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Board structure and price informativeness ☆

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ABSTRACT

We develop and test the hypothesis that stock price informativeness affects the structure of corporate boards. We find a negative relation between price informativeness and board independence. This finding is robust to the inclusion of many firm-level controls, including firm fixed effects, and to the choice of the measure of price informativeness. Consistent with the hypothesis that price informativeness and board monitoring are substitutes, this relation is particularly strong for firms more exposed to both external and internal governance mechanisms and for firms in which firm-specific knowledge is relatively unimportant. Our results suggest that firms with more informative stock prices have less demanding board structures.

1. Introduction

The view that prices aggregate information that is dispersed among market participants dates back to Hayek (1945). The modern version of such an idea is found in the works of Grossman and Stiglitz (1980) and Kyle (1985), in which the main role of stock markets is the production and aggregation of information as a consequence of trading between speculators and other types of (perhaps less informed) investors. The idea that this type of

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information can also be useful for the provision of incentives in firms and for the design of corporate governance mechanisms is a more recent one. Holmstrom and Tirole (1993) and Faure-Grimaud and Gromb (2004) examine the role of stock prices in disciplining managers and providing incentives to insiders. A set of related studies exists on the role of stock prices in guiding corporate investment decisions (Khanna, Slezak, and Bradley, 1994; Dow and Gorton, 1997; and Dow, Goldstein, and Guembel, 2007).

We contribute to this literature by providing robust evidence of a negative relation between stock price informativeness and corporate board independence. Our main proxy for price informativeness is the probability of informed trading (PIN), which is developed in a series of papers beginning with Easley, Kiefer, and O'Hara (1996). The results are unchanged when we use alternative proxies for the rate of information flow into stock prices, such as firm-specific stock return variation (Morck, Yeung, and Yu, 2000) and measures of illiquidity or price impact of order flow (Amihud, 2002). We also investigate the relation between price informativeness and additional characteristics of the board of directors. We find that price informativeness is positively related to the number of directors with low attendance at board meetings and negatively related to the number of board meetings. These results are compatible with board monitoring and price informativeness being substitutes.

We show that the negative correlation between price informativeness and board independence remains strong after controlling for a long list of possible covariates. This correlation is not explained by firm size and complexity, performance, governance mechanisms, ownership structure, and earnings informativeness, among others. In fact, the results are unchanged after the inclusion of firm fixed effects, suggesting that time-invariant unobserved firm characteristics cannot explain our empirical findings. This effect is at least as strong as the ones between board independence and other firm-level variables that have been shown in the literature on corporate boards (Boone, Field, Karpoff, and Raheja, 2007; Coles, Daniel, and Naveen, 2008; and Linck, Netter, and Yang, 2008). Regarding the direction of causality, we use instrumental variables methods to estimate the effect of price informativeness on board independence. As instruments, we use variables that are known to be correlated with price informativeness, such as share turnover, analyst coverage, and Standard & Poor's 500 membership, but have never been used as explanatory variables of board independence in previous studies. Our evidence suggests that price informativeness affects board structure.

We develop a simple adverse selection model that rationalizes the relation between board independence and price informativeness. The goal of the model is to clarify the role of price informativeness in the choice of board structures. We argue that the information revealed by stock prices should affect how directors monitor managers. We identify two mechanisms by which prices can affect monitoring. On the one hand, the information revealed by stock prices allows external monitoring mechanisms to operate more efficiently. For example, if prices fall due to the announcement of value-decreasing investments, the firm becomes a cheaper takeover target. Managers who value control would avoid undertaking such value-destroying projects. Thus, stock markets play an important monitoring role. On the other hand, more informative prices bring new information to both markets and boards. Directors could use the information revealed by stock prices as an input to their monitoring task. Arguably, a better informed board of directors should be a better monitor.

Our model predicts that price informativeness matters for board monitoring, but that the sign of this relation is ambiguous. Changing board structure in the direction preferred by shareholders could be difficult (i.e., costly), especially when ownership is dispersed, in which case coordination costs arise. More informative prices make boards more effective but also reduce the need for board independence. Thus, whether price informativeness and board independence are substitutes or complements is in the end an empirical question.

A parallel segment of the literature focuses on moral hazard models (e.g., Adams and Ferreira, 2007) that lead more naturally to the question of substitutability between board independence and managerial incentives through equity-based compensation (e.g., Coles, Lemmon, and Wang, 2008). Our focus on adverse selection issues (as in Hermalin and Weisbach, 1998) is a natural choice for understanding the role of stock prices in determining board structure. We see the two approaches as complementary. In a simple extension to the model, we introduce moral hazard to study the relation between compensation incentives, board monitoring, and price informativeness.

Our model also has unambiguous predictions that we explore in our empirical analysis. We find that the negative relation between price informativeness and board independence is particularly strong for firms more exposed to both external and internal governance mechanisms. The substitution effect between price informativeness and board independence is stronger for firms more exposed to the market for corporate control (i.e., firms with few takeover defenses). The substitution effect is stronger for firms with a high concentration of institutional ownership and with a high chief executive officer (CEO) pay-performance sensitivity. Intuitively, when prices become more informative, incentive contracts solve moral hazard problems more often, making board monitoring less important. We also find that the substitution effect is stronger for firms in which firm-specific knowledge is relatively unimportant.

Few empirical studies have been conducted on the interaction between different governance mechanisms. Mikkelson and Partch (1997) find evidence consistent with the effectiveness of board oversight being enhanced by an active takeover market. More recent examples include Cremers and Nair (2005), who find a complementarity effect between openness to the market for corporate control and the presence of institutional investors, and Gillan, Hartzell, and Starks (2006), who find that an independent board can act as a substitute for the market for corporate control. Coles, Lemmon, and Wang (2008) provide evidence of a substitution effect between board

independence and pay-performance sensitivity. Our paper adds to this growing literature by showing that stock price informativeness also affects organization design, in particular, board structure.

Our results are consistent with the notion that the optimal board structure depends on the characteristics of the firm; that is, "one size" does not fit all firms. The evidence is consistent with board structure being affected by the degree of complexity of firms' operations and the trade-off between the costs and benefits of advising and monitoring management (Boone, Field, Karpoff, and Raheja, 2007; Coles, Daniel, and Naveen, 2008; and Linck, Netter, and Yang, 2008).

Our paper is related to the literature on how corporate governance mechanisms affect the public release of information. Warfield, Wild, and Wild (1995) find that managerial ownership improves earnings informativeness. Klein (2002) and Petra (2007) find that more independent boards improve earnings quality and informativeness, while Vafeas (2000) find no such a relation. Leuz, Triantis, and Wang (2008) (see also Coles, 2008) find that board independence reduces the likelihood of a firm going private after enactment of the 2002 Sarbanes-Oxley Act. Our paper differs from this strand of the literature by studying the interaction between two corporate governance mechanisms (board and market monitoring), instead of the effects of governance on disclosure and earnings informativeness. While earnings informativeness measures the accuracy of accounting information provided to investors, price informativeness measures for the intensity of stock market monitoring.

On the theoretical side, our model integrates two independent lines of research. The first one explains board structure as the result of optimal shareholder choices under incomplete contracts (Hermalin and Weisbach, 1998; Raheja, 2005; and Adams and Ferreira, 2007). The second one examines the role of stock prices in disciplining managers and providing incentives to insiders (Holmstrom and Tirole, 1993; Faure-Grimaud and Gromb, 2004; Almazan, Banerji, and Motta, 2008; and Edmans, 2009). To the best of our knowledge, these two strands of the literature have never been integrated.

The remainder of the paper is organized as follows. In Section 2 we present a simple model to motivate the relation between stock price informativeness and board independence. Section 3 describes the sample and the data. Section 4 presents our core evidence on the relation between board independence and stock price informativeness. In Section 5 we further investigate some of the additional implications of the model, and in Section 6 we perform robustness checks. Section 7 concludes.

2. The model

Using a simple model, we show that a link can exist between the board's monitoring role and the information revealed by stock prices. On the one hand, more informative prices can reinforce the internal monitoring activity performed by the board of directors. On the other hand, higher price informativeness can enhance the effectiveness of external monitoring mechanisms, such as disciplining takeovers. Hence, board independence and price informativeness can interact as either complements or substitutes. We examine this trade-off and discuss the empirical predictions that are tested later in the paper.

In what follows, we take the degree of price informativeness as exogenously given and focus on the optimal choice of board monitoring. We keep the model as simple as possible by focusing only on what is essential for the empirical analysis.

2.1. Setup

We model the need for monitoring the CEO in a simple adverse selection setting. In this setup, board monitoring amounts to replacing a low-quality CEO. In Section 2.6, we extend the model to introduce CEO's effort and incentive contracts.

There are three dates (0, 1, and 2) and four types of participants: shareholders, a board of directors, a CEO, and the stock market. Shareholders are risk–neutral agents who care about the market value of the firm, appoint directors to the board, and delegate firm management to the CEO. The sequence of events is as follows.

At date 0, the shareholders choose the composition of the board of directors (i.e., its level of independence i) and hire a CEO whose type is not known by anyone. The value of the firm is equal to t, the talent of its CEO. CEOs can be of two types $t \in \{L=0, H=1\}$. For simplicity, we assume that both types are equally likely in the population. The unconditional expected value of the firm when a new CEO is appointed is then $\frac{1}{2}$.

The board of directors is characterized by its level of independence $i \in [0,1]$. This level i corresponds to the probability that the board monitors and replaces a CEO who is revealed to be of type L at date 1. The choice of board independence is nontrivial because a more independent board is costlier but also generates more monitoring of the CEO. We assume that board independence has an ex ante cost $ki^2/2$ to shareholders. This cost can arise due to the fact that dispersed shareholders find it difficult to influence board composition.[1]

At date 1, the board can learn about the CEO's type from two sources: stock prices or its own assessment. With probability p (which we interpret as the degree of price informativeness), stock prices reveal the CEO's type to everyone. If the CEO is of type L, the board replaces the CEO with probability i. If the board does not replace the CEO when his type is L, an external raider takes over the firm and replaces its CEO with probability $\tau \in [0,1]$, which we interpret as a measure of takeover threat.

With probability $(1-p)$, stock prices do not reveal the CEO's type, but the board can unilaterally learn it with probability β. If the board learns that the CEO is of type L, the board replaces the CEO with probability i.

In case the CEO is replaced at date 1 by either the board or an outside raider, his successor is randomly

[1] For a model that endogenizes the cost of board independence, see Adams and Ferreira (2007).

drawn from the population. Thus, conditional on the market or the board being informed and willing to replace the CEO, or both, the firm's expected value is $\frac{3}{4}$. If the CEO's type is not revealed, or if the type is revealed to be H, the CEO is not replaced (i.e., neither the market nor the board is interested in monitoring and replacing the incumbent CEO).[2]

At date 2, the value of the firm, which depends on the type of the CEO in charge, is revealed to everyone.

2.2. Board independence and price informativeness

The shareholders' problem at date 0 is to maximize the expected value of the firm by choosing the level of monitoring of the board of directors according to

$$\max_{i\in[0,1]} EV = p\left[(i+\tau-i\tau)\frac{3}{4}+(1-i-\tau+i\tau)\frac{1}{2}\right] + (1-p)\left[\beta i\frac{3}{4}+\beta(1-i)\frac{1}{2}+(1-\beta)\frac{1}{2}\right]-k\frac{i^2}{2}. \quad (1)$$

Assuming an interior solution, the optimal board structure is given by

$$i^* = \frac{1}{4k}[p(1-\tau)+(1-p)\beta]. \quad (2)$$

Proposition 1. *The optimal degree of board independence varies with the degree of price informativeness according to*

$$\frac{\partial i^*}{\partial p} = \frac{1-\tau-\beta}{4k}. \quad (3)$$

The sign of the relation between board independence and price informativeness is ambiguous, depending on the values of the parameters. This result is explained by the interaction of two effects. The marginal benefit of i conditional on the market being informed is $(1-\tau)/4$, and the marginal benefit of i conditional on the market not being informed is $\beta/4$. Changes in p shift the weights on these two terms. If $1-\tau>\beta$, the marginal value of board independence is higher when the market is informed. An increase in p shifts more weight to the case of the market being informed, increasing the equilibrium level of board monitoring. In this case, price informativeness and board monitoring are complements. If $1-\tau<\beta$, the marginal value of board independence is higher when there is no market information. Thus, an increase in p makes board independence marginally less valuable, reducing the equilibrium level of board monitoring. In this case, board independence and price informativeness are substitutes.[3]

Price informativeness and board monitoring can be complements because price informativeness is a nonrival good that can be used by both insiders and outsiders.[4] Price informativeness and board monitoring can be substitutes because both internal and external monitoring mechanisms perform the same task of disciplining the CEO. Intuitively, the substitution effect is likely to dominate when the probability of takeovers is high and the board's knowledge of firm-specific information is high. Ultimately, finding out which effect dominates is an empirical question.

