleaning the NYSE Trades and Quotes (TAQ) database

To compute the market microstructure variables from January 1993 to December 2007, we use the intra-day quotes and trades from the NYSE TAQ database, which consists of a trades file and a quotes file. To ensure data integrity, we remove the errors and outliers from the files.

For the trades file, we retain the following:

1. Trades inside regular trading hours (9:30-16:00);
2. Good trades (corr = 0, 1);
3. Regular sale conditions (cond = blank or *);
4. Trades with a positive trade price (price > 0) and a positive trade size (siz > 0);
5. Trades with an absolute change in trade price from the previous trade price of less than or equal to 10%.

For the quotes file, we retain the following:

1. Quotes inside regular trading hours (9:30-16:00);
2. Regular quotes (mode = 12);
3. Quotes with a positive bid price (bid > 0), a positive ask price (ofr > 0), a bid price greater than the ask price (ofr > bid), a positive bid size (bidsiz > 0) or a positive ask size (ofrsiz > 0);
4. Quotes with relative quoted spreads of less than or equal to 20%;
5. Quotes with an absolute change in bid price from the previous bid price in each day of less than or equal to 10% and with an absolute change in ask price from the previous ask price in each day of less than or equal to 10%;
6. For the computation of relative effective spreads only, quotes with relative effective spreads of less than or equal to 20%.

1.B Matching of trades and quotes

The matching of trades and quotes is required for the computation of effective spreads. In combining the trades and quotes, we take the following steps. Following Lee and Ready (1991), we match each trade with the latest available quote from at least five seconds earlier. Then, as in Huang and Stoll (1997), we collapse all trades that took place at the same price and quotes (bid price and ask price) into a single trade. According to Huang and Stoll, "a large order may be executed at a single price but be reported in a series of smaller trades" and "a single large limit order may be executed at a single price against various incoming market orders".

1.C Computation of PIN

PIN measures the information asymmetry between informed and uninformed traders in individual stocks. Its value is estimated by the numerical maximization of the likelihood function of the underlying market microstructure model specified in Easley *et al*. (1997). This model is a learning model in which market makers draw inferences about the probability of information asymmetry based on the observed order flow. Specifically, the model uses the number of daily buys and daily sells within a certain period, usually a quarter or a year, to estimate *PIN*.[15] Within each day, trades are assumed to arrive in the market sequentially according to Poisson processes. Mathematically, the model specifies that, on any day i, the likelihood of observing the number of buys B_i and the number of sells S_i is given by:

$$
\begin{aligned}
L(\theta|B_i,S_i) = {} & \alpha(1-\delta)e^{-(\mu+\varepsilon_B)}\frac{(\mu+\varepsilon_B)^{B_i}}{B_i!}e^{-\varepsilon_S}\frac{\varepsilon_S^{S_i}}{S_i!} \\
& +\alpha\delta e^{-\varepsilon_B}\frac{\varepsilon_B^{B_i}}{B_i!}e^{-(\mu+\varepsilon_S)}\frac{(\mu+\varepsilon_S)^{S_i}}{S_i!}+(1-\alpha)e^{-\varepsilon_B}\frac{\varepsilon_B^{B_i}}{B_i!}e^{-\varepsilon_S}\frac{\varepsilon_S^{S_i}}{S_i!}
\end{aligned}
\tag{C1}
$$

where $\theta = (\alpha, \delta, \mu, \varepsilon_B, \varepsilon_S)$ are the five structural parameters in the model to be estimated, α is the probability of an information event occurring, δ is the probability of good news when an information event occurs, μ is the daily arrival rate of informed traders on a day when an information event occurs, ε_B is the daily arrival rate of buy orders from uninformed traders who are not aware of the new information, and ε_S is the daily arrival rate of sell orders from uninformed traders who are not aware of the new information.

