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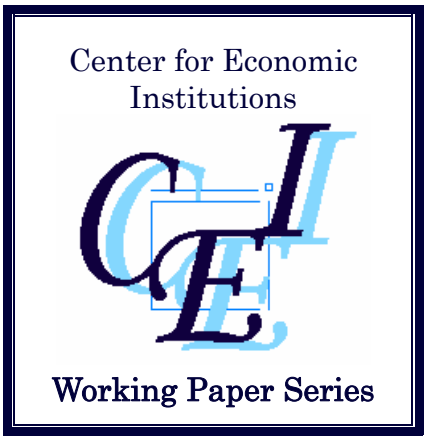
Daniel Ferreira, Miguel A. Ferreira, Clara C. Raposo



Institute of Economic Research
Hitotsubashi University
2-1 Naka, Kunitachi, Tokyo, 186-8603 JAPAN
Tel: +81-42-580-8405
Fax: +81-42-580-8333
e-mail: cei-info@ier.hit-u.ac.jp

Board Structure and Price Informativeness*

Daniel Ferreira
London School of Economics
CEPR and ECGI

Miguel A. Ferreira
ISCTE Business School

Clara C. Raposo
ISCTE Business School

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Abstract

We develop and test the hypothesis that private information incorporated into stock prices affects the structure of corporate boards. Stock price informativeness may be a complement to board monitoring, because the information revealed by prices can be used by directors to monitor management. But price informativeness may also be a substitute for board monitoring, because more informative prices can trigger external monitoring mechanisms, such as takeovers. We find robust evidence for the substitution effect: Stock price informativeness, as measured by the probability of informed trading (PIN), is negatively related to board independence. Consistent with the model's predictions, this relationship is particularly strong for firms exposed to external governance mechanisms and internal governance mechanisms, and firms for which firm-specific knowledge is relatively unimportant. We address endogeneity concerns in a number of different ways and conclude that our results are unlikely to be driven by omitted variables or reverse causality. The results are also robust to using different measures of price informativeness and different proxies for board monitoring

JEL classification: G32, G34
Keywords: Corporate boards, Independent directors, Price informativeness

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1. Introduction

The idea that prices aggregate information that is dispersed among market participants dates back to at least Hayek (1945). The modern version of such an idea is found in, among others, 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 information can also be useful for the provision of incentives in firms and for the design of corporate governance mechanisms is an even more recent idea. Articles by Holmstrom and Tirole (1993) and Faure-Grimaud and Gromb (2004) examine the role of stock prices in disciplining managers and providing incentives to insiders. There is also a set of related studies on the role of stock prices in guiding corporate investment decisions (Dow and Gorton (1997), Subrahmanyam and Titman (1999), and Dow, Goldstein, and Guembel (2007)).

In this paper, we argue that the information revealed by stock prices should affect how directors perform their monitoring of management. We identify two intuitive mechanisms by which prices may affect board 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 thus 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 may 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.

In order to clarify these ideas, we develop a simple model of the relationship between shareholders, markets, boards, and managers. The model predicts that price informativeness matters for board monitoring, but that the sign of this relationship is ambiguous. Thus, whether price informativeness and board independence are substitutes or complements is

in the end an empirical question. Our model, however, has a number of unambiguous predictions that we also explore in our empirical analysis.

A crucial assumption behind our theoretical analysis and our empirical strategy is that different stocks have different amounts of information incorporated into them. This heterogeneity in price informativeness arises due to the different costs of collecting and producing private information. Grossman and Stiglitz (1980) predict that improving the cost-benefit trade-off of private information collection encourages more extensive informed trading and leads to more informative pricing. They suggest that in a market with many risky stocks, those which can be investigated more cheaply are more attractive to traders. As traders acquire more information about such stocks, their prices become naturally more informative.

While the model helps us to identify the main hypotheses, our main contribution is however on the empirical side. We find a robust negative correlation between proxies for price informativeness and board independence. This is a novel and surprising finding, and one that, even without knowing the direction of causality, deserves further scrutiny.