2.3. Takeover threats

More external monitoring makes the substitution effect between price informativeness and board independence stronger. If a disciplining takeover is more likely when the market is informed, there is less need for boards to monitor. Hence, we expect the level of board independence of those firms that are more exposed to the market for corporate control to exhibit higher sensitivity to stock price informativeness. In sum, the substitution effect is unambiguously stronger when takeover threats are more likely.

Proposition 2. *The higher is the likelihood of a takeover, the stronger (weaker) is the substitution (complementarity) effect of price informativeness on the choice of board independence*:

$$\frac{\partial^2 i^*}{\partial p\partial \tau} = -\frac{1}{4k}. \quad (4)$$

This prediction can be tested by using takeover defenses as an inverse proxy for the likelihood of takeovers.

2.4. Institutional investors

Evidence shows that institutional investors also perform an active role in corporate governance (e.g., Gillan and Starks, 2007). We interpret parameter k as a measure of how costly internal monitoring is (i.e., the costs to shareholders of changing the board structure). If there is significant institutional ownership concentration, k is likely to be low (Shleifer and Vishny, 1986).

Proposition 3. *The relation between board independence and price informativeness is stronger when the marginal cost of internal monitoring is smaller*:

$$\frac{\partial^2 i^*}{\partial p\partial k} = -\frac{1}{k}\frac{\partial i^*}{\partial p}. \quad (5)$$

The relation (in absolute values) between board independence and price informativeness is less pronounced when the marginal cost of external monitoring k is higher (i.e., when $\partial i^*/\partial p>0$, then $\partial^2 i^*/\partial p\partial k<0$, reducing the complementarity effect; and when $\partial i^*/\partial p<0$, then $\partial^2 i^*/\partial p\partial k>0$, reducing the substitution effect). These results suggest that price informativeness significantly affects board independence only when the board can effectively act as an internal monitoring mechanism (low monitoring cost k).

[2] The model could easily accommodate a positive probability of a raider acquiring information and placing a takeover bid, even if prices are uninformative.

[3] Note that $\partial^2 EV/\partial i\partial p=(1-\tau-\beta)/4$ and also that $\partial^2 EV/\partial i^2=-k$. Thus, $\partial i^*/\partial p=-(\partial^2 EV/\partial i\partial p)/(\partial^2 EV/\partial i^2)=(1-\tau-\beta)/4k$, which is Proposition 1.

[4] Gordon (2007) proposes the hypothesis that board independence and stock price informativeness are complements. He claims that the monitoring advantages of independent directors are more clear in an environment with increasing stock price informativeness as insiders lose their information advantage about the firm's prospects.

Empirically, we use the concentration of institutional investors as a (inverse) proxy for k.

2.5. Firm-specific knowledge

The parameter β reflects the board's ability to gather firm-specific information. The model predicts that the effect of β on the relation between board independence and price informativeness is as follows.

Proposition 4. *The higher is the probability that the board learns firm-specific information, the stronger (weaker) is the substitution (complementarity) effect of price informativeness on the choice of board independence:*

$$\frac{\partial^2 i^*}{\partial p \partial \beta} = -\frac{1}{4k}. \tag{6}$$

The board should find it harder to acquire firm-specific information in more innovative firms than in firms that undertake simple and well-known projects. According to this interpretation, innovative firms would have low β. This result suggests that the (absolute value of the) effect of price informativeness on board independence is stronger in less innovative firms when there is a substitution effect, but weaker when there is a complementarity effect. Empirically, we use research and development expenditures as a (inverse) proxy for β.

2.6. An extension: effort and incentive compensation

To analyze the impact of CEO compensation contracts on the relation between price informativeness and board monitoring, we now add moral hazard elements to the model. Specifically, we assume that the market value of the firm (gross of CEO compensation) is given by

$$v = t + e + \varepsilon, \tag{7}$$

where $t \in \{0,1\}$ is the CEO's talent as before, $e \in [0,\infty)$ is the effort exerted by the CEO, and $\varepsilon \sim N(0,\sigma^2)$ is luck. Effort choices are made after date 1 and before firm value is publicly revealed at date 2.

We continue to assume that prices are fully informative about firm fundamentals with probability p and that prices are not informative with probability $1-p$. In this setup, informative prices allow one to break down v into its components (i.e., talent t and effort e are perfectly observable). If prices are not informative, only v can be observed. In this case, we also assume that $\sigma^2 = \infty$ to guarantee that no information can be inferred from prices.

As in the case of pure adverse selection, informed monitoring by either the board or the market can discipline managers by firing those with low talent and those who exert low levels of effort. If prices are informative, both the board and the market observe effort choice e and fire the CEO with combined probability $i+\tau-i\tau$ if the first-best level of effort e^{FB} is not chosen.[5] In case there is no monitoring (which happens with probability $1-i-\tau+i\tau$), the firm can offer a compensation contract to the CEO that is contingent on his type and on firm value $w(v,t)$. Compensation contracts can induce CEO effort and substitute for direct monitoring when boards are unwilling to monitor or when the takeover market is ineffective.

Even if prices are not informative, the board can be informed (with probability β) and fire the CEO if the first-best level of effort e^{FB} is not chosen (with probability i). However, if the board is uninformed or if it is informed but does not monitor, contracts contingent on v cannot induce CEO effort because of the assumption that $\sigma^2 = \infty$.

We assume that the compensation contract is linear in $v-t$:

$$w = \alpha + \delta(v-t). \tag{8}$$

Because compensation contracts are written only when prices are informative, the firm offers different contracts to CEOs of different types t.[6]

We assume that the CEO has a (Bernoulli) utility function (defined over wealth and effort) with constant absolute risk-aversion coefficient of one:

$$u(w,e) = -\exp\left[-\left(w - \frac{e^2}{2}\right)\right]. \tag{9}$$

When prices are informative but there is no monitoring, the firm chooses an optimal compensation contract (that is, a fixed transfer α and a bonus δ) for the CEO. Formally, the problem is to

$$\max_{\alpha,\delta} e^* - \alpha - \delta e^*, \tag{10}$$

subject to the incentive compatibility (IC) constraint

$$e^* = \operatorname*{argmax}_e E\left\{-\exp\left(-\left[\alpha + \delta(e+\varepsilon) - \frac{e^2}{2}\right]\right)\right\} \tag{11}$$

and to the individual rationality (IR) constraint

$$E\left\{-\exp\left(-\left[\alpha + \delta(e+\varepsilon) - \frac{e^2}{2}\right]\right)\right\} \geq U_0, \tag{12}$$

where U_0 is the CEO's expected outside utility (we assume that $U_0 = -1$ for simplicity).

In the standard linear contracts setup, we can rewrite the IC constraint in certainty equivalent form

$$e^* = \operatorname*{argmax}_e \left(\alpha + \delta e - \frac{e^2}{2} - \frac{\delta^2\sigma^2}{2}\right). \tag{13}$$

Because the objective function is strictly concave, the CEO's chosen level of effort is given by the first-order condition, which implies $e^* = \delta$.

[5] Because effort is observable when prices are informative or when the board is informed, the board only needs to threaten to fire a CEO in case he does not choose e^{FB}. We assume that this threat is credible. Therefore, in equilibrium the CEO always chooses e^{FB} when the board monitors and the board never fires the CEO for low effort.

[6] Holmstrom and Milgrom (1987) rationalize the use of linear contracts in environments similar to this one, in a continuous-time dynamic moral hazard setup. However, in a static world these linear contracts are usually not optimal (e.g., Bolton and Dewatripont, 2005). In line with many other applications, we use the linear contracts setup only for tractability and simplicity.

We can also rewrite the IR constraint in certainty-equivalent form. Because the fixed transfer α does not enter the IC constraint, the IR constraint must be binding, implying that

$$\alpha = -\delta e + \frac{e^2}{2} + \frac{\delta^2\sigma^2}{2}. \tag{14}$$

After replacing e^* and α in the firm's maximization problem, the optimal compensation contract is given by

$$\alpha^* = \frac{\sigma^2-1}{2(1+\sigma^2)^2} \tag{15}$$

and

$$\delta^* = \frac{1}{1+\sigma^2}. \tag{16}$$

The expected value of the firm (net of the effect of talent t and of compensation) when an incentive contract is used is given by

$$(1-\delta^*)e^* - \alpha^* = \frac{1}{2(1+\sigma^2)} = \frac{\delta^*}{2}. \tag{17}$$

When either the board or the market is informed and monitors the CEO, the first best level of effort $e^{FB}=1$ is implemented and the CEO receives a flat wage of $w^{FB} = \frac{1}{2}$ (he is fired and earns his outside utility if he chooses any different effort level). Thus, the value of the firm (net of the effect of talent) when the market or the board monitors the CEO is $\frac{1}{2}$.

The introduction of moral hazard changes slightly the shareholders' problem at date 0. Shareholders now choose the level of monitoring of the board of directors according to

$$\max_{i\in[0,1]} p\left[(i+\tau-i\tau)\frac{5}{4} + (1-i-\tau+i\tau)\left(\frac{1+\delta^*}{2}\right)\right] + (1-p)\left[\beta i\frac{5}{4} + \beta(1-i)\frac{1}{2} + (1-\beta)\frac{1}{2}\right] - k\frac{i^2}{2}. \tag{18}$$

The optimal board independence is now given by

$$i^* = \frac{1}{4k}[p(1-\tau)(3-2\delta^*) + 3(1-p)\beta], \tag{19}$$

which is virtually identical to Eq. (2) except for the added benefit of board monitoring on inducing effort and for the impact of the pay-performance sensitivity parameter δ^* on board independence.

As before, the impact of price informativeness on board independence is ambiguous:

$$\frac{\partial i^*}{\partial p} = \frac{1}{4k}[3(1-\tau-\beta) - 2\delta^*(1-\tau)]. \tag{20}$$

In our model, δ^* changes only due to changes in exogenous risk σ^2. Increases in σ^2 always reduce pay-performance sensitivity δ^*, which reflects the trade-off between risk and incentives. Consistent with this hypothesis, Aggarwal and Samwick (1999) find a negative correlation between proxies for risk and equity-based incentives. However, Prendergast (2002) surveys the empirical literature on this topic and finds no systematic evidence of a trade-off between incentives and risk. For example, Core and Guay (1999) find that more risk leads to more incentives.

Through its effect on δ^*, exogenous risk affects board independence i^*. Empirically, it is more convenient to test hypotheses concerning the effect of δ^* on i^*. Because both i^* and δ^* are endogenously chosen, implicitly we are assuming that changes in exogenous risk are driving the changes in pay-performance sensitivity, which then have an impact on board independence. Proposition 5 addresses the effect of pay-performance sensitivity on board independence.

Proposition 5. *The optimal degree of board independence varies with pay-performance sensitivity according to*

$$\frac{\partial i^*}{\partial \delta^*} = -\frac{p(1-\tau)}{2k}. \tag{21}$$

Board independence and incentive compensation are substitutes. This is not a novel implication of our model. It has been shown in a number of papers (Denis and Sarin, 1999; Shivdasani and Yermack, 1999; Coles, Daniel, and Naveen, 2008; and Coles, Lemmon, and Wang, 2008). The novel result that our model delivers is given by Proposition 6.