Trading is a game between a market maker and a trader that repeats over the trading days within the period. Assuming that the days are independent, the joint likelihood of observing a series of daily buys and daily sells over trading days i = 1,..., I is the product of daily likelihoods:

$$
L(\theta|M) = \prod_{i=1}^{I} L(\theta|B_i,S_i), \tag{C2}
$$

where $M = ((B_1, S_1),...,(B_I, S_I))$ represents the dataset.

Maximizing the joint likelihood in Eq. (C2) over the parameters in θ provides the estimates of the parameters. Since there is no closed form solution to the maximization problem, numerical maximization is used to estimate the parameters. Using the estimated parameters, the *PIN* can be estimated using the following equation:

$$
PIN = \frac{\alpha\mu}{\alpha\mu+\varepsilon_B+\varepsilon_S} \tag{C3}
$$

In Eq. (C3), the numerator is the expected number of orders from privately informed investors and the denominator is the number of orders each day. Hence, the *PIN* is the expected fraction of trades that are information based.

[15] The order flow of each trade is classified as a buy or a sell using the standard Lee-Ready algorithm (Lee and Ready, 1991), which involves a "quote test" and a "tick test". For the "quote test", any trade that takes place above (below) the midpoint of the current quoted spread is classified as a buy (sell) order because trades originating from buyers (sellers) are most likely to be executed at or near the ask (bid). For trades taking place at the midpoint, a "tick test" is used to classify the trade. This test classifies a trade as a buy (sell) order if the trade price is above (below) the previous price. In the event there is no change in the trade price, the order flow is regarded as indeterminable and the trade is not used in computations. The daily number of buy orders and sell orders is determined by adding up the number of orders in each category for each day for each firm.

Appendix 2: Variables Definition (in alphabetical order)

Adj_PIN	The information asymmetry component of PIN, based on Duarte and Young (2009).
Analyst coverage	The average of the monthly number of analysts following the firm.
Board connections	The fraction of directors who are also sitting on at least one other board with above median proportion of independent directors of the year.
Board independence	The proportion of board members who are independent.
Board locations	The number of external directors located in the state where the firm's headquarters is located in the year.
Board size	The number of directors on the board.
Book-to-market ratio	The ratio of the book value of equity to the market value of equity.
Business segments	The number of segments the firm has.
Excess return	The average of the monthly difference between the firm's return and the value-weighted market index.
Ext Board Seats	The total number of external independent board seats held by the directors of the firm.
Forecast frequency	The total number of annual and quarterly management forecasts of earnings per share.
G-index	The index of corporate governance constructed by Gompers, Ishii and Metrick (2003); it consists of 24 antitakeover and shareholder rights provisions.
Information cost	The proxy for information acquisition cost, measured as the negative of the R^2 from the regression of firm daily returns on market returns, following Bhushan (1989).
Litigation risk	The estimate of the firm's litigation risk exposure based on the litigation risk model in Rogers and Stocken (2005). According to this model, the litigation risk of a firm in each calendar quarter is defined as: -5.738 + 0.141 x *Size* + 0.284 x *Turn* + 0.012 x *Beta* - 0.237 x *Returns* - 1.340 x *Std_Ret* + 0.011 x *Skewness* - 3.161 x *Min_Ret* - 0.025 x *Bio_Tech* + 0.378 x *Computer Hardware* + 0.075 x *Electronics* - 0.034 x *Retailing* + 0.211 x *Computer Software*; where *Size* is the natural log of the average market value of equity measured in dollars, *Beta* is the slope coefficient from regressing daily returns on the CRSP Equal-Weighted index, *Returns* is defined as buy and hold returns, *Std_Ret* is the standard deviation of the daily returns, *Skewness* is defined as the skewness of the daily returns, *Min_Ret* is the minimum of the daily returns, *Bio_Technology* is an industry indicator variable equaling one if the firm is in the bio-tech industry (SIC 2833 to 2836) and zero otherwise, *Computer Hardware* is an industry indicator variable equaling one if the firm is in the computer hardware industry (SIC 3570 to 3577) and zero otherwise, *Electronics* is an industry indicator variable equaling one if the firm is in the electronics industry (SIC 3600 to 3674) and zero otherwise, *Retailing* is an