We also test some of the implications of our model. We find that the negative relationship between price informativeness and board independence is particularly strong for firms with few takeover defenses (that is, the ones for which the market is an effective external monitor), for firms with a high concentration of institutional ownership (for which large shareholder monitoring is present), and for firms with low R&D expenses (which are less innovative firms, for which firm-specific knowledge is not crucial). These findings are all consistent with the theory and, considered together, they increase our confidence in the interpretation of the results.

Our results remain qualitatively unchanged if we use firm fixed-effect methods to address concerns about omitted variables. We also use instrumental variable (IV) methods to address the possibility of reverse causality. As instruments, we use variables that are known to be correlated with price informativeness, such as share turnover, S&P 500 membership, and analyst coverage, but have never been used as explanatory variables in board independence

regressions in previous studies. Although it is not possible to prove the validity of the instruments, we provide a careful discussion of the advantages and limitations of our IV approach. Finally, we show that using lagged versions of the price informativeness variable also yields similar results.

In most of our empirical specifications, our measure of price informativeness is the probability of informed trading (PIN), which was developed in a series of papers beginning with Easley, Kiefer, and O'Hara (1996) and Easley, Kiefer, and O'Hara (1997). This measure has strong theoretical foundations, since it comes from a structural microstructure model. A high PIN indicates that more of the information incorporated into a stock's price is coming from private sources than public ones. Vega (2006) shows that stocks with higher PIN have smaller reactions following an earnings announcement, which is consistent with the idea that these stocks incorporate more private information and track their fundamental values more closely. In a recent paper, Chen, Goldstein, and Jiang (2007a) adopt this measure to assess the impact of price informativeness on corporate investment. They 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. Our work provides complementary evidence on the importance of price information for corporate decisions by focusing on the relationship between price informativeness and governance mechanisms, which ultimately determine investment decisions.

Among the several robustness checks that we perform, we use alternative measures of stock price informativeness, such as firm-specific stock return variation (Morck, Yeung, and Yu (2000)) and a measure of illiquidity or price impact of order flow (Amihud (2002)). We also investigate the impact of price informativeness on additional characteristics of the board of directors. We find that price informativeness is positively related to the number of directors with attendance problems and negatively related to the number of board meetings. These results are compatible with board monitoring and price informativeness being substitutes. We also find that price informativeness is negatively related to board size. This evidence

is harder to interpret; while size has been sometimes considered detrimental to monitoring (Lipton and Lorsch (1992), Jensen (1993)), it has also been linked to better advising and strategy formation by boards (Coles, Daniel, and Naveen (2008), Linck, Netter, and Yang (2008)).

Overall, our results suggest that, empirically, board independence and price informativeness are substitutes rather than complements. There are few empirical studies on the interaction of between different governance mechanisms. Examples are the work of Cremers and Nair (2005), who find a complementary effect between openness to the market for corporate control and large institutional investors presence, and Gillan, Hartzell, and Starks (2006), who find that an independent board can act as a substitute for the market for corporate control. Our paper adds to this growing literature.

Our results are also consistent with the idea that the optimal board structure depends on the characteristics of the firm; that is, "one size" does not fit all firms. In particular, there is some evidence 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 (Boone, Field, Karpoff, and Raheja (2007), Coles et al. (2008), and Linck et al. (2008)). Similarly, Chhaochharia and Grinstein (2007) find evidence that the stronger board independence requirements mandated in 2002 benefited large firms, while negatively affecting small ones. Finally, our work is also related to recent papers that investigate the impact of corporate directors' knowledge and expertise on firm outcomes (Guner, Malmendier, and Tate (2006)) and the information available to and monitoring ability of independent directors (Ravina and Sapienza (2006)).

On the theoretical side, our model integrates two independent lines of research. The first explains board structure as the result of optimal shareholder choices under incomplete contracts (Hermalin and Weisbach (1998), Raheja (2005), Song and Thakor (2006), Adams and Ferreira (2007), and Harris and Raviv (2007)). The second examines the role of stock prices in disciplining managers and providing incentives to insiders (Holmstrom and Tirole

(1993), Faure-Grimaud and Gromb (2004), and Almazan, Banerji, and Motta (2007)). To the best of our knowledge, these two strands of the literature have never before been put together.