Proposition 6. *The higher is pay-performance sensitivity, the stronger (weaker) is the substitution (complementarity) effect of price informativeness on the choice of board independence:*

$$\frac{\partial^2 i^*}{\partial p \partial \delta^*} = -\frac{1-\tau}{2k} < 0. \tag{22}$$

Intuitively, when prices become more informative, incentive contracts solve moral hazard problems more often, making board monitoring less important. Another way to understand the intuition behind this result is to consider a situation in which moral hazard exists but the firm is constrained to use flat compensation contracts (i.e., $\delta = 0$). In such a case, firms cannot pay for performance, and a change in price informativeness leads to a lower adjustment in board independence compared with a case in which both governance mechanisms (board independence and incentive contracts) are available. Formally,

$$\left.\frac{\partial i^*}{\partial p}\right|_{\delta=0} - \left.\frac{\partial i^*}{\partial p}\right|_{\delta=\delta^*} = \frac{2\delta^*(1-\tau)}{4k} > 0. \tag{23}$$

This expression indicates that there is a more pronounced substitution effect between i and p when firms are allowed to choose pay-performance sensitivity δ optimally.

3. Sample and variables

In this section, we describe the measures of board structure and price informativeness, the sample, and the control variables used in this study.

3.1. Measures and determinants of board structure

Our main dependent variable is the fraction of independent directors, which is a proxy for the monitoring intensity of the board. For a director to qualify as independent, he must not be an employee, a former

executive, or a relative of a current corporate executive of the company. In addition, the director must not have any business relations with the company.

In Section 6.3, we also consider other board structure variables. As alternative proxies for the monitoring activity performed by the board of directors, we use the annual number of regular board meetings and the fraction of directors with low attendance.[7]

To identify the effect of price informativeness on the structure of corporate boards, we need to control for other possible determinants of board structure. The literature provides many suggestions in this regard (Boone, Field, Karpoff, and Raheja, 2007; Coles, Daniel, and Naveen, 2008; and Linck, Netter, and Yang, 2008). Our goal in this paper is not to replicate these works, but rather to make sure that our results are not driven by the omission of variables that have been found to correlate with board structure. The determinants of board structure can be classified into three broadly defined hypotheses: the scope of operations hypothesis, the monitoring hypothesis, and the negotiation hypothesis.

The scope of operations hypothesis suggests that the size and complexity of a firm's operations affect its board structure (Fama and Jensen, 1983). As a firm grows and diversifies, it faces an increasing demand for specialized board members who can perform tasks such as auditing and setting managerial compensation. Under this hypothesis, more complex firms face larger agency costs and thus require additional board monitoring.

We consider three proxies to capture firms' operational complexity: firm size (as measured by equity market capitalization), firm age (the number of years since the firm's stock is exchange-listed), and the number of business segments. We expect larger, older, and more diversified firms to have a higher fraction of independent directors. We also add leverage to this list, because Coles, Daniel, and Naveen (2008) argue that more leveraged firms are more dependent on external resources and thus leverage can be considered as a proxy for firm complexity and the CEO's need for advice.

The monitoring hypothesis is the set of formal and informal theories emphasizing the importance of a firm's business environment for the optimal design of its board structure (e.g., Demsetz and Lehn, 1985; Raheja, 2005; and Adams and Ferreira, 2007). We use several variables to capture some of the elements of these theories. To control for the costs of outside monitoring, we use growth opportunities as proxied by the market-to-book ratio and R&D expenditures, stock price volatility as proxied by the variance of stock returns, and CEO pay-performance sensitivity as proxied by stock and stock options ownership. We also consider free cash flow, profitability, and industry concentration, because these variables are possibly related to agency conflicts and other opportunities for the CEO to extract private benefits. Similarly, we include as controls several of the takeover defenses in a firm's charter. We control for staggered boards, poison pills, cumulative voting, and supermajority provisions, which have been identified as the most important takeover impediments (Gillan, Hartzell, and Starks, 2006; and Larcker, Richardson, and Tuna, 2007).[8]

Finally, the negotiation hypothesis emphasizes the role of the negotiation between the CEO and outside directors as an important determinant of board composition (Hermalin and Weisbach, 1998). We include two measures of CEO influence: CEO's tenure and pay-performance sensitivity (PPS).

We introduce institutional ownership variables as additional controls in our empirical specifications. Because the trading activity of large institutional investors can have a direct effect on the rate of information flow into stock prices, we expect institutional ownership to correlate with price informativeness. There is also evidence that institutional investors perform an active role in corporate governance (Gillan and Starks, 2007). Institutional investors are expected to have more influence when they are large shareholders, because they have easier access to board members and benefit from economies of scale in monitoring activities (Carleton, Nelson, and Weisbach, 1998). Thus, we consider the concentration of institutional ownership as measured by the Herfindahl index as in Hartzell and Starks (2003). We also control for the total institutional ownership (defined as the percentage of shares outstanding held by institutions).[9]

3.2. Measures of price informativeness

Our primary measure of stock price informativeness is the probability of informed trading (PIN) developed by Easley, Kiefer, and O'Hara (1996). This measure is based on a structural market microstructure model, in which trades come from either noise traders or informed traders. The trading process is modeled in the following way. At the beginning of each day, there is a probability λ that some traders acquire new (private) information about the fundamental value of the firm. Trading orders arrive throughout the day according to three different Poisson distributions: Informed orders come in at the average rate μ, uninformed buy orders come in at the rate ε_b, and uninformed sell orders come in at the rate ε_s. The probability

[7] We interpret low attendance to board meeting as indicating less monitoring. For some firms, low attendance could be optimal because less monitoring is needed.

[8] We also include other important takeover defenses in the regressions (results not tabulated): blank check preferred, fair price provision, limitation of shareholders' ability to call a special meeting, limit to shareholders' action by written consent, and unequal voting rights. None of these takeover defenses displays statistically significant effects on board independence.

[9] Some of the literature discusses whether some types of institutions specialize in monitoring and activism instead of trading. Research by Chen, Harford, and Li (2007) shows that "independent" institutions (mutual fund managers and investment advisers) are effective monitors, while "grey" institutions (bank trusts, insurance companies, and other institutions) are not. Independent institutions tend to be "pressure-resistant," while grey institutions tend to be "pressure-sensitive" or loyal to corporate management. For example, Brickley, Lease, and Smith (1988) find that banks and insurance companies are more supportive of antitakeover amendment proposals than other types of institutional investors.

that the opening trade of the day is information-based is given by

$$\text{PIN} = \frac{\lambda\mu}{\lambda\mu+\varepsilon_b+\varepsilon_s}. \quad (24)$$

Easley, Hvidkjaer, and O'Hara (2002) use intra-day transaction data to estimate the above parameters and thus the probability of informed trading in a stock. PIN should be low for stocks with little fluctuation in their daily buy and sell orders, which are more likely to come from liquidity or noise trading. Likewise, PIN should be high for stocks that display frequent large deviations from their normal order flows.

Previous empirical work generally supports the use of PIN as a valid measure of the probability of informed trading and a proxy for stock price informativeness. Easley, Hvidkjaer, and O'Hara (2002) find that the risk of private information trading is priced, i.e., stocks with higher PIN have higher expected returns.[10] Vega (2006) shows that stocks with higher PIN have smaller reactions following an earnings announcement, which is consistent with the idea that their prices incorporate more private information and track their fundamental values more closely. PIN also seems to be related to managerial decisions. Chen, Goldstein, and Jiang (2007) find a positive relation between PIN and the sensitivity of firm investment to stock prices, which supports the hypothesis that managers learn from the private information incorporated into stock prices. Ferreira and Laux (2007) find a positive relation between strong corporate governance (few takeover defenses) and PIN, suggesting that strong shareholder protection induces private information collection and trading by informed market participants.

Although we use PIN as our main proxy for the rate of information flow into stock prices, we acknowledge that this measure is imperfect. PIN might capture some illiquidity effects that are not related to private information.[11] Nevertheless, it is important to keep in mind that there is no reason to believe that measurement error in PIN can explain our findings. If anything, it makes it harder to detect any underlying relation between the latent variables.

As an alternative to PIN, we also consider other price informativeness variables to corroborate our interpretation of the results. We first consider firm-specific stock return variation. French and Roll (1986) and Roll (1988) show that a significant portion of stock return variation is not explained by market movements. They suggest that firm-specific return variation measures the rate of private information incorporation into prices via trading. Although both uninformed trading and trading on the basis of public information can in principle explain firm-specific return variation, considerable empirical evidence supports the use of firm-specific return variation as a measure of the rate of information flow into stock prices. High levels of firm-specific return variation are associated with more efficient capital allocation (Durnev, Morck, and Yeung, 2004) and with more information about future earnings embedded in stock prices (Durnev, Morck, Yeung, and Zarowin, 2003).[12]

We estimate annual firm-specific return variation by regressing stock returns on the three factors from the Fama-French model. For each firm-year, firm-specific return variation is estimated by $1-R^2$ from the regression

$$r_{it} = \alpha_i + \beta_{1i}RM_t + \beta_{2i}SMB_t + \beta_{3i}HML_t + e_{it}, \quad (25)$$

using daily return data, where r_{it} is the return of stock i in day t in excess of the risk-free rate, RM_t is the value-weighted excess market return, SMB_t is the small-minus-big size factor return, and HML_t is the high-minus-low book-to-market factor return.[13] We conduct our tests using a logistic transformation of $1-R^2$:

$$\Psi = \log\left(\frac{1-R^2}{R^2}\right). \quad (26)$$

The variable Ψ measures firm-specific stock return variation relative to market-wide variation or lack of synchronicity with the market.[14]

Finally, as an alternative measure of price informativeness, we use the illiquidity ratio of Amihud (2002). This measure is defined as the annual average of the daily ratio between a stock's absolute return and its dollar volume (multiplied by 10^6):

$$\text{ILLIQ} = \frac{1}{D_i}\sum_{t=1}^{D_i}\frac{|r_{it}|}{\text{VOLD}_{it}}, \quad (27)$$

where D_i is the annual number of valid observation days for stock i and VOLD_{it} is the dollar volume of stock i on day t. The illiquidity ratio gives the absolute (percentage) price change per dollar of daily trading volume and proxies for the price impact of order flow. The magnitude of the price impact should be a positive function of the perceived amount of informed trading on a stock (Kyle, 1985), although illiquidity also reflects the inventory costs associated with trading a given order size.

3.3. Sample

We start with firms in the Investor Responsibility Research Center (IRRC) database between 1990 and 2001.[15] The IRRC database contains detailed information

[10] See Mohanram and Rajgopal (2009) for a critique of this finding.

[11] A recent paper by Duarte and Young (2009) suggests that the relation between PIN and expected returns is explained by the fact that PIN is also a proxy for illiquidity that is not related to private information.

[12] Cross-country patterns of firm-specific return variation also correspond to likely patterns of price informativeness. Morck, Yeung, and Yu (2000) and Jin and Myers (2006) find high firm-specific stock return variation in developed markets, but low firm-specific return variation in emerging markets.

[13] The daily returns for the small-minus-big (SMB) and high-minus-low (HML) factors are drawn from French's website: http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

[14] Alternative estimates of firm-specific return variation are provided by a market model that assumes $\beta_{2i}=\beta_{3i}=0$ in Eq. (25) and by a two-factor (market and industry) model. We obtain similar findings using these alternative estimates.

[15] Our sample ends in 2001 because PIN estimates are less reliable when short sales represent a significant fraction of the trading volume. In fact, PIN relies on trade classification algorithms that in some cases fail to classify short sales correctly (Asquith, Oman, and Safaya, 2007).

on governance and director characteristics for a large number of US firms. We obtain board data for these firms from Compact Disclosure for the 1990–1995 period and from IRRC for the 1996–2001 period.[16] We exclude financial firms (standard industrial classification codes 6000–6999). After these adjustments the number of firms in the sample is 2,188. Next we merge the IRRC database with the probability of informed trading for each firm-year, based on data from Easley, Hvidkjaer, and O'Hara (2002).[17] The final sample contains 1,443 firms and a total of 9,447 firm-year observations.