	industry indicator variable equaling one if the firm is in the retail industry (SIC 5200 to 5961) and zero otherwise, and *Computer Software* is an industry indicator variable equaling one if the firm is in the computer software industry (SIC 7371 to 7379) and zero otherwise. To measure the litigation risk in a year, we take the average across four quarters.
Loss	An indicator variable equaling one if the firm has negative net income before extraordinary items, zero otherwise.
Market cap	The average of the monthly closing capitalization of the ordinary shares of the firm (in trillions).
PIN	The probability of information-based trading.
R&D	The research and development expenses scaled by total assets.
ROA	The return on assets of the firm.
Return volatility	The standard deviation of monthly returns.
Stock turnover	The average of the monthly ratio of trading volume to shares outstanding.
Spread	The average of the daily relative effective bid-ask spread (in percent).
Tangibility	The amount of tangible assets scaled by total assets. Berger *et al.* (1996), in determining the asset liquidation value, find that a dollar of book value yields, on average, 72 cents in asset value for total receivables, 55 cents for inventory, and 54 cents for fixed assets. Therefore, tangible assets is defined as: 0.715 x *Receivables* + 0.547 x *Inventory* + 0.535 x *Capital* + *Cash*; where *Receivables* is total receivables, *Inventory* is total inventory, *Capital* is plant, property, and equipment, and *Cash* is cash and short-term investments.

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TABLE 1 Sample construction

This table provides a description of the sample that is used in this study. Panel A describes the construction of the sample used in all the analyses. Panel B presents the distribution of the sample across the years; the year is based on the year of the meeting date recorded in the Riskmetrics database. *Board independence* is the proportion of board members who are independent. *PIN* is the probability of information-based trading. *Spread* is the average of the daily relative effective bid-ask spread (in percents). *Market cap* is the average of the monthly closing capitalization of the ordinary shares of the firm (in trillions). *Book-to-market ratio* is the ratio of the book value of equity to the market value of equity. *ROA* is the return on assets of the firm. *Loss* is an indicator variable equaling one if the firm has negative net income before extraordinary items, zero otherwise. *Excess return* is the average of the monthly difference between the firm's return and the value-weighted market index. *Return volatility* is the standard deviation of monthly returns. *Stock turnover* is the average of the monthly ratio of trading volume to shares outstanding. *G-index* is the index of corporate governance constructed by Gompers, Ishii and Metrick (2003); it consists of 24 antitakeover and shareholder rights provisions. *Ext Board Seats* is the total number of external independent board seats held by the directors of the firm. *Board size* is the number of directors on the board. *Forecast frequency* is the total number of annual and quarterly management forecasts of earnings per share. *Analyst coverage* is the average of the monthly number of analysts following the firm. *Litigation risk* is the estimate of the firm's litigation risk exposure based on the litigation risk model in Rogers and Stocken (2005). *R&D* is the research and development expenses scaled by total assets. *Tangibility* is the amount of tangible assets scaled by total assets. *Information cost* is the proxy for information acquisition cost, measured as the negative of the R^2 from the regression of firm daily returns on market returns. *Business segments* is the number of segments the firm has.

Panel A: Sample construction

	Observations
For the sample period from 1997 to 2006, all firms in the Riskmetrics database for which *Board independence* can be computed.	14,023
Remove observations for which the *G-index* is not available from the Riskmetrics database.	12,643
Link observations from Riskmetrics database to CRSP database via CUSIP. Remove firms that do not have ordinary shares (share code 10 and 11) listed on NYSE, AMEX, and NASDAQ (exchange codes 1, 2, and 3 respectively) as at the annual general meeting date.	12,502
Remove observations for which *PIN* and *Spread*, which are computed using intraday data from the TAQ database, are not available.	11,284
Remove observations for which the following control variables are not available: *Market cap*, *Book-to-market*, *ROA*, *Loss, Excess return*, *Return volatility, Stock turnover, G-index, Ext Board Seats, Board size, Litigation risk, R&D, Tangibility*, *Information cost*, and *Business segments*.	10,744