The remainder of the paper is organized as follows. In Section 2 we present a simple model to motivate the relationship between stock prices and board independence. The model is used to derive the hypotheses that we test in subsequent sections. Section 3 describes the sample, the data, and the construction of variables. In Sections 4 and 5 we present our core evidence on the relationship between board independence and stock price informativeness. In Section 6 we perform additional checks on the robustness of our findings. Section 7 concludes.

2. The Model

In a simple model, we show that there can be a link between the board's monitoring role and the price informativeness of a stock. Intuitively, more informative prices can reinforce the internal monitoring activity performed by the board of directors. On the other hand, higher price informativeness can also reinforce the role of external monitoring mechanisms, via disciplining takeovers. Hence, board independence and price informativeness can interact as either complements or substitutes. We examine this trade-off, and generate some empirical predictions which are tested later in the paper.

2.1. The Setup

We model the need for monitoring of the CEO in a simple adverse selection setting (see for example Hermalin and Weisbach (1998)) with three dates and four types of participants: Shareholders, Board of Directors, CEO, and Stock Market. 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 of an unknown type. At date 1, the type of

the incumbent CEO may be revealed. With probability p (which can be interpreted as the degree of price informativeness), stock prices reveal the CEO's type to everyone. If prices do not reveal the CEO's type, the board alone learns it with probability β. If the board is informed, it may replace the CEO with a new one, whom is randomly selected from the population. Likewise, if the market is informed, an external raider could also take over the firm, replacing the CEO.[1] At date 2, the value of the firm is revealed to everyone. The value of the firm depends on the type of the CEO in charge.

There are two types $j \in \{H, L\}$ of **CEOs** in this market. At date 0, the type of the CEO is not known by anyone. For simplicity, we assume that both types are equally likely in the population. The **value of the firm**, V^j, will depend on the quality j of its CEO. We assume $V^H > V^L$. The unconditional expected value of the firm when a new CEO is appointed is then $V^E = \frac{1}{2}\left(V^H + V^L\right)$.

The **Board of Directors** is characterized by its level of independence i. This level i corresponds to the probability of the board monitoring and replacing a CEO that is revealed to be of type L at time 1.[2] The board can learn about the type of the CEO at date 1 from two sources: (1) stock prices or (2) own assessment. We assume that, even if the market is uninformed, the board unilaterally learns the CEO's type at date 1 with probability β. This is a very natural assumption: Insiders (i.e., the board) know more than outsiders.

Shareholders are risk-neutral agents who care about the market value of the firm and delegate firm management to the CEO. Shareholders choose the composition of the firm's board of directors, i.e., its level of independence $i \in [0, 1]$. This choice is non-trivial since a more independent board is assumed to be costlier, but also generates more monitoring of the CEO.[3] We assume that board independence has an ex ante cost $k\frac{i^2}{2}$.

The **Stock Price** will be informative at date 1 with probability p, in which case it reveals

[1] Aternative interpretations are also possible. For example, the CEO could have made wrong decisions that could be reversed only if monitors intervene at this stage.

[2] More independent boards are likely to perform their monitoring role more effectively and there is evidence that outside directors can affect crucial decisions such as hiring and firing the CEO (Weisbach (1988)).

[3] For models that endogenize the cost of board independence, see Song and Thakor (2006) and Adams and Ferreira (2007).

the CEO's type, which becomes public information. If the price does not reveal the type of the CEO (with probability $(1-p)$), or if it reveals that the CEO is of type H (with probability $\frac{p}{2}$), the probability of a takeover taking place is zero.[4] Conditional on the market being informed that the CEO is of type L (with probability $\frac{p}{2}$), 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 (or an inverse measure of takeover defenses). If the market is informed that the CEO is of type L, the board may also directly monitor and replace the CEO with probability i.[5] For simplicity, we assume that, at date 1, τ and i are independent from each other. If both the board and the market want to replace the CEO simultaneously, we assume that they flip a coin. Because the outcome for the firm is the same regardless of who monitors, it is not relevant to know the ultimate identity of the successful monitor.

In case the CEO is replaced at date 1, his successor is randomly drawn from the population. Thus, conditional on the market and/or the board being informed, the CEO is subject to monitoring and the firm's expected value in such cases is defined as $V^M = \frac{1}{2}\left(V^H + V^E\right)$.