We obtain financial and segment data from Compustat and stock returns and turnover data from Center for Research in Security Prices. The governance index of Gompers, Ishii, and Metrick (2003) (GIM), individual takeover defenses, and board attendance are from the IRRC database. We obtain data on institutional holdings and the number of analysts covering each firm from Thomson CDA/Spectrum Institutional 13F Holdings and Institutional Brokers' Estimate System. Blockholder ownership is based on data from Dlugosz, Fahlenbrach, Gompers, and Metrick (2006). Finally, we obtain additional director characteristics such as CEO stock and stock options ownership, CEO tenure, and number of board meetings from ExecuComp. We compute a measure of CEO pay-performance sensitivity that includes the effects of stock ownership and existing and newly granted stock options. For stock ownership, we compute PPS as the number of shares held by the CEO divided by the number of shares outstanding. For stock options, we compute PPS as the option delta from the Black-Scholes option-pricing model multiplied by the ratio of the number of shares held to shares outstanding. We winsorize all variables at the bottom and top 1% level. Table A1 in the Appendix defines in detail the variables used in this study and lists their sources.

Table 1 presents descriptive statistics of our data. The median fraction of independent directors is 0.778 and the median PIN is 0.154. These statistics (and others in Table 1) are comparable to those in other studies (e.g., Easley, Hvidkjaer, and O'Hara, 2002; and Coles, Daniel, and Naveen, 2008).

4. Main evidence

Fig. 1 presents a visual summary of the relation between board independence and PIN. We first sort firms into quintile portfolios ranked by PIN. We then calculate the average board independence within each portfolio. The main finding in this paper is clear from the figure: The average board independence for the lowest PIN (low market monitoring) portfolio (Q1) is greater than the one for the highest PIN (high market monitoring) portfolio (Q5). The low-PIN portfolio displays board independence of about 80%, and the corresponding figure for the high-PIN portfolio is about 70%. The 10 percentage point difference between the two extreme quintile portfolios (i.e., one director for an average board size of ten) is statistically significant (t-statistic of 22.1). Moreover, all intermediate PIN portfolios display lower board independence than the low-PIN portfolio. The economic effect of PIN on board independence is sizable if compared with the analogous effects of other well-known determinants of board structure.

Table 2 presents the outcome of several ordinary least squares (OLS) panel regressions, where the dependent variable y is a logistic transformation (or the log odds ratio) of the fraction of independent directors z (i.e., $y=\ln(z/1-z)$). We use a logistic transformation because the fraction of independent directors is bounded between zero and one. Our explanatory variable of interest is PIN. All regressions include industry (two-digit SIC) and year dummy variables. All reported t-statistics are adjusted for heteroskedasticity and within-firm correlation using clustered standard errors. In addition, the inclusion of year dummies accounts for some forms of cross-sectional dependence.

Column 1 presents the coefficients of a regression of the fraction of independent directors on PIN. There is strong evidence of a negative and statistically significant relation. The PIN coefficient is -3.1376, with a t-statistic of -13.60.

Controlling for other firm characteristics does not change this result qualitatively. Column 2 presents estimates for a specification that does not include PPS and tenure as controls because these variables are not available for the 1990–1991 period. The PIN coefficient is -1.9860 with a t-statistic of -7.76. In Column 3 we add PPS and tenure as controls, but the PIN estimate and t-statistic are barely affected. Overall, we find that the probability of informed trading displays a significant negative relation with board independence.

With respect to the other explanatory variables, we find that leverage, firm age, and the number of business segments are all positively and significantly related to board independence. Firm size enters with a positive but insignificant coefficient (at the 5% level) in the majority of specifications. These findings are consistent with the scope of the operations hypothesis that more complex firms require more independent boards.

Consistent with the findings of Boone, Field, Karpoff, and Raheja (2007) and Coles, Daniel, and Naveen (2008), we find no statistically significant relations between board independence and market-to-book ratio, R&D expenditures, return on assets, free cash flow, and stock return variance. In contrast, we find that the coefficients of PPS and tenure are both negative and statistically significant, which is consistent with the suggestion of Hermalin and Weisbach (1998) that board structure is influenced by the negotiations between CEOs and outside directors. The evidence indicates that board independence is negatively related to the degree of CEO influence.

[16] We thank Tina Yang for helping us with the Compact Disclosure board data. While IRRC provides detailed information on affiliation of directors, Compact Disclosure identifies only whether the director is an officer of the firm. Thus, board composition is described only in terms of the percentage of executive directors (insiders or officers) and nonexecutive directors on the board. In the robustness section, we report results using only IRRC data.

[17] The estimates of PIN are obtained from Soeren Hvidkjaer's website: http://www.smith.umd.edu/faculty/hvidkjaer/data.htm.

Table 1
Summary statistics.

This table reports the mean, median, standard deviation, minimum, maximum, and number of observations (*N*) for each variable. The sample consists of observations on Investor Responsibility Research Center (IRRC) firms from 1990 to 2001. Financial industries are omitted (standard industrial classification codes 6000–6999). Board data are taken from IRRC and Compact Disclosure. Governance data are taken from IRRC. Executive compensation data are from ExecuComp. Accounting and segment data are from Compustat. Stock return and volume data are from the Center for Research in Security Prices. Institutional holdings data are from Thomson CDA/Spectrum 13F Holdings. Analysts data are from the Institutional Brokers' Estimate System. Refer to Table A1 in the Appendix for variable definitions. All variables are winsorized at the bottom and top 1% level.

Variable	Mean	Median	Standard deviation	Minimum	Maximum	*N*
Fraction of independent directors	0.753	0.778	0.135	0.100	0.955	9,447
Board size	9.819	10.000	2.798	3.000	17.000	9,447
Number of board meetings	7.282	7.000	2.689	3.000	16.000	6,233
Board attendance	0.025	0.000	0.054	0.000	0.250	4,922
Probability of informed trading (PIN)	0.162	0.154	0.056	0.068	0.357	9,447
Firm-specific return variation	0.738	0.756	0.101	0.424	0.917	11,755
Illiquidity	0.165	0.009	0.711	0.000	6.881	12,964
Firm size	3,819	1,079	7,989	14	51,179	9,236
Leverage	0.274	0.270	0.176	0.000	0.919	9,228
Firm age	32.026	39.917	15.758	1.167	50.917	9,447
Number of business segments	2.158	1.000	1.461	1.000	6.000	9,447
Market-to-book	2.861	2.063	2.979	0.528	23.957	9,236
R&D expenditures	0.019	0.000	0.038	0.000	0.368	8,774
Stock return variance	0.173	0.113	0.206	0.012	2.189	9,447
Free cash flow	0.076	0.079	0.090	−0.447	0.332	9,086
Return on assets	0.145	0.141	0.082	−0.352	0.409	9,241
CEO pay-performance sensitivity (PPS)	0.019	0.003	0.044	0.000	0.258	9,447
CEO tenure	4.257	1.000	6.318	0.000	27.000	9,447
Governance index (GIM)	9.433	10.000	2.746	3.000	5.000	8,404
Staggered board dummy	0.616	1.000	0.486	0.000	1.000	8,335
Poison pill dummy	0.587	1.000	0.492	0.000	1.000	8,335
Cumulative voting dummy	0.137	0.000	0.344	0.000	1.000	8,335
Supermajority dummy	0.188	0.000	0.390	0.000	1.000	8,335
Institutional ownership	0.472	0.524	0.260	0.000	0.914	9,447
Institutional Herfindahl	0.067	0.050	0.073	0.000	0.477	9,447
Blockholder ownership	0.192	0.162	0.184	0.000	0.663	5,235
Outside blockholder ownership	0.136	0.096	0.148	0.000	0.557	5,235
Stock return	−0.074	−0.053	0.412	−1.754	1.251	9,447
Stock return (absolute)	0.303	0.220	0.289	0.000	1.754	9,447
Industry Herfindahl	0.128	0.097	0.120	0.026	1.000	9,447
Earnings quality	0.100	0.056	0.127	0.005	0.578	7,783
Earnings informativeness	0.658	0.722	0.267	0.029	0.997	7,594
NYSE dummy	0.881	1.000	0.323	0.000	1.000	9,295
Number of analysts	8.322	6.000	8.205	0.000	31.000	9,447
Share turnover	0.909	0.727	0.699	0.068	8.136	9,447
S&P 500 dummy	0.266	0.000	0.442	0.000	1.000	9,294

In particular, the negative and significant coefficient of PPS is consistent with board independence and managerial ownership being substitutes, as in Denis and Sarin (1999), Shivdasani and Yermack (1999), Coles, Daniel, and Naveen (2008), and Coles, Lemmon, and Wang (2008).[18] Our model also predicts a negative relation between PPS and board independence (see Proposition 5).

The effect of PIN on board independence is economically significant if compared with the effects of other important board structure determinants. Using the specification in Column 3, a one standard deviation increase in PIN reduces board independence by roughly 2 percentage points (at the averages of the data). If we perform the same experiment with the other variables that also enter significantly in the regression, we obtain effects of 1.2 percentage points for increasing leverage by one standard deviation, 2.2 percentage points for increasing firm age, 1.2 percentage points for increasing the number of business segments, and −1.6 percentage points for increasing PPS.[19]

In Columns 4–5 we control for takeover defenses, total institutional ownership, and institutional ownership concentration. The staggered board, poison pill, and cumulative voting coefficients are positive and statistically significant, which is consistent with the idea that board independence is higher in firms that are insulated from the market for corporate control (Gillan, Hartzell, and Starks, 2006). The institutional ownership variables are not significantly related to board independence.

[18] Others, however, have found a positive relation between insider ownership and board independence (Ryan and Wiggins, 2004; and Davila and Penalva, 2006).

[19] Coles, Lemmon, and Wang (2008) find quantitatively stronger effects of PPS on board structure in a structural model estimation. Our reduced-form approach is bound to be less efficient. We are able to produce qualitatively similar results, but the magnitudes of the effects are smaller.

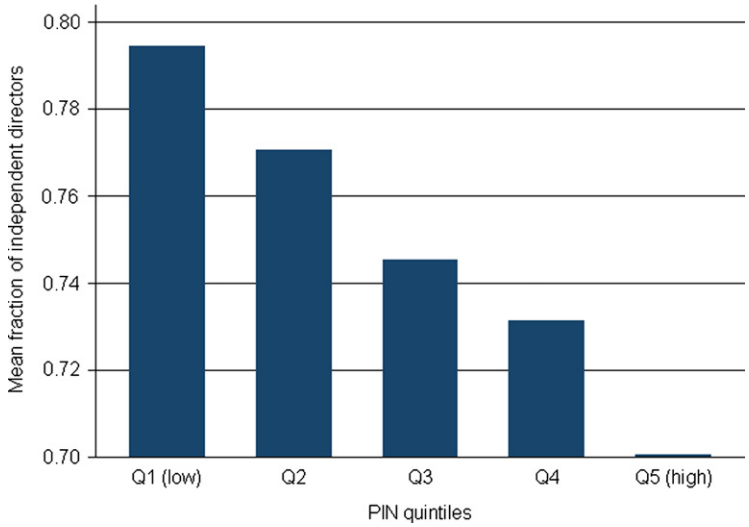

Fig. 1. Board independence by probability of informed trading quintiles. This figure plots the mean fraction of independent directors by probability of informed trading (PIN) quintiles. Refer to Table A1 in the Appendix for variable definitions. The sample consists of observations on Investor Responsibility Research Center firms from 1990 to 2001. Financial industries are omitted (standard industrial classification codes 6000–6999).

Table 2
Board independence and probability of informed trading.

Estimates of ordinary least squares panel regressions of the logistic transformed fraction of independent directors are shown. Refer to Table A1 in the Appendix for variable definitions. The sample consists of observations on Investor Responsibility Research Center firms from 1990 to 2001. Financial industries are omitted (standard industrial classification codes 6000–6999). Regressions include industry and year dummies. Robust *t*-statistics adjusted for firm-level clustering are in parentheses.