Panel B: Distribution of sample across years

Year	Firms	*Board independence*	
		Mean	Median
1997	803	0.602	0.625
1998	1148	0.590	0.615
1999	1059	0.606	0.625
2000	1107	0.618	0.636
2001	1098	0.639	0.667
2002	1125	0.661	0.667
2003	1087	0.689	0.714
2004	1155	0.706	0.714
2005	1100	0.722	0.750
2006	1062	0.728	0.750
Total	10,744		

TABLE 2 Descriptive statistics

This table provides descriptive statistics of the variables in this study. This sample consists of 10,744 firm-year observations from 1,947 firms. *Board independence* is the proportion of board members who are independent. *PIN* is the probability of information-based trading. *Spread* is the average of the daily relative effective bid-ask spread (in percents). *Market cap* is the average of the monthly closing capitalization of the ordinary shares of the firm (in trillions). *Book-to-market ratio* is the ratio of the book value of equity to the market value of equity. *ROA* is the return on assets of the firm. *Loss* is an indicator variable equaling one if the firm has negative net income before extraordinary items, zero otherwise. *Excess return* is the average of the monthly difference between the firm's return and the value-weighted market index. *Return volatility* is the standard deviation of monthly returns. *Stock turnover* is the average of the monthly ratio of trading volume to shares outstanding. *G-index* is the index of corporate governance constructed by Gompers, Ishii and Metrick (2003); it consists of 24 antitakeover and shareholder rights provisions. *Ext Board Seats* is the total number of external independent board seats held by the directors of the firm. *Board size* is the number of directors on the board. *Forecast frequency* is the total number of annual and quarterly management forecasts of earnings per share. *Analyst coverage* is the average of the monthly number of analysts following the firm. *Litigation risk* is the estimate of the firm's litigation risk exposure based on the litigation risk model in Rogers and Stocken (2005). *R&D* is the research and development expenses scaled by total assets. *Tangibility* is the amount of tangible assets scaled by total assets. *Information cost* is the proxy for information acquisition cost, measured as the negative of the R^2 from the regression of firm daily returns on market returns. *Business segments* is the number of segments the firm has.

	Mean	Std Dev	Lower Quartile	Median	Upper Quartile
Board independence	0.6575	0.1764	0.5556	0.6667	0.8000
PIN	0.1247	0.0632	0.0893	0.1155	0.1523
Spread	0.4590	0.5970	0.1610	0.2783	0.5203
Market cap	0.0078	0.0250	0.0006	0.0017	0.0051
Book-to-market	0.4961	0.4394	0.2617	0.4280	0.6272
ROA	0.0428	0.1018	0.0149	0.0447	0.0833
Loss	0.1315	0.3380	0.0000	0.0000	0.0000
Excess return	0.0049	0.0356	-0.0134	0.0033	0.0223
Return volatility	0.1044	0.0659	0.0639	0.0898	0.1282
Stock turnover	0.1491	0.1357	0.0674	0.1077	0.1832
G-index	9.2374	2.7122	7.0000	9.0000	11.0000
Ext Board Seats	2.4080	3.3765	0.0000	1.0000	3.0000
Board size	9.5558	2.8000	8.0000	9.0000	11.0000
Forecast frequency	2.9885	4.0512	0.0000	1.0000	5.0000
Analyst coverage	10.4297	7.4346	4.6667	8.9167	14.9167
Litigation risk	-2.5175	0.2359	-2.6816	-2.5476	-2.3797
R&D	0.0801	2.3666	0.0000	0.0000	0.0304
Tangibility	0.4712	0.1424	0.3854	0.4785	0.5512
Information cost	0.1948	0.1358	0.0832	0.1794	0.2822
Business segments	5.7429	5.3073	1.0000	3.0000	9.0000

TABLE 3 Correlations among key variables

This table provides the Pearson correlations for the key variables in this study. The variables are defined in Table 2. All the correlations are statistically significant at the 1 percent level.