2.2. Board Independence and Price Informativeness

The shareholders' problem at date 0 is to choose the level of monitoring of the board of directors according to:

$$\begin{aligned} \max_{i\in[0,1]} \quad & p\left[(i+\tau-i\tau)\,V^M + (1-i-\tau+i\tau)\,V^E\right] \\ & + (1-p)\left[\beta i V^M + \beta\,(1-i)\,V^E + (1-\beta)\,V^E\right] - k\frac{i^2}{2}. \end{aligned} \tag{1}$$

Assuming an interior solution, the optimal board structure is characterized by:

$$i^* = \frac{1}{k}\left[p\,(1-\tau) + (1-p)\,\beta\right]\left(V^M - V^E\right). \tag{2}$$

[4] This assumption is not crucial. The model could easily accommodate a positive probability of a raider acquiring information and placing a takeover bid, even if prices are uninformative.

[5] If prices reveal that the CEO is of type H, neither the market nor the board are interested in monitoring and replacing the incumbent CEO.

We are now able to establish a relationship between board independence and price informativeness:

Proposition 1 *The optimal degree of board independence depends on the informativeness of stock prices, according to:*

$$\frac{\partial i^*}{\partial p} = \frac{1}{k}\left(1-\tau-\beta\right)\left(V^M - V^E\right). \tag{3}$$

The relationship between board independence and price informativeness is ambiguous: The sign can be either positive or negative, depending on the values of the parameters. We can interpret this result by examining the interaction of two intuitive effects.

On the one hand, price informativeness and board monitoring can be complements – the better informed the board is, the more effective board monitoring becomes. This effect arises because price informativeness is a non-rival good that can be used by both insiders and outsiders. This result is a robust one, and not specific to our model: The public good nature of price informativeness would always generate a complementary effect in any realistic model.[6]

On the other hand, price informativeness can act as a substitute for board monitoring. A better informed market can directly perform external monitoring via takeovers. This result arises because internal and external monitoring both perform the same task of disciplining the CEO. Any model in which internal monitoring is costly should predict a lower level of board monitoring when there is an increase in the level of external monitoring (due to more information being available in the market).

Turning to the parameters' values, if $\tau + \beta > 1$, board independence and price informativeness are substitutes, i.e., there is a negative relationship between price informativeness and board independence. Conversely, if $\tau + \beta < 1$, board independence and price informa-

[6] 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 firm's prospects.

tiveness act as complements. Ultimately, finding out which effect dominates is an empirical question.

2.3. The Threat of a Takeover

The model allows us to predict, without ambiguity, the effect of the degree of exposure to takeover threats on the relationship between board independence and price informativeness. More formally, we can state that:

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

$$\frac{\partial^2 i^*}{\partial p \partial \tau} = -\frac{1}{k}\left(V^M - V^E\right). \tag{4}$$

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 the monitoring role of the board of directors. Hence, we would 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 stronger when takeover threats are more likely. This implication could be tested by using takeover defenses as a proxy for the likelihood of takeovers (Ambrose and Megginson (1992)).

2.4. The Role of Institutional Investors

There is evidence that institutional investors also perform an active role in corporate governance (e.g., Hartzell and Starks (2003)). We examine the role played by institutional investors in the relationship between board structure and price informativeness. We interpret parameter k as a measure of how costly internal monitoring is. When institutional

investors are present as large shareholders (or high concentration of institutional holdings), it is likely that this cost of board monitoring is lower.

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

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

We can see that (in absolute values) the relation between board independence and price informativeness is less pronounced when the marginal cost of external monitoring k is higher (i.e., when $\frac{\partial i^*}{\partial p} > 0$, $\frac{\partial^2 i^*}{\partial p \partial k} < 0$, reducing the complementarity effect; and when $\frac{\partial i^*}{\partial p} < 0$, we find $\frac{\partial^2 i^*}{\partial p \partial k} > 0$, reducing the substitution effect). These results suggest that price informativeness only significantly affects board independence when the board can *effectively* act as an internal monitoring mechanism (lower monitoring cost k). We consider this scenario of lower cost of board monitoring to be more likely in the presence of substantial concentration of institutional shareholders who supervise the board themselves (Shleifer and Vishny (1986) and Carleton, Nelson, and Weisbach (1998)).