Variable	(1)	(2)	(3)	(4)	(5)
Probability of informed trading (PIN)	−3.1376	−1.9860	−1.9204	−1.5890	−1.5830
	(−13.60)	(−7.76)	(−7.02)	(−5.32)	(−5.34)
Firm size (log)		0.0259	0.0184	0.0288	0.0275
		(1.79)	(1.27)	(1.91)	(1.78)
Leverage		0.4392	0.3812	0.3450	0.3501
		(4.33)	(3.85)	(3.26)	(3.28)
Firm age (log)		0.1566	0.1519	0.1212	0.1256
		(7.05)	(6.96)	(4.81)	(4.98)
Number of business segments (log)		0.0997	0.1062	0.0883	0.0881
		(4.14)	(4.63)	(3.79)	(3.79)
Market-to-book (log)		0.0066	0.0146	0.0235	0.0244
		(0.28)	(0.60)	(0.94)	(0.98)
R&D expenditures		0.1626	−0.0524	−0.3821	−0.3568
		(0.40)	(−0.13)	(−0.86)	(−0.80)
Stock return variance		−0.0723	−0.0381	−0.0089	−0.0115
		(−1.27)	(−0.64)	(−0.14)	(−0.18)
Free cash flow		0.3023	0.3765	0.2489	0.2431
		(1.05)	(1.33)	(0.77)	(0.75)
Return on assets		−0.5283	−0.5432	−0.5269	−0.5384
		(−1.56)	(−1.65)	(−1.47)	(−1.49)
CEO pay-performance sensitivity (PPS)			−1.9301	−1.4872	−1.4945
			(−5.83)	(−4.06)	(−4.08)
CEO tenure			−0.0048	−0.0065	−0.0066
			(−1.86)	(−2.50)	(−2.56)
Staggered board dummy				0.0743	0.0776
				(2.03)	(2.12)
Poison pill dummy				0.1673	0.1629
				(4.73)	(4.57)
Cumulative voting dummy				0.1375	0.1398
				(2.87)	(2.93)
Supermajority dummy				0.0009	0.0008
				(0.02)	(0.02)
Institutional ownership					0.0893
					(1.44)
Institutional Herfindahl					0.1222
					(0.46)
R^2	0.082	0.144	0.162	0.160	0.161
Number of observations	9,447	8,610	7,504	6,675	6,675

In summary, we find that the probability of informed trading displays a statistically and economically significant negative relation with board independence. This relation is robust to the inclusion of many variables that are likely to correlate with board independence.

5. Interpreting the relation between board independence and the probability of informed trading

In Section 4, we find evidence of a negative relation between board independence and the probability of informed trading. Our findings suggest that when more information flows to the market (via trading on private information), firms tend to choose less independent boards. The interpretation is that when stock prices are more revealing, the stock market is a substitute for the monitoring role of corporate boards. In this section, we present additional results that strengthen this interpretation by investigating whether the relation between price informativeness and board independence is heterogeneous across groups of firms in the way predicted by our model.

5.1. Takeover defenses

If a firm adopts a large number of takeover defenses, it might become partially insulated from the market for corporate control (Field and Karpoff, 2002; and Masulis, Wang, and Xie, 2007). In such cases, the takeover market cannot play an effective disciplinary role. Our hypothesis is that the trade-off between board independence and price informativeness is more relevant when there are few takeover defenses. This is implied by Proposition 2.

We use the governance index of Gompers, Ishii, and Metrick (2003) as a proxy for the number of takeover defenses a firm has in place. Column 1 of Table 3 presents the results of a regression that includes an interaction between PIN and a dummy variable that takes the value of one if a firm has a GIM index above the median in our sample (10 takeover defenses) and zero otherwise. In the specifications of Table 3 we use the same set of control variables as in Column 5 of Table 2 (coefficients not shown).

We find that the interaction variable (PIN × GIM dummy) coefficient is positive and significant, while the PIN coefficient remains negative and significant.

Table 3
Board independence and probability of informed trading: the role of takeover defenses, institutional ownership, firm-specific knowledge, pay-performance sensitivity, and stock performance.

Estimates of ordinary least squares panel regressions of the logistic transformed fraction of independent directors are shown. GIM dummy takes the value of one if a firm has a governance index (GIM) above the median. Poison pill dummy takes the value of one if a firm has a poison pill provision. Institutional Herfindahl dummy takes the value of one if a firm has institutional ownership above the median. R&D dummy takes the value of one if a firm has research and development expenditures to assets ratio above the 80th percentile. PPS dummy takes the value of one if a firm has chief executive officer pay-performance sensitivity above the median. Stock return (absolute) dummy takes the value of one if a firm has absolute abnormal stock return above the 80th percentile. Refer to Table A1 in the Appendix for variable definitions. The sample consists of observations on Investor Responsibility Research Center firms from 1990 to 2001. Financial industries are omitted (standard industrial classification codes 6000–6999). Regressions include the control variables (coefficients not shown) used in Column 5 of Table 2 and industry and year dummies. Robust *t*-statistics adjusted for firm-level clustering are in parentheses.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Probability of informed trading (PIN)	−1.7810	−2.0272	−0.8873	−1.7323	−0.8364	−1.2740	−0.9626
	(−5.10)	(−4.70)	(−2.24)	(−5.48)	(−2.31)	(−4.25)	(−2.19)
PIN × GIM dummy	0.8113						
	(2.09)						
PIN × Poison pill dummy		0.8068					0.7896
		(2.39)					(2.37)
PIN × Institutional Herfindahl dummy			−1.1500				−1.0200
			(−3.27)				(−2.87)
PIN × R&D dummy				0.9609			0.4144
				(2.29)			(1.09)
PIN × PPS dummy					−0.9383		−0.8878
					(−2.42)		(−2.29)
PIN × Stock return (absolute) dummy						−0.6907	−0.6461
						(−2.09)	(−1.97)
GIM dummy	0.0177						
	(0.21)						
Poison pill dummy		0.0419					0.0633
		(0.80)					(1.21)
Institutional Herfindahl dummy			0.2153				0.1784
			(3.94)				(3.24)
R&D dummy				−0.1741			−0.1176
				(−2.68)			(−1.96)
PPS dummy					0.0572		0.0534
					(1.01)		(0.94)
Stock return (absolute) dummy						0.1190	0.0675
						(1.86)	(1.07)
R^2	0.165	0.162	0.163	0.161	0.156	0.164	0.169
Number of observations	6,675	6,675	6,675	6,675	6,675	6,675	6,675

The interpretation is that the negative relation between board independence and PIN is stronger for low GIM firms. We use alternatively an interaction variable between PIN and a particularly important takeover defense: the poison pill. Brickley, Coles, and Terry (1994) show that takeover outcomes are affected by poison pill provisions and outside directors. We find that the coefficient on this interaction variable is positive and significant, while the PIN coefficient remains negative and significant (see Column 2 of Table 3).

We conclude that the market for corporate control has an important role to play in shaping the relation between board independence and price informativeness. Price informativeness can substitute for independent directors only when the firm is open to the market for corporate control. This finding is consistent with the evidence provided by Gillan, Hartzell, and Starks (2006), who show that if a disciplining takeover is more likely, then there is less need for board monitoring.

5.2. Institutional ownership concentration

If our theory is correct, shareholders should frequently intervene to change the board structure in response to exogenous changes in price informativeness.[20] Our theory is thus less plausible in dispersed ownership structures in which shareholders have no incentives to engage in activism. Unlike individual investors, institutional investors (especially if they hold large blocks of stock) could have a clear incentive to maximize firm value by changing board structure whenever necessary. Our hypothesis is that the trade-off between board independence and price informativeness is more relevant when there are large shareholders or when there is a higher concentration of institutional ownership. This is implied by Proposition 3.

Column 3 of Table 3 presents the results of a regression that includes an interaction between PIN and an institutional ownership concentration dummy that takes the value of one for firms whose institutional Herfindahl index is above the median in our sample and zero otherwise. The interaction variable is negative and statistically significant, i.e., PIN is more strongly negatively related to board independence for those firms with a high concentration of institutional ownership.[21]

These results suggest that price informativeness is a more effective substitute for internal monitoring by the board when large institutional shareholders supervise the board themselves. Without a substantial concentration of institutional ownership, perhaps the board plays only a minor role. In such cases, it would be natural to find a weaker relation between board independence and stock price informativeness.

[20] See Karpoff (2001) and Gillan and Starks (2007) for a summary of the evidence on shareholder activism and governance structure. The evidence suggests that active shareholders do affect governance structures, although the effect of activism on firm performance is not clear-cut.

[21] Results (not tabulated) show consistent findings if we use the institutional Herfindahl index as an interaction term, instead of the high institutional Herfindahl dummy.

5.3. Firm-specific knowledge

When firm-specific knowledge is important, a board that is too independent could fail to obtain crucial information. The idea is simply that CEOs and inside directors possess more firm-specific knowledge than outside directors. We thus expect that costs associated with the acquisition of firm-specific knowledge can affect the relation between board structure and price informativeness. Specifically, if stock markets can substitute for corporate boards as monitors of management, we expect to find a stronger negative relation between board independence and price informativeness when firm-specific knowledge is less important. This hypothesis is formally derived in Proposition 4.

Measuring firm-specific knowledge is a difficult task. Following Coles, Daniel, and Naveen (2008), we use R&D expenditures as a proxy for the importance of firm-specific knowledge. If the kind of information that market prices convey cannot substitute for the knowledge that insiders possess, the substitution effect should be weaker for firms with high R&D.

Column 4 of Table 3 presents the results of a regression that includes an interaction between PIN and a dummy variable that takes the value of one for firms whose ratio of R&D expenditures to assets is above the 80th percentile.[22] The evidence shows that the negative relation between board independence and PIN is more pronounced in low R&D firms. This evidence is consistent with the hypothesis that when firm-specific knowledge is less important, the private information revealed by stock prices can substitute for the monitoring role of corporate boards.

5.4. Pay-performance sensitivity

Executive compensation plans can help to align the interests of managers with those of shareholders. Previous models on the monitoring role of stock prices (Holmstrom and Tirole, 1993; and Coles, Lemmon, and Wang, 2008) have focused on executive compensation as the main mechanism through which stock prices discipline managers. Thus, we expect to find a stronger relation between price informativeness and board independence in firms in which pay-performance sensitivity of CEO compensation contracts is high. This is implied by Proposition 6.

Column 5 of Table 3 presents the results of a regression that includes an interaction between PIN and a PPS dummy that takes the value of one for firms whose PPS is above the median in our sample. We find a negative and statistically significant interaction variable coefficient. The PIN coefficient remains negative and significant. These results suggest that price informativeness is a more effective substitute for internal monitoring by the board when managerial incentives are closely tied to shareholder value.

[22] The 80th percentile corresponds to the median for firms with positive R&D expenditures as only 40% of the observations have positive R&D. The findings are similar if we use the 75th percentile as the cutoff.

5.5. Extreme stock performance

We investigate whether corporate boards matter more during certain periods. Independent boards seem to be particularly effective in performing specific tasks, such as hiring and firing the CEO (Weisbach, 1988; and Borokhovich, Parrino, and Trapani, 1996), adopting takeover defenses (Brickley, Coles, and Terry, 1994), and negotiating takeovers (Cotter, Shivdasani, and Zenner, 1997). We proxy for these special circumstances using abnormal stock returns. Abnormal stock returns are calculated as a firm's stock return minus the value-weighted market return. The idea is that a firm's stock price is likely to display sharp falls or rises during these events. Column 6 of Table 3 presents the results of a regression that includes an interaction between PIN and an absolute abnormal stock return dummy that takes the value of one for firms whose absolute abnormal return is above the 80th percentile. The coefficient on the interaction variable is negative and statistically significant, suggesting that the negative relation between price informativeness and board independence is more pronounced during periods of extreme stock performance. Consistent with the hypothesis that board composition is more likely to change during crises and other exceptional events, the absolute abnormal stock return coefficient is positive but statistically weak.

Finally, in Column 7 we include all interactions jointly. The results confirm the previous findings with the exception of the R&D interaction term that becomes insignificant.

6. Robustness

In this section, we check the robustness of our main results. We first present several alternative estimation methods, which address several concerns with our estimates, such as omitted variables, reverse causality, and measurement errors. We then present results using alternative measures of price informativeness and additional board-related variables. In the final subsection, we present other robustness checks such as different samples and additional control variables.

6.1. Endogeneity: omitted variables and reverse causality

Endogeneity problems are ubiquitous in empirical research on corporate governance. In our setting, there could be many reasons for board structure and price informativeness to be jointly determined.