	Board independence	*Forecast frequency*	*Analyst coverage*	*PIN*	*Spread*
Board independence		0.140	0.102	-0.156	-0.177
Forecast frequency			0.161	-0.176	-0.189
Analyst coverage				-0.427	-0.325
PIN					0.453

TABLE 4 Regressions of information asymmetry on board independence

This table reports the results of the regressions that examine the effect of *Board independence* on information asymmetry, as proxied by *PIN* and *Spread*. Panel A reports the results based on Ordinary Least Squares (OLS), and Panel B reports the results based on two-stage least squares (2SLS). A constant sample of 10,744 observations from 1,947 firms is used in the regressions. *Board independence* is the proportion of board members who are independent. *PIN* is the probability of information-based trading. *Spread* is the average of the daily relative effective bid-ask spread (in percents). *Market cap* is the average of the monthly closing capitalization of the ordinary shares of the firm (in trillions). *Book-to-market ratio* is the ratio of the book value of equity to the market value of equity. *ROA* is the return on assets of the firm. *Loss* is an indicator variable equaling one if the firm has negative net income before extraordinary items, zero otherwise. *Excess return* is the average of the monthly difference between the firm's return and the value-weighted market index. *Return volatility* is the standard deviation of monthly returns. *Stock turnover* is the average of the monthly ratio of trading volume to shares outstanding. *G-index* is the index of corporate governance constructed by Gompers, Ishii and Metrick (2003); it consists of 24 antitakeover and shareholder rights provisions. *Ext Board Seats* is the total number of external independent board seats held by the directors of the firm. *Board size* is the number of directors on the board. *Board connections* is the fraction of directors who are also sitting on at least one other board with above median proportion of independent directors of the year. *Board locations* is the number of external directors located in the state where the firm's headquarters is located in the year. t-statistics based on robust standard errors clustered by firm are presented in parentheses. Tests of the validity of the 2SLS research design are found at the bottom of Panel B. *, **, and *** indicate significance at the 10, 5, and 1 percent levels, respectively.

Panel A: Ordinary Least Squares (OLS) Regression

	PIN	*Spread*
Constant	0.186***	0.720***
	(13.74)	(5.40)
Board independence	-0.015***	-0.097**
	(-3.01)	(-2.30)
Market cap	-0.250***	-0.568***
	(-4.73)	(-3.06)
Book-to-market	0.022***	0.271***
	(6.82)	(6.17)
ROA	-0.038***	-0.457***
	(-5.22)	(-4.52)
Loss	0.003	0.170***
	(1.31)	(5.87)
Excess return	-0.172***	-4.989***
	(-10.47)	(-16.88)
Return volatility	0.111***	2.525***
	(8.55)	(8.77)
Stock turnover	-0.098***	-0.871***
	(-11.52)	(-9.84)
G-index	-0.001***	-0.005*
	(-3.42)	(-1.70)
Ext Board Seats	-0.002***	-0.010***
	(-7.88)	(-6.00)
Board size	-0.003***	-0.027***
	(-7.22)	(-10.31)
Year fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Adjusted R-square	0.2432	0.4422