2.5. Firm-Specific Knowledge of the Board

If we consider β, the likelihood that the board learns information on its own, independently from the market, as a parameter that reflects how easy it is for the board to gather firm-specific information to assess the ability of the CEO, we can offer the following interpretation for the effect of β on the board independence-informativeness relation:

Proposition 4 *The higher is the likelihood of the board learning firm-specific information, the stronger (weaker) is the substitution (complementary) effect of price informativeness on the choice of board independence:*

$$\frac{\partial^2 i^*}{\partial p \partial \beta} = -\frac{1}{k}\left(V^M - V^E\right). \tag{6}$$

Arguably, in more innovative firms (R&D-intensive firms), independent board members should find it harder to acquire firm-specific knowledge that is needed to assess the CEO's ability. According to our interpretation, these firms would have low β. This result suggests that the (absolute value of the) effect of price informativeness on board independence should be stronger in firms with low R&D in case the overall effect is negative, but weaker in case the overall effect is positive.

2.6. Discussion of the Main Assumptions

For the sake of simplicity and clarity of exposition, we have chosen a particular setting for the model. We believe that the most relevant ingredients are present, but acknowledge that in some instances they are oversimplified. One of the main simplifications is the formation of stock prices, which we treat as a black box. We could develop a detailed microstructure model with endogenous price formation, but we believe that the current simple structure is just sufficient to model the link between the composition of the board of directors and price informativeness.

The way in which we model the board of directors is also simplified. We could have followed the existing board literature by endogenizing all the costs and benefits of board monitoring. Since most of those results are now well known, we believe that replicating their underlying analysis in unnecessary.

Finally, regarding the relationship between the firm and the CEO, we formulate the agency problem as an adverse selection problem (as in Hermalin and Weisbach (1998)). Alternatively, we could have presented a moral hazard problem (as in Dow and Raposo (2005) and Adams and Ferreira (2007)), in which the incentives given to the CEO would be an additional concern. Once again, since these results are well established in the literature, we have chosen the adverse selection formulation in which the specific problem solved by the CEO does not distract us from the main issues.

3. Sample and Variables

3.1. Measures and Determinants of Board Structure

Our main dependent variable is board independence, which is a proxy for the monitoring intensity of the board. Board independence is proxied by the fraction of independent directors. In order 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 a later section, we 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 attendance problems (attend less than 75% of board meetings). We also consider board size as defined by the number of directors on the board. We explore the idea that larger boards represent a larger pool of expertise and thus provide better advice to managers that may substitute for the information provided by stock markets. On the other hand, larger boards are usually considered less effective at monitoring due to coordination and free-riding problems.

In order 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. One hypothesis is that the scope and complexity of operations affect a firm's board structure (Fama and Jensen (1983)). According to this hypothesis, larger and more complex firms require larger boards. As a firm grows and diversifies, it faces an increasing demand for specialized board members who can perform tasks such as managerial compensation and auditing. Furthermore, the scope and complexity of operations can also have an effect on board independence. Under this hypothesis, more complex firms face larger agency costs and thus require additional board monitoring (Coles et al. (2008)).

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.

Many theories emphasize the importance of a firm's business environment (Demsetz and Lehn (1985), Raheja (2005), Adams and Ferreira (2007), and Harris and Raviv (2007)). We use several control variables to capture some of the elements of these theories. To control for the costs of outside monitoring, we take into account 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 stock ownership. We consider free cash flow, leverage, profitability, and industry concentration, because these variables could be related to agency conflicts and other opportunities for the CEO to extract private benefits. Similarly, we include Gompers, Ishii, and Metrick (2003) governance index (GIM) as a measure of the number of takeover defenses in the firm's charter. We control for earnings quality as measured by the Dechow and Dichev (2002) model as the quality of accounting numbers is a central element of the information flow. Others, in contrast, emphasize the negotiation between the CEO and outside directors (Hermalin and Weisbach (1998)). We include two measures of the CEO's influence: CEO's tenure and stock ownership. A more comprehensive discussion of some of these variables and their relationship to board structures can be found in Boone et al. (2007), Coles et al. (2008), Gillan et al. (2006), and Linck et al. (2008).