We first address the potential endogeneity problems using firm fixed effects methods that control for unobserved sources of firm heterogeneity. Fixed effects methods solve joint determination problems in which an unobserved time-invariant variable simultaneously determines both PIN and board independence. It is also equivalent to looking only at within-firm changes in PIN.

Columns 1 and 2 of Table 4 present the firm fixed effects estimates (with t-statistics adjusted for firm-level clustering). There is still evidence of a negative relation between board independence and PIN. In Column 2, the estimate of the PIN coefficient is -0.5755 with a significant t-statistic of -2.88.

The fixed effects results go a long way toward dismissing omitted variables explanations as sources of endogeneity. Because only the effects of within-firm changes in board independence are taken into account, firm-specific omitted variables cannot explain the observed relation between PIN and board independence. An issue here is whether there is enough variation in PIN and board independence over time so that one can estimate this relation with precision. The short answer is yes. Although t-statistics are lower, suggesting a lower precision in the estimates, they are still high by traditional standards.[23]

Another approach to address endogeneity concerns is to use lagged PIN as an explanatory variable. Columns 3 and 4 of Table 4 present the results of these estimations, confirming a negative relation between board independence and PIN.

We also use two-stage least squares (2SLS) address the potential endogeneity of PIN. Two-stage least squares methods allow us to address omitted variables and reverse causality issues simultaneously. The caveat is that, unlike the fixed effects method, it requires stronger assumptions that are usually not possible to test for. Under standard identification assumptions, we apply 2SLS methods to isolate the effect of PIN on board independence. To this end, we need instruments for PIN: a variable that is correlated with PIN (this assumption can be tested), but uncorrelated with board structure except indirectly through other independent variables. That is, the instrument should be a variable that can be excluded from the original list of control variables without affecting the results. This last requirement cannot be tested by statistical methods. It is, in the end, an act of faith.

We use analyst coverage, share turnover, and S&P 500 membership as instruments. Easley, O'Hara, and Paperman (1998) suggest that analysts can turn private information into public information and do not have significant firm-specific information. Analysts can attract additional uninformed order flow to a stock, an effect that would also reduce PIN. Empirical evidence seems to support a negative relation between price informativeness and analyst coverage (Piotroski and Roulstone, 2004; and Chan and Hameed, 2006). Share turnover is also likely to be negatively related to PIN, again consistent with the notion that stocks with greater trading activity tend to have more uninformed order flow (Easley, Hvidkjaer, and O'Hara, 2002). We use as an additional instrument a dummy variable that takes the value of one if a stock is included in the S&P 500 index as these firms tend to attract more investor attention (Denis, McConnell, Ovtchinnikov, and Yu, 2003). Thus, our instruments have

[23] The idea that board structure does not change much over time could be more a myth than reality. Cicero, Wintoki, and Yang (2008) find that two-thirds of the firms in their sample change either board size or independence during a two-year period. They also find that firms close 63% of the gap between their actual and target board independence over a two-year period.

Table 4
Board independence and probability of informed trading: firm fixed effects and lagged explanatory variable.

Estimates of panel regressions of the logistic transformed fraction of independent directors using alternative estimation methods are shown. Columns 1 and 2 present estimates of panel regressions with firm fixed effects. Columns 3 and 4 present estimates of regressions using lagged PIN as the explanatory variable. Refer to Table A1 in the Appendix for variable definitions. The sample consists of observations on Investor Responsibility Research Center firms from 1990 to 2001. Financial industries are omitted (standard industrial classification codes 6000–6999). Regressions include industry and year dummies. Robust *t*-statistics adjusted for firm-level clustering are in parentheses.

	Firm fixed effects		Lag PIN	
Variable	(1)	(2)	(3)	(4)
Probability of informed trading (PIN)	−0.6940	−0.5755	−1.6905	−1.3996
	(−3.90)	(−2.88)	(−6.47)	(−4.93)
Firm size (log)	0.0738	0.0730	0.0297	0.0316
	(3.29)	(3.05)	(2.08)	(2.11)
Leverage	0.3394	0.2558	0.4344	0.3422
	(3.42)	(2.41)	(4.18)	(3.16)
Firm age (log)	0.4413	0.6588	0.1595	0.1222
	(8.82)	(7.47)	(6.97)	(4.79)
Number of business segments (log)	0.0150	0.0109	0.1024	0.0871
	(0.84)	(0.61)	(4.27)	(3.72)
Market-to-book (log)	0.0098	−0.0138	0.0080	0.0259
	(0.48)	(−0.67)	(0.32)	(1.04)
R&D expenditures	−0.4203	−0.6375	0.0910	−0.4870
	(−0.96)	(−1.08)	(0.22)	(−1.07)
Stock return variance	0.2085	0.1563	−0.0746	−0.0142
	(4.26)	(2.70)	(−1.23)	(−0.22)
Free cash flow	−0.1143	−0.2589	0.2094	0.1690
	(−0.64)	(−1.13)	(0.69)	(0.52)
Return on assets	0.0063	0.1342	−0.4355	−0.4848
	(0.03)	(0.48)	(−1.23)	(−1.33)
CEO pay-performance sensitivity (PPS)		0.6723		−1.4900
		(2.19)		(−4.04)
CEO tenure		−0.0053		−0.0067
		(−2.67)		(−2.58)
Staggered board dummy		−0.0550		0.0810
		(−0.74)		(2.20)
Poison pill dummy		0.0339		0.1635
		(1.00)		(4.54)
Cumulative voting dummy		−0.0347		0.1426
		(−0.39)		(2.97)
Supermajority dummy		−0.0700		−0.0026
		(−1.03)		(−0.06)
Institutional ownership		0.0442		0.0983
		(0.61)		(1.56)
Institutional Herfindahl		0.2783		0.0535
		(1.91)		(0.20)
R^2	0.095	0.084	0.139	0.159
Number of observations	8,610	6,675	7,927	6,594

been found to be significantly correlated with price informativeness but have never been used as explanatory variables of board independence in previous studies. We report results using all three instruments jointly.[24]

Columns 1 and 2 of Table 5 present the results of the first stage regressions that use PIN as the dependent variable. The results support the conclusion that analyst coverage and share turnover are negatively and significantly related to PIN, and the S&P 500 membership dummy is positively related to PIN. *F*-tests that the instruments can be excluded from the first-stage regressions are strongly rejected (*F*-statistics are 24.47 and 10.8 in Columns 1 and 2). We conclude that our instruments are associated with PIN and that our specifications do not suffer from weak instruments concerns.

Columns 3 and 4 of Table 5 present the coefficients of the second-stage regression that uses board independence as the dependent variable. There is still evidence of a negative relation between board independence and PIN after taking into account the possibility that PIN is endogenous. The evidence suggests the existence of a causal link from price informativeness to board structure. To assess the quality of the instruments formally, we also perform a Hansen χ^2- test of instrument orthogonality. This statistic jointly tests the null hypotheses of correct model specification and orthogonality between the instruments and the errors. Our instruments perform adequately in our tests (*p*-value is 0.12 and 0.87 in the specifications of Columns 3 and 4), indicating that we cannot reject the null hypothesis of instrument suitability.

[24] In untabulated results, we obtain similar results using analyst coverage, share turnover, or S&P 500 dummy as instruments one at a time. We also obtain consistent results using lagged PIN as an instrument. See Aslan, Easley, Hvidkjaer, and O'Hara (2008) for a discussion of alternative instruments for PIN.

Table 5
Board independence and probability of informed trading: two-stage least squares and simultaneous equations.

Estimates of panel regressions of the logistic transformed fraction of independent directors using alternative estimation methods are shown. The two-stage least squares (2SLS) panel regression uses analyst coverage, share turnover, and S&P 500 dummy as instruments for probability of informed trading (PIN). Columns 1 and 2 present first-stage regression estimates with PIN as the dependent variable. Columns 3 and 4 present second stage regression estimates with the logistic transformed fraction of independent directors as the dependent variable. Columns 5 and 6 present the estimates of a system of simultaneous equations in which the dependent variables are the logistic transformed fraction of independent directors and PIN. Refer to Table A1 in the Appendix for variable definitions. The sample consists of observations on Investor Responsibility Research Center firms from 1990 to 2001. Financial industries are omitted (standard industrial classification codes 6000–6999). Regressions include industry and year dummies. Robust *t*-statistics adjusted for firm-level clustering are in parentheses.

	Two-stage least squares				Three-stage least squares	
	First stage	First stage	Second stage	Second stage	Fraction of independent directors	PIN
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Probability of informed trading (PIN)			−8.8139	−17.5817	−17.0020	
			(−4.54)	(−2.18)	(−2.20)	
Fraction of independent directors						−0.0051
						(−1.65)
Firm size (log)	−0.0232	−0.0212	−0.1375	−0.3100	−0.2966	−0.0208
	(−51.59)	(−42.28)	(−2.95)	(−1.83)	(−1.82)	(−44.87)
Leverage	−0.0154	−0.0162	0.3395	0.0934	0.1115	−0.0137
	(−5.18)	(−5.07)	(5.87)	(0.63)	(0.79)	(−4.32)
Firm age (log)	−0.0045	−0.0022	0.1303	0.0951	0.0907	−0.0018
	(−6.84)	(−2.72)	(9.46)	(3.93)	(3.98)	(−1.98)
Number of business segments (log)	−0.0056	−0.0034	0.0645	0.0369	0.0359	−0.0031
	(−7.68)	(−4.44)	(3.85)	(1.18)	(1.17)	(−3.65)
Market-to-book (log)	0.0042	0.0046	0.0370	0.0998	0.0972	0.0047
	(4.94)	(5.17)	(2.23)	(2.31)	(2.35)	(5.66)
R&D expenditures	0.0191	0.0299	0.2163	0.0552	0.0313	0.0270
	(1.48)	(2.00)	(0.95)	(0.14)	(0.08)	(1.95)
Stock return variance	−0.0277	−0.0302	−0.3181	−0.5516	−0.5250	−0.0299
	(−8.94)	(−8.86)	(−3.88)	(−1.98)	(−1.96)	(−10.23)
Free cash flow	−0.0135	−0.0113	0.2832	0.1246	0.1589	−0.0081
	(−1.65)	(−1.21)	(1.88)	(0.57)	(0.73)	(−0.90)
Return on assets	0.0091	0.0055	−0.5447	−0.5000	−0.5479	−0.0001
	(0.97)	(0.53)	(−3.08)	(−2.02)	(−2.32)	(−0.01)
CEO pay-performance sensitivity (PPS)		−0.0035		−1.5850	−1.3866	
		(−0.29)		(−5.43)	(−6.99)	
CEO tenure		−0.0003		−0.0107	−0.0055	
		(−3.64)		(−3.92)	(−2.34)	
Staggered board dummy		−0.0025		0.0388	0.0770	
		(−2.54)		(1.24)	(3.05)	
Poison pill dummy		−0.0032		0.1109	0.1533	
		(−3.13)		(3.12)	(4.96)	
Cumulative voting dummy		−0.0007		0.1272	0.1280	
		(−0.53)		(3.96)	(5.37)	
Supermajority dummy		0.0006		0.0105	−0.0006	
		(0.50)		(0.36)	(−0.03)	
Institutional ownership		−0.0090		−0.0719	−0.0866	−0.0096
		(−3.73)		(−0.79)	(−0.97)	(−4.54)
Institutional Herfindahl		0.0660		1.2384	1.2865	0.0714
		(6.55)		(2.08)	(2.27)	(9.42)
Number of analysts	−0.0013	−0.0042				0.0001
	(−3.11)	(−3.98)				(0.15)
Share turnover	−0.0059	−0.0023				−0.0021
	(−7.04)	(−2.51)				(−2.69)
S&P 500 dummy	0.0034	0.0016				0.0017
	(3.11)	(1.37)				(1.80)
R^2	0.462	0.442				
Number of observations	8,610	6,675	8,610	6,675	6,675	6,675

In a final approach to address endogeneity concerns, we estimate simultaneous equations of board independence and PIN using three-stage least squares (3SLS) regressions. We use internal governance variables such as PPS, CEO tenure, and takeover defenses as excluded variables from the PIN equation. Columns 5 and 6 of Table 5 report the 3SLS estimates. The PIN coefficient is negative and significant at the 5% level in the board independence equation. The board independence coefficient is negative in the PIN equation, but insignificant at the 5% level. Thus, the simultaneous equations evidence shows that PIN affects board structure, while there is

weak evidence that board independence affects PIN. These results should, however, be interpreted with caution, especially because no strong theoretical justifications exist for the instruments for board independence.