Panel B: Two-Stage Least Squares (2SLS) Regression

	Board independence	*PIN*	*Spread*
	1st stage	*2nd stage*	*2nd stage*
Constant	0.524***	0.252***	1.214***
	(6.81)	(10.58)	(7.74)
Board connections	0.262***		
	(16.78)		
Board locations	0.000**		
	(2.48)		
Board independence		-0.137***	-1.018***
		(-7.79)	(-7.43)
Market cap	-0.221**	-0.243***	-0.521***
	(-1.99)	(-5.40)	(-2.94)
Book-to-market	0.008	0.022***	0.272***
	(1.50)	(7.08)	(6.34)
ROA	-0.027	-0.043***	-0.495***
	(-1.13)	(-5.33)	(-4.68)
Loss	0.004	0.004	0.175***
	(0.58)	(1.50)	(5.97)
Excess return	-0.022	-0.173***	-5.000***
	(-0.52)	(-10.05)	(-17.04)
Return volatility	-0.087**	0.096***	2.412***
	(-2.13)	(7.16)	(8.93)
Stock turnover	0.068***	-0.087***	-0.791***
	(3.01)	(-9.78)	(-8.89)
G-index	0.009***	0.000	0.005
	(6.89)	(0.33)	(1.52)
Ext Board Seats	0.003***	-0.001*	0.000
	(3.09)	(-1.78)	(0.21)
Board size	-0.002*	-0.003***	-0.028***
	(-1.69)	(-6.78)	(-9.40)
Year fixed effects	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes
R-square	0.3041	0.1558	0.3866
Tests of weak instrument:			
Partial R^2	0.075		
F-statistic	142.216***		
Test of no endogeneity:			
F-statistic		58.365***	52.423***
Test of overidentification:			
Sargan's statistic		0.150	0.104

TABLE 5 Regressions of information asymmetry on board independence and information quality proxies

This table reports the results of the ordinary least squares (OLS) regressions that examine the effect of *Board independence* on information quality, as proxied by *Forecast Frequency* and *Analyst coverage* (Panel A), and the effect of *Board independence* on information asymmetry, as proxied by *PIN* and *Spread,* after controlling for information quality proxies (Panel B). A constant sample of 10,744 observations from 1,947 firms is used in the regressions. *Board independence* is the proportion of board members who are independent. *PIN* is the probability of information-based trading. *Spread* is the average of the daily relative effective bid-ask spread (in percents). *Market cap* is the average of the monthly closing capitalization of the ordinary shares of the firm (in trillions). *Book-to-market ratio* is the ratio of the book value of equity to the market value of equity. *ROA* is the return on assets of the firm. *Loss* is an indicator variable equaling one if the firm has negative net income before extraordinary items, zero otherwise. *Excess return* is the average of the monthly difference between the firm's return and the value-weighted market index. *Return volatility* is the standard deviation of monthly returns. *Stock turnover* is the average of the monthly ratio of trading volume to shares outstanding. *G-index* is the index of corporate governance constructed by Gompers, Ishii and Metrick (2003); it consists of 24 antitakeover and shareholder rights provisions. *Ext Board Seats* is the total number of external independent board seats held by the directors of the firm. *Board size* is the number of directors on the board. *Forecast frequency* is the total number of annual and quarterly management forecasts of earnings per share. *Analyst coverage* is the average of the monthly number of analysts following the firm. *Litigation risk* is the estimate of the firm's litigation risk exposure based on the litigation risk model in Rogers and Stocken (2005). *R&D* is the research and development expenses scaled by total assets. *Tangibility* is the amount of tangible assets scaled by total assets. *Information cost* is the proxy for information acquisition cost, measured as the negative of the R^2 from the regression of firm daily returns on market returns. *Business segments* is the number of segments the firm has. t-statistics based on robust standard errors clustered by firm are presented in parentheses. *, **, and *** indicate significance at the 10, 5, and 1 percent levels, respectively.

Panel A: Board independence and information quality

	Forecast Frequency	*Analyst Coverage*
Constant	10.008***	59.287***
	(8.56)	(33.34)
Board independence	0.854**	1.908***
	(2.45)	(3.64)
Market cap	1.981	17.891**
	(0.44)	(2.23)
Book-to-market	-0.354***	-0.105
	(-2.97)	(-0.73)
ROA	0.889*	2.663***
	(1.87)	(3.29)
Loss	-0.909***	-0.104
	(-6.83)	(-0.51)
Litigation risk	3.346***	21.581***
	(9.55)	(36.25)
R&D	-0.002	-0.041***
	(-0.65)	(-4.21)
Tangibility	-2.593***	0.005
	(-5.31)	(0.01)
Information cost	-2.445***	0.135
	(-5.03)	(0.22)
Business segments	0.011	-0.070***
	(0.69)	(-3.49)
G-index	0.082***	0.079**