We introduce institutional ownership variables as additional controls in our empirical specifications. Because the trading activity of large institutional investors may have a direct effect on the amount of private information revealed by stock prices, we expect institutional ownership to be correlated with price informativeness. Because there is evidence that institutional investors also perform an active role in corporate governance (e.g., Hartzell and Starks (2003)), omitting the institutional ownership variables may lead to spurious correlations between price informativeness and board structure.[7] Institutional investors are expected to

[7] There is some discussion in the literature over whether some types of institutions specialize in monitoring and activism rather than trading. Research by Brickley, Lease, and Smith (1988), Almazan, Hartzell,

have more influence when they are large shareholders, because they have easier access to board members (Carleton et al. (1998)) and benefit from economies of scale in monitoring activities. Thus, we consider two measures of concentrated holdings: the concentration of institutional ownership (as measured by the Herfindahl index) and institutional blockholder ownership (defined as stock holdings by the firm's largest institutional investors with at least 5% of shares outstanding following Cremers and Nair (2005)). We also control for the total institutional ownership (defined as the percentage of shares outstanding held by institutions).[8]

3.2. Measures of Price Informativeness

Our primary measure of stock price informativeness is the probability of information-based trading (PIN) developed by Easley et al. (1996). This measure is based on a structural market microstructure model, where trades may come from "noise traders" or from "informed traders." Easley, Hvidkjaer, and O'Hara (2002) provide a detailed theoretical description of the PIN variable. Here we simply explain its intuition.

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 information about the fundamental value of the firm. Trading orders arrive throughout the day according to three different Poisson distributions: informed trade 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 that the opening trade of the day is information-based is given by

$$\text{PIN} = \frac{\lambda\mu}{\lambda\mu + \epsilon_b + \epsilon_s}, \tag{7}$$

and Starks (2005), and Chen, Harford, and Li (2007b) show that "independent institutions" (mutual fund managers and investment advisors) are effective monitors, while "grey" institutions (bank trusts, insurance companies, and other institutions) are not.

[8]We obtain similar results using alternative measures of concentrated holdings: ownership by the five largest institutional investors; ownership by institutional blockholders (defined as stock holdings by institutional investors with at least 5% of shares outstanding); ownership by all blockholders; and ownership by outside blockholders. We present some these results in the robustness section.

where $\lambda\mu$ is the arrival rate for informed orders and $\lambda\mu + \epsilon_b + \epsilon_s$ is the arrival rate for all orders.

Easley et al. (2002) use intra-day transaction data over a given period to estimate the above parameters and thus the probability of informed trading in a stock. Notice that 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 et al. (2002) find that the risk of private information trading is priced, and find that it carries a positive risk premium, i.e. stocks with higher PIN have higher expected returns. Vega (2006) shows that stocks with higher PIN have smaller reactions following an earnings announcement, which is consistent with the idea that these stocks incorporate more private information and track their fundamental values more closely. PIN also seems to be related to managerial decisions. Chen et al. (2007a) 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. All this empirical evidence supports the interpretation of PIN as a valid measure of stock price informativeness.[9]

In a later section, we consider other price informativeness variables to confirm our interpretation of the results. We first consider firm-specific stock return variation as a measure of price informativeness. Considerable research establishes that firm-specific stock return variation and price informativeness are closely related. French and Roll (1986) and Roll

[9] A recent paper by Duarte and Young (2007) questions this interpretation. Their findings suggest that the relation between PIN and expected returns is explained by the fact that PIN is also a proxy of illiquidity not related to private information.

(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. Empirical evidence supports the use of firm-specific return variation as a measure of stock price informativeness and particularly of private information about firms. In the U.S. market, high levels of firm-specific return variation are associated with more efficient capital allocation (Durnev, Morck, and Yeung (2004) and Chen et al. (2007a)), and with more information about future earnings embedded in stock prices (Durnev, Morck, Yeung, and Zarowin (2003)). Cross-country patterns of firm-specific return variation also correspond to likely patterns of price informativeness. Morck et al. (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. Bris, Goetzmann, and Zhu (2007) find high firm-specific return variation in countries where short sales are allowed.