Our conclusion here is twofold. Omitted variables are unlikely to explain the relation between PIN and board independence: On top of our long list of control variables, firm fixed effects take care of most time-invariant unobserved variables. We also find evidence consistent with a causal effect from price informativeness to board independence, but only weak evidence in the opposite direction.

6.2. Alternative measures of price informativeness

Is the empirical relation between board independence and PIN driven by the rate of information flow into stock prices? In this subsection, we use two alternative measures of stock price informativeness. First, we use firm-specific stock return variation, or nonsynchronicity of stock returns (Morck, Yeung, and Yu, 2000). Second, we use the illiquidity ratio of Amihud (2002), which is a proxy for the price impact of order flow.

We estimate board independence regressions similar to those in Table 2. We report the results in Table 6. Columns 1 and 2 show results for the regressions using the logistic transformation of the annual firm-specific return variation (Ψ) as the measure of price informativeness. We find that the coefficients on Ψ are negative and statistically significant. Thus, board independence is lower in firms whose stock returns are less synchronized with the market.

Columns 3 and 4 in Table 6 present estimates using the annual illiquidity ratio (ILLIQ). ILLIQ is also negatively related to board independence, which supports the

Table 6
Board independence and alternative measures of stock price informativeness.
Estimates of ordinary least squares panel regressions of alternative price informativeness measures are shown. Columns 1 and 2 use the logistic transformed relative firm-specific return variation as the explanatory variable. Columns 3 and 4 use the logarithm of the illiquidity measure or price impact measure of Amihud (2002) as the explanatory variable. Refer to Table A1 in the Appendix for variable definitions. The sample consists of observations on Investor Responsibility Research Center firms from 1990 to 2001. Financial industries are omitted (standard industrial classification codes 6000–6999). Regressions include industry and year dummies. Robust *t*-statistics adjusted for firm-level clustering are in parentheses.

Variable	(1)	(2)	(3)	(4)
Firm-specific return variation (logistic)	−0.0877	−0.0597		
	(−4.88)	(−3.01)		
Illiquidity (log)			−0.0829	−0.0781
			(−6.96)	(−4.71)
Firm size (log)	0.0748	0.0653	−0.0208	−0.0303
	(7.23)	(5.58)	(−1.07)	(−1.32)
Leverage	0.2839	0.2217	0.3264	0.2619
	(3.79)	(2.59)	(4.46)	(3.12)
Firm age (log)	0.1417	0.1158	0.1500	0.1293
	(8.64)	(5.58)	(9.22)	(6.21)
Number of business segments (log)	0.0996	0.0645	0.1111	0.0815
	(4.92)	(3.14)	(5.42)	(4.02)
Market-to-book (log)	0.0137	0.0374	−0.0262	0.0110
	(0.85)	(2.02)	(−1.40)	(0.52)
R&D expenditures	0.9549	0.4927	0.6232	0.1074
	(4.47)	(1.78)	(2.85)	(0.38)
Stock return variance			−0.0266	−0.0285
			(−0.83)	(−0.70)
Free cash flow	0.4644	0.3398	0.6486	0.5587
	(2.09)	(1.30)	(2.94)	(2.11)
Return on assets	−0.9283	−0.7424	−1.0350	−0.9125
	(−3.80)	(−2.64)	(−4.17)	(−3.18)
CEO pay-performance sensitivity (PPS)		−1.3878		−1.4063
		(−4.78)		(−4.74)
CEO tenure		−0.0058		−0.0067
		(−2.72)		(−3.09)
Staggered board dummy		0.0958		0.0889
		(3.06)		(2.85)
Poison pill dummy		0.1844		0.1757
		(6.23)		(5.90)
Cumulative voting dummy		0.0888		0.0809
		(2.18)		(1.98)
Supermajority dummy		−0.0213		−0.0194
		(−0.53)		(−0.48)
Institutional ownership		0.1015		0.0596
		(1.92)		(1.10)
Institutional Herfindahl		0.0373		0.3003
		(0.17)		(1.34)
R^2	0.151	0.157	0.159	0.159
Number of observations	11,755	9,196	12,964	8,911

hypothesis that firms with a higher price impact of order flow (perhaps due to private information trading) have less independent boards.

The effect of the alternative price informativeness measures on board independence is economically significant if compared with the effects of other important board independence determinants. A one standard deviation increase in firm-specific return variation and illiquidity reduces board independence by roughly 1 and 4 percentage points, respectively. If we perform the same experiment with PPS, we obtain effects of roughly 1 percentage point for increasing PPS by one standard deviation. In sum, the results using alternative proxies of price informativeness confirm our basic finding: Stock market monitoring via prices and board monitoring appear to be substitutes.

6.3. Other board structure variables

It is natural to ask whether price informativeness also affects other variables that are likely to be associated with the monitoring intensity of the board. Here we use the number of board meetings and the fraction of directors with low attendance at board meetings as alternative proxies for the monitoring intensity of the board. We also analyze the effect of PIN on board size, although previous research has found that size does not have a one-to-one relation to monitoring intensity and is likely to be influenced by firms' need for board advice (Coles, Daniel, and Naveen, 2008; and Linck, Netter, and Yang, 2008).

It has been argued that a board that meets more often is likely to be a better monitor (e.g., Vafeas, 1999). In Table 7, Columns 1 and 2 present the estimates of

Table 7
Other board structure variables and probability of informed trading.
Estimates of ordinary least squares panel regressions of the logarithm of the number of board meetings, the fraction of directors with low board attendance (ratio of directors that attended less than 75% of board or committee meetings by the board size), and the logarithm of board size (number of board members) are shown. Refer to Table A1 in the Appendix for variable definitions. The sample consists of observations on Investor Responsibility Research Center firms from 1990 to 2001. Financial industries are omitted (standard industrial classification codes 6000–6999). Regressions include industry and year dummies. Robust *t*-statistics adjusted for firm-level clustering are in parentheses.

	Number of board meetings (log)		Board attendance		Board size (log)	
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Probability of informed trading (PIN)	−0.3878	−0.4174	0.0477	0.0485	−0.2942	−0.2939
	(−2.08)	(−2.16)	(2.11)	(2.12)	(−2.51)	(−2.28)
Firm size (log)	0.0415	0.0359	0.0018	0.0016	0.0844	0.0848
	(5.06)	(4.02)	(2.30)	(1.86)	(16.84)	(14.86)
Leverage	0.0965	0.1163	0.0050	0.0035	0.1183	0.0714
	(1.82)	(2.05)	(0.96)	(0.62)	(3.37)	(1.93)
Firm age (log)	0.0316	0.0199	−0.0002	−0.0010	0.0676	0.0696
	(2.87)	(1.43)	(−0.19)	(−0.71)	(8.19)	(7.17)
Number of business segments (log)	0.0272	0.0192	0.0011	0.0008	0.0295	0.0197
	(2.15)	(1.50)	(0.84)	(0.63)	(3.19)	(2.14)
Market-to-book (log)	0.0054	−0.0034	0.0001	0.0003	−0.0457	−0.0393
	(0.47)	(−0.28)	(0.10)	(0.23)	(−5.11)	(−4.13)
R&D expenditures	0.0571	0.3698	0.0249	0.0444	−0.5089	−0.6932
	(0.24)	(1.47)	(0.99)	(1.54)	(−2.89)	(−3.56)
Stock return variance	0.1895	0.1558	0.0023	0.0001	−0.1330	−0.1204
	(3.98)	(3.20)	(0.52)	(0.01)	(−4.54)	(−3.52)
Free cash flow	0.0262	0.0247	0.0257	0.0214	0.0892	0.1269
	(0.17)	(0.14)	(1.97)	(1.45)	(0.86)	(1.04)
Return on assets	−0.4269	−0.4464	−0.0279	−0.0174	−0.3287	−0.3445
	(−2.51)	(−2.35)	(−1.78)	(−1.00)	(−2.73)	(−2.51)
CEO pay-performance sensitivity (PPS)		−0.6948		−0.0550		−0.6388
		(−3.05)		(−2.86)		(−3.90)
CEO tenure		−0.0046		0.0003		0.0009
		(−3.11)		(2.30)		(0.90)
Staggered board dummy		−0.0159		0.0050		0.0236
		(−0.80)		(2.64)		(1.76)
Poison pill dummy		−0.0126		−0.0056		0.0164
		(−0.67)		(−2.86)		(1.20)
Cumulative voting dummy		−0.0058		0.0029		−0.0145
		(−0.22)		(1.12)		(−0.74)
Supermajority dummy		0.0008		−0.0037		0.0109
		(0.04)		(−1.73)		(0.63)
Institutional ownership		−0.0847		−0.0094		−0.0397
		(−2.39)		(−2.56)		(−1.68)
Institutional Herfindahl		−0.0598		0.0275		0.1334
		(−0.40)		(1.85)		(1.43)
R^2	0.091	0.113	0.006	0.013	0.329	0.333
Number of observations	4,827	4,151	5,031	4,664	8,923	6,965

regressions in which the logarithm of the annual number of board meetings is the dependent variable. We find a negative relation between the number of board meetings and PIN. This result is compatible with board monitoring and price informativeness being substitutes.

The Securities Exchange Act of 1934 requires corporations to list in their proxy statements the name of each director who attended fewer than 75% of the board meetings and board committees meetings on which they serve. A higher fraction of directors with low attendance at meetings is likely to indicate a low monitoring intensity. Columns 3 and 4 present the estimates of regressions in which the annual fraction of directors with low attendance is the dependent variable. We find a positive relation between less-assiduous boards and PIN. Again, this result is compatible with board monitoring and price informativeness being substitutes.

Finally, Columns 5 and 6 present the outcome of regressions in which the dependent variable is the logarithm of board size. There is evidence of a negative and statistically significant relation between board size and PIN. Most of the other firm-level characteristics enter with their expected signs and are usually consistent with the literature on board structure determinants. It has been argued that larger boards are poor monitors (Jensen, 1993). However, some also argue that larger boards are more diverse and produce more specialized advice to managers (Coles, Daniel, and Naveen, 2008; and Linck, Netter, and Yang, 2008). Thus, although the evidence that we find is interesting, it is difficult to interpret. It should also be noted that board size and independence are positively correlated in the sample.

6.4. Additional robustness checks

This subsection discusses several additional robustness checks. We check whether our findings are robust to the sample period, to functional form assumptions, and to the inclusion of additional control variables. These results appear in Table 8. In the specifications of Table 8 we use the same set of control variables as in Column 5 of Table 2 (coefficients not shown).

Column 1 uses the 1996–2001 sample period, not 1990–2001. The 1996–2001 period corresponds to the period for which the IRRC directorship data are available. Therefore, Column 1 uses only IRRC directorship data, not both Compact Disclosure (1990–1995) and IRRC data (1996–2001). A potential concern arises because Compact Disclosure classifies each director as either executive or nonexecutive, while IRRC uses a finer definition of independence. Column 2 uses board data from Compact Disclosure for the whole sample period (1990–2001) as an alternative to the IRRC directorship data.

Column 3 uses the logarithm of board independence, instead of the logistic transformation, as the dependent variable. Column 4 uses the fraction of independent directors (i.e., restricted to [0,1]) as the dependent variable.

Column 5 reports results after controlling for blockholder ownership, considering all types of blockholders instead of institutional investors only. Column 6 reports results after controlling for outside blockholders ownership, not 13F institutional investors only. These blockholder ownership data are taken from Dlugosz, Fahlenbrach, Gompers, and Metrick (2006) and cover the 1996–2001 sample period.

Column 7 presents results that take into account product market competition. Shleifer and Vishny (1997) suggest that product market competition is one of the most effective mechanisms to eliminate managerial inefficiency. We try to capture the competitive structure of an industry by using the industry Herfindahl index, calculated as the sum of squared market shares of all firms in each industry (two-digit SIC) in each year. Industries with lower Herfindahl indices possess more competitive product markets.