	(3.37)	(2.08)
Ext Board Seats	0.004	0.084***
	(0.21)	(2.73)
Board size	0.018	0.229***
	(0.71)	(5.77)
Year fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Adjusted R-square	0.2679	0.6287

Panel B: Board independence, information quality and information asymmetry

	PIN	*Spread*
Constant	0.181***	0.694***
	(16.65)	(5.32)
Board independence	-0.010**	-0.066
	(-2.12)	(-1.60)
Forecast frequency	-0.000**	-0.001
	(-2.45)	(-0.84)
Analyst coverage	-0.003***	-0.016***
	(-19.98)	(-15.77)
Market cap	0.001	0.931***
	(0.05)	(4.29)
Book-to-market	0.016***	0.236***
	(6.20)	(5.78)
ROA	-0.024***	-0.373***
	(-3.62)	(-3.96)
Loss	0.003	0.173***
	(1.45)	(6.10)
Excess return	-0.171***	-4.984***
	(-11.14)	(-17.28)
Return volatility	0.078***	2.329***
	(6.72)	(8.58)
Stock turnover	-0.051***	-0.589***
	(-7.49)	(-7.48)
G-index	-0.001***	-0.003
	(-2.92)	(-1.16)
Ext Board Seats	-0.001***	-0.005***
	(-4.85)	(-3.05)
Board size	-0.001***	-0.017***
	(-3.93)	(-7.03)
Year fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Adjusted R-square	0.2973	0.4639

TABLE 6 Path analysis of the relation between board independence and information asymmetry

This table reports the path analysis of the relation between board independence and information asymmetry into indirect and direct effects. Panels A and B presents the path analysis with *PIN* and *Spread*, respectively, as the proxy for information asymmetry. In these panels, the following acronyms are used for brevity: BI – *Board independence*; FF –*Forecast frequency*; AC – *Analyst coverage*; PIN – *PIN*; S – *Spread*.

Panel A: Decomposition of the effect of *Board independence* on *PIN*

Board independence (BI) on *PIN* (PIN)			
Indirect effects	Mediating path coefficients		
BI -> FF -> PIN	0.854	-0.004	-0.004
BI -> AC -> PIN	1.908	-0.003	-0.005
Total indirect effects			-0.009
Direct effect			
BI -> PIN			-0.010
Total effect			-0.019

Panel B: Decomposition of the effect of *Board independence* on *Spread*

Board independence (BI) on *Spread* (S)			
Indirect effects	Mediating path coefficients		
BI -> FF -> S	0.854	-0.001	-0.001
BI -> AC -> S	1.908	-0.016	-0.031
Total indirect effects			-0.032
Direct effect			
BI -> S			-0.066
Total effect			-0.098

TABLE 7 Regressions of adjusted PIN on board independence and information quality

This table reports the results of the ordinary least squares (OLS) regressions that examine the effect of *Board independence* on the information asymmetry component of PIN (*Adj_PIN*). *Board independence* is the proportion of board members who are independent. *Forecast frequency* is the total number of annual and quarterly management forecasts of earnings per share. *Analyst coverage* is the average of the monthly number of analysts following the firm. *Market cap* is the average of the monthly closing capitalization of the ordinary shares of the firm (in trillions). *Book-to-market ratio* is the ratio of the book value of equity to the market value of equity. *ROA* is the return on assets of the firm. *Loss* is an indicator variable equaling one if the firm has negative net income before extraordinary items, zero otherwise. *Excess return* is the average of the monthly difference between the firm's return and the value-weighted market index. *Return volatility* is the standard deviation of monthly returns. *Stock turnover* is the average of the monthly ratio of trading volume to shares outstanding. *G-index* is the index of corporate governance constructed by Gompers, Ishii and Metrick (2003); it consists of 24 antitakeover and shareholder rights provisions. *Ext Board Seats* is the total number of external independent board seats held by the directors of the firm. *Board size* is the number of directors on the board. t-statistics based on robust standard errors clustered by firm are presented in parentheses. *, **, and *** indicate significance at the 10, 5, and 1 percent levels, respectively.