We estimate annual firm-specific return variation by regressing stock returns on the Fama and French (1992) three-factor. For each firm-year, firm-specific return variation is estimated by $1 - R^2$ from the regression:

$$r_{it} = \alpha_i + \beta_{1i} RM_t + \beta_{2i} SMB_t + \beta_{3i} HML_t + e_{it}, \tag{8}$$

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 local 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.[10] Given the bounded nature of R^2, we conduct our tests using a logistic transformation of $1 - R^2$:

$$\Psi = log\left(\frac{1 - R^2}{R^2}\right) = log\left(\frac{\sigma_e^2}{\sigma^2 - \sigma_e^2}\right). \tag{9}$$

[10]The daily returns for the Fama and French (1992) 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

The variable Ψ measures firm-specific stock return variation relative to market-wide variation, or lack of synchronicity with the market.[11]

Finally, as an alternative measure of price informativeness or private information incorporated into stock prices, 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):

$$\text{ILLIQ} = \frac{1}{D_i} \sum_{t=1}^{D_i} \frac{|r_{it}|}{\text{VOLD}_{it}} \tag{10}$$

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 is a proxy 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 will also reflect 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. The IRRC database contains detailed information on governance and director characteristics for a large number of U.S. firms. We obtain board data for these firms from Compact Disclosure for the 1990-1995 period and from IRRC for the 1996-2001 period.[12] We exclude financial firms (SIC codes 6000-6999). We winsorize variables at the bottom and top 1% level.[13] After these adjustments the number of firms in the sample is 2,188. Next we

[11] Alternative estimates of firm-specific return variation are provided by the market model that assumes $\beta_{2i} = \beta_{3i} = 0$ in equation (8) and by the two-factor (market and industry) model. We obtain similar findings using these alternative estimates.

[12] 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 only described in terms of the percentage of executive directors (insiders or officers) and non-executive directors on the board. In the robustness section, we report results using only IRRC data.that are consistent with our primary findings

[13] We obtain similar findings when we winsorize variables at the bottom and top 5% level.

merge the IRRC database with our main variable of price informativeness – the probability of information-based trading (PIN) for each firm-year, based on data from Easley et al. (2002).[14] 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 CRSP. The governance index of Gompers et al. (2003) (GIM) and board attendance problems are available 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 IBES. Blockholder ownership is based on data from Dlugosz, Fahlenbrach, Gompers, and Metrick (2006). Finally, we obtain additional director characteristics such as CEO ownership and tenure and number of board meetings from ExecuComp. Table 1 defines in detail the variables used in this study and describes their sources.

Table 2 presents descriptive statistics of our data. The median fraction of independent directors is 0.778. Board size ranges from 3 to 17 directors, with a median of 10 directors. There are on average 7.2 board meetings a year and 2.5% of the directors have attendance problems (attend less than 75% of board meetings).

Table 2 presents descriptive statistics of PIN. The mean (median) PIN is our sample is 0.162 (0.154), and the standard deviation is 0.056. These statistics are comparable to those reported in Easley et al. (2002). The mean firm-specific return variation ($1 - R^2$) from the market model is 0.85, indicating that the market return factor accounts only for 15% of total stock return variation. The mean illiquidity ratio (ILLIQ) is 0.165.

The median firm in our sample has a market capitalization of $1.1 billion, an age of 39.9 years, and a leverage ratio of 27.0%. The mean number of business segments is 2.2, the mean R&D expenditures-to-assets ratio is 1.9%, and the mean CEO ownership is 1.4%. The median firm has 10 takeover defenses (out of a maximum of 24). The mean total institutional ownership is 47.2% and the mean institutional blockholder ownership is 6.9%. These statistics are comparable to those found in similar studies, such as those of Coles et al.

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

(2008) and Gillan et al. (2006).

4. Board Independence and Probability of Informed Trading

In this section we present our main results on the relation between board independence and probability of informed trading (PIN). Specifically, we estimate the sign of the board independence-informativeness relationship. In the next sections, we provide additional evidence and perform several robustness checks.

Figure 1 presents a visual summary of the relation between board independence and PIN. We first sort firms into quintiles portfolios ranked by PIN. We then calculate the average board independence within each quintile portfolio of PIN. The main finding in this paper is clear from the figure: Average board independence for the lowest PIN portfolio (Q1) is greater than the one for the highest PIN portfolio (Q5). The low-PIN portfolio displays board independence of about 80%, while the corresponding figure for the high-PIN portfolio is about 70%. The difference between the two extreme quintile portfolios is highly statistically significant (t-statistic of 22.1). Moreover, all intermediate PIN portfolios present lower board independence than the low-PIN portfolio.