Column 8 includes lagged board size as an additional control variable following Boone, Field, Karpoff, and Raheja (2007) and Coles, Daniel, and Naveen (2008). To control for the potential differences in liquidity and governance requirements between stock exchanges, in Column 9 we include a dummy variable that takes the value of one if a firm is listed on the New York Stock Exchange.

In Columns 1–9, the estimated coefficient on the probability of informed trading remains negative and strongly significant. Our basic result is thus confirmed: Higher rate of information incorporation into stock prices via trading is strongly associated with less board independence or, in other words, with less need for board monitoring.

Others have shown that board structure affects firms' disclosure policy (e.g., Leuz, Triantis, and Wang, 2008) and accounting quality (e.g., Petra, 2007). Columns 10 and 11 present results that control for earnings quality and earnings informativeness. Earnings quality is measured by the annual absolute value of firm-specific residuals from an industry regression of total accruals on lagged, contemporaneous, and leading cash flow from operations (Dechow and Dichev, 2002). This variable is an inverse index of accounting quality, in that it increases in the magnitude of unexpected accruals. Following Francis and Schipper (1999) and Bushman, Chen, Engel, and Smith (2004), we measure earnings informativeness by the R^2 of a firm-level regression of 15-month stock returns (ending three months after the end of fiscal year t) on income before extraordinary items (NIBE) in year t and the change in NIBE from year $t-1$ to t, scaled by market value at the beginning of year t. Weak evidence exists of a positive association between board independence and earnings quality and informativeness. Most important, the magnitude of the PIN coefficient is not affected by these controls.

A different concern with our measure of price informativeness is that PIN is a proxy for extreme stock performance. We find this to be true in our sample. Firms with abnormal stock returns in the bottom and top quintiles have significantly higher PIN than firms with moderate levels of abnormal returns. It could be the case that PIN is simply proxying for extreme stock price performance and that board structure changes as a

Table 8
Board independence and probability of informed trading: additional robustness checks.

Estimates of panel regressions of the fraction of independent directors are shown. The dependent variable is the logistic transformed fraction of independent directors in all columns, with the exceptions of Column 3, which uses the log fraction of independent directors, and of Column 4, which uses the fraction of independent directors. Column 1 uses the 1996–2001 period. Column 2 uses only board data from Compact Disclosure. Columns 5 and 6 control for blockholders ownership. Column 7 controls for industry concentration using the industry Herfindahl index. Column 8 controls for lagged board size. Column 9 controls for stocks traded in the NYSE. Column 10 controls for the earnings quality measure of Dechow and Dichev (2002). Column 11 controls for earnings informativeness using the R^2 from a regression of stock returns on income before extraordinary items and changes on income before extraordinary items (scaled by market value of equity). Column 12 controls for extreme abnormal stock return using two dummy variables, one indicating those firms with abnormal stock return below the 20th percentile (Q1) and one indicating those firms with abnormal stock return above the 80th percentile (Q5). Column 13 uses as explanatory variable PIN Q5–Q1 dummy that equals one for firm-years with probability of informed trading (PIN) above the 80th percentile (Q5) and zero for firm-years with PINs below the 20th percentile (Q1) (observations with intermediate values of PIN are not included in this regression). Column 14 uses as explanatory variable PIN dummy that equals one for firm-years above the median and zero otherwise. Column 15 shows estimates of median regressions (least absolute deviations). Column 16 shows estimates of the Fama-MacBeth estimation method. Refer to Table A1 in the Appendix for variable definitions. The sample consists of observations on Investor Responsibility Research Center firms from 1990 to 2001. Financial industries are omitted (standard industrial classification codes 6000–6999). Regressions include the control variables (coefficients not shown) used in Column 5 of Table 2 and industry and year dummies. Robust *t*-statistics adjusted for firm-level clustering are in parentheses.

	1996 –2001	Compact disclosure	Board independence (log)	Board independence	All blockholders	Outside blockholders	Industry Herfindahl	Board size
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Probability of informed trading	−0.9345	−0.9884	−0.3668	−0.1975	−0.9084	−0.9871	−1.5924	−1.5657
	(−2.56)	(−3.52)	(−4.23)	(−2.99)	(−2.44)	(−2.63)	(−5.38)	(−5.15)
Blockholders ownership					0.0325			
					(0.31)			
Outside blockholders ownership						0.3567		
						(3.11)		
Industry Herfindahl							0.1393	
							(1.08)	
Board size (lag)								0.0196
								(2.44)
R^2	0.162	0.155	0.143	0.092	0.162	0.167	0.161	0.169
N	4,439	5,955	6,827	6,965	4,439	4,439	6,675	6,133

	NYSE	Earnings quality	Earnings informativeness	Abnormal stock return	PIN Q5–Q1	PIN dummy	Median regression	Fama-MacBeth
Variable	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Probability of informed trading	−1.5464	−1.3023	−1.6186	−1.5887			−1.9516	−0.8826
	(−5.21)	(−4.48)	(−4.93)	(−5.28)			(−5.92)	(−3.61)
Probability of informed trading (Q5-Q1)					−0.2923			
					(−5.04)			
Probability of informed trading (dummy)						−0.1247		
						(−4.89)		
NYSE dummy	0.0953							
	(1.62)							
Earnings quality		−0.1487						
		(−1.77)						
Earnings informativeness			−0.0168					
			(−0.40)					
Abnormal stock return (Q1 bottom dummy)				0.0131				
				(0.55)				
Abnormal stock return (Q5 top dummy)				0.0079				
				(0.34)				
R^2	0.162	0.182	0.174	0.161	0.182	0.159		0.157
Number of observations	6,675	5,664	5,751	6,675	2,722	6,675	6,675	6,675

response to such events. To address this concern, in Column 12 we include as controls two dummy variables: one indicating those firms with past abnormal stock returns below the 20th percentile (Q1) and one indicating those firms with past abnormal stock returns above the 80th percentile (Q5). The evidence that extreme abnormal returns affect board structure directly is weak, while the PIN coefficient is not materially affected.

So far we have treated PIN as a continuous variable. We now take an alternative approach and classify firms as either low PIN or high PIN. Specifically, we define two dummy variables: PIN Q5–Q1 is equal to one for firm-years with PINs above the 80th percentile (Q5) and zero for firm-years with PINs below the 20th percentile (Q1) (observations with intermediate values of PIN are not included in this regression), and a PIN dummy equals one for firm-years above the median and zero otherwise. This procedure tackles some possible measurement errors problems in the PIN variable. Columns 13 and 14 report the results that confirm a negative relation between PIN and board independence.

Finally, as alternative procedures to tackle potential problems with outliers and cross-sectional error correlation, we present results using a least-absolute deviation (median) regression (Column 15) and the Fama-MacBeth procedure (Column 16). If anything, outliers seem to reduce the magnitude of the estimated effects.

7. Conclusion

We theoretically and empirically identify important interactions between internal and external governance mechanisms. We find evidence that stock market monitoring is a substitute for board monitoring. The strength of this relation is influenced by other governance mechanisms such as pay-performance sensitivity and the market for corporate control.

We add a new element to the list of determinants of board structure: price informativeness. We find robust empirical evidence that stock price informativeness is negatively related to board independence. The correlation between price informativeness and board independence is as strong as the ones between board independence and other firm-level variables that have been shown in the literature on corporate boards. Given our long list of control variables and the use of fixed effects methods, it is unlikely that price informativeness is capturing the effects of omitted variables.

Table A1
Definitions of variables.

Variable	Definition
Fraction of independent directors	Ratio of number of independent directors to board size [1990–1995 data from Compact Disclosure and 1996–2001 data from Investor Responsibility Research Center (IRRC)]
Board size	Number of board members (IRRC)
Number of board meetings	Number of board meetings per year (ExecuComp)
Board attendance	Ratio of directors that attended less than 75% of board or committee meetings to board size (IRRC)
Probability of informed trading (PIN)	Probability of informed trading of Easley, Hvidkjaer, and O'Hara (2002)
Firm-specific return variation	$1-R^2$ of the Fama-French three-factor regression model using daily stock returns
Illiquidity	Average daily ratio of a stock absolute return by the dollar volume (Amihud, 2002)
Firm size	Market capitalization in millions of dollars (Compustat: item 25 × item 199)
Leverage	Ratio of total debt to total assets (Compustat: (item 9 + item 34)/item 6)
Firm age	Number of years since the stock inclusion in the Center for Research in Security Prices (CRSP) database
Number of business segments	Number of business segments in which firm operates (Compustat)
Market-to-book	Ratio of market value of equity to book value of equity (Compustat: item 25 × item 199/item 60)
R&D expenditures	Ratio of research and development expenditures to total assets (Compustat: item 46/item 6)
Stock return variance	Stock return variance (annualized) estimated with daily stock returns (CRSP)
Free cash flow	Ratio of operating income before depreciation minus capital expenditures to total assets (Compustat: (item 13 − item 128)/item 6)
Return on assets	Ratio of operating income before depreciation to total assets (Compustat: item 13/item 6)
CEO pay-performance sensitivity(PPS)	Sensitivity of chief executive officer's stock and stock options holdings to changes in shareholder wealth, as a percentage of the number of shares outstanding (ExecuComp)
CEO tenure	Number of years since the date the director became chief executive officer (ExecuComp)
Governance index (GIM)	Governance index of Gompers, Ishii, and Metrick (2003), which is based on 24 antitakeover provisions (IRRC)
Staggered board dummy	Dummy variable that takes the value of one if a firm has a staggered board, and zero otherwise
Poison pill dummy	Dummy variable that takes the value of one if a firm has a poison pill provision, and zero otherwise
Cumulative voting dummy	Dummy variable that takes the value of one if a firm has a cumulative vote provision, and zero otherwise
Supermajority dummy	Dummy variable that takes the value of one if a firm has a supermajority vote requirement, and zero otherwise
Institutional ownership	Number of shares held by institutions divided by the number of shares outstanding (Thomson CDA/Spectrum 13F Holdings)
Institutional Herfindahl	Institutional Herfindahl index calculated using institutional ownership
Blockholder ownership	Number of shares held by all blockholders divided by the number of shares outstanding
Outside blockholder ownership	Number of shares held by outside blockholders divided by the number of shares outstanding
Stock return	Annual abnormal stock return calculated as firm's stock return minus the return on the CRSP value-weighted index (CRSP)
Stock return (absolute)	Annual absolute abnormal stock return (CRSP)
Industry Herfindahl	Industry Herfindahl index calculated as the sum of squared market shares of firms' sales (COMPUSTAT: item 12) in the industry [two-digit standard industrial classification (SIC) code]
Earnings quality	Absolute value of firm-specific residuals from an annual industry regression (two-digit SIC) of total accruals on lagged, contemporaneous, and leading cash flow from operations; variables scaled by total assets
Earnings informativeness	R^2 of a firm-level regression of 15-month stock returns (ending three months after the end of fiscal year t) on income before extraordinary items (NIBE) in year t and the change in NIBE from year $t-1$ to t, scaled by market value of equity at the beginning of year t
NYSE dummy	Dummy variable that takes the value of one if a firm is listed on the NYSE, and zero otherwise (CRSP)
Number of analysts	Number of analysts covering a firm (Institutional Brokers' Estimate System)
Share turnover	Annual number of shares traded divided by the number of shares outstanding (CRSP)
S&P 500 dummy	Dummy variable that takes the value of one if a firm is a member of the Standard & Poor's 500 index, and zero otherwise (CRSP)

Our model delivers many empirical predictions that find support in the data. The negative relation between price informativeness and board monitoring is particularly strong for firms with few takeover defenses, high concentration of institutional shareholders, high pay-performance sensitivity in CEO compensation, and low firm-specific knowledge. We conclude that the strength of the substitutability between price informativeness and board independence can be accurately measured only when taking into account the overall governance framework.

Our results suggests that, if stock prices are informative, stock markets are able to perform a monitoring role like the one normally associated with the board of directors. The evidence that more informative prices are associated with a lower degree of board independence, fewer board meetings, low attendance at board meetings, and smaller board size all point in the same direction: Firms with more informative stock prices require less demanding board structures. Our findings suggest that stock price informativeness affects optimal organization design.

Appendix

See Table A1.

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