	Adj_PIN	*Adj_PIN*
Constant	0.169***	0.162***
	(12.81)	(15.07)
Board independence	-0.015***	-0.007*
	(-3.15)	(-1.79)
Forecast frequency		-0.001***
		(-3.66)
Analyst coverage		-0.002***
		(-19.61)
Market cap	-0.312***	-0.063**
	(-4.38)	(-2.38)
Book-to-market	0.018***	0.013***
	(5.51)	(5.20)
ROA	-0.044***	-0.034***
	(-3.43)	(-3.07)
Loss	-0.001	0.000
	(-0.33)	(0.09)
Excess return	-0.153***	-0.146***
	(-9.26)	(-9.43)
Return volatility	0.124***	0.093***
	(8.27)	(6.89)
Stock turnover	-0.152***	-0.083***
	(-10.54)	(-7.02)
G-index	-0.000	-0.000
	(-0.74)	(-0.32)
Ext Board Seats	-0.001***	-0.001***
	(-7.12)	(-3.57)
Board size	-0.003***	-0.002***
	(-9.18)	(-5.98)
Year fixed effects	Yes	Yes
Industry fixed effects	Yes	Yes
Adjusted R-square	0.4120	0.5018

TABLE 8 Alternative approaches to deal with cross-correlation in error terms

This table reports the results of implementing alternative approaches to deal with cross-correlation in error terms in Table 4 Panel A, Table 5 Panel A, and Table 5 Panel B. Panel A presents the results with two-way clustering of the standard errors by firm and by year. Panel B presents the results of using the Fama-MacBeth approach; the regressions are first estimated for each year and the average coefficients and corresponding t-statistics across the years are then computed. *, **, and *** indicate significance at the 10, 5, and 1 percent levels, respectively.

Panel A: Two-way clustering by firm and year

	Table 4 Panel A		*Table 5 Panel A*		*Table 5 Panel B*	
	PIN	*Spread*	*Forecast Frequency*	*Analyst Coverage*	*PIN*	*Spread*
Intercept	0.186***	0.720***	10.008***	59.287***	0.181***	0.694***
	(16.10)	(6.18)	(8.06)	(15.24)	(24.46)	(6.42)
Board independence	-0.015***	-0.097***	0.854**	1.908***	-0.010**	-0.066*
	(-2.80)	(-2.66)	(2.39)	(3.59)	(-2.21)	(-1.91)
Forecast frequency					-0.000**	-0.001
					(-2.51)	(-0.52)
Analyst coverage					-0.003***	-0.016***
					(-11.77)	(-5.03)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-square	0.2432	0.4422	0.2679	0.6287	0.2973	0.4639

Panel B: Fama-MacBeth approach

	Table 4 Panel A		*Table 5 Panel A*		*Table 5 Panel B*	
	PIN	*Spread*	*Forecast Frequency*	*Analyst Coverage*	*PIN*	*Spread*
Intercept	0.165***	0.475***	12.175***	61.769***	0.160***	0.438***
	(13.54)	(6.48)	(8.68)	(19.83)	(15.38)	(7.57)
Board independence	-0.012**	-0.091***	0.848***	1.321***	-0.007*	-0.057**
	(-2.69)	(-4.09)	(4.01)	(3.80)	(-2.15)	(-2.68)
Forecast frequency					-0.001**	-0.008***
					(-3.06)	(-3.40)
Analyst coverage					-0.003***	-0.015***
					(-14.24)	(-5.88)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R-square	0.2101	0.3825	0.0765	0.5760	0.2608	0.3997