In Table 3, we present the outcome of several ordinary least squares (OLS) panel regressions, where the dependent variable y is a logistic transformation 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.[15] Our explanatory variable of interest is the probability of information-based trading. Table 3 presents the results from several specifications of the board independence regression, including one restricted to the PIN and one with the full set of control variables. We always include industry (two-digit

[15]In the robustness section, we obtain similar results using the fraction of independent directors or the logarithm of the fraction of independent directors as dependent variables.

SIC) and year dummy variables.[16] In our setting, cross-correlation and autocorrelation are likely to occur in our dependent variable. When this happens, conventional standard errors may be biased downwards. All reported t-statistics are therefore 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 univariate regression between the fraction of independent directors and PIN. There is strong evidence of a negative and significant relationship. The PIN coefficient is -3.1376, with a high t-statistic of -13.60. This effect is economically significant: an increase in PIN from the 20th percentile to the 80th percentile (i.e., an increase in PIN from 0.11 to 0.21) predicts a decrease of roughly 6 percentage points in board independence (for a board with average independence).

Controlling for other firm characteristics does not change this result qualitatively. In column (2) we present estimates for a specification that does include CEO ownership 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 CEO ownership and tenure as controls, but the PIN estimate and t-stastistic are barely affected. Overall, we find that the probability of informed trading displays a statistically and economically significant negative relationship 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 et al. (2007) and Coles et al. (2008), we find no statistically significant relationships between board independence and market-book ratio, R&D expenditures, return-on-assets, and stock return variance. The free cash flow variable

[16] We obtain similar results when we do not include industry or year dummies in the regression specification.

also does not have a statistically significant point estimate. In contrast, we find that the coefficients of CEO ownership 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.

In columns (4) - (6) we control for the governance index (GIM), total institutional ownership, and institutional ownership concentration. The GIM coefficient is positive and statistically significant, which is consistent with the idea that board independence increases in firms that are insulated from the market for corporate control. This finding is consistent with the empirical evidence of Gillan et al. (2006), who show that an independent board can act as a substitute for the market for corporate control. The institutional ownership variables are not significantly related to board independence.

So far we have treated PIN as a continuous variable. We now take an alternative approach and classify firms as low PIN (low market monitoring) versus high PIN (high market monitoring). Specifically, we define a dummy variable that 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). We re-estimate the board independence regressions in Table 3 using this dummy variable. The estimated coefficient on the PIN dummy variable measures the difference in board independence between firms with high and low PIN, or price informativeness. Notice that the intermediate observations in terms of PIN are not included in this regression. Table 4 presents the results.

Column (1) presents the coefficients of a univariate regression between the fraction of independent directors and the PIN dummy variable (Q5 - Q1). There is strong evidence of a negative and significant relationship. The PIN dummy variable coefficient is -0.5193, with a high t-statistic of -13.08. This effect is economically significant: a move from the PIN bottom quintile (Q1) to the top quintile (Q5) predicts a decrease of roughly 10 percentage points in board independence (for a board with average independence). Controlling for other

firm characteristics again does not change this result. In column (2), the PIN coefficient is -0.3404 with a t-statistic of -6.33.

In summary, we find that the probability of informed trading displays a statistically and economically significant negative relationship with board independence.

5. Interpreting the Relationship between Board Independence and Probability of Informed Trading

In the previous section we have found evidence of strong negative correlations between board independence and the probability of informed trading (PIN). 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 acts as a substitute for corporate boards in its monitoring role.

In this section, we present additional results that strengthen this interpretation. In the initial two subsections, we present evidence that takeover defenses and large shareholders have an impact on the relationship between board independence and the probability of informed trading. In the last subsection, we investigate the role of firm-specific knowledge (proxied by research and development expenditures).

5.1. Takeover Defenses

If a firm adopts a large number of takeover defenses, it becomes partially insulated from the market for corporate control. 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 hypothesis is implied by Proposition 2.

We use the governance index of Gompers et al. (2003) (GIM) as a proxy for the number of takeover defenses a firm has in place. Columns (1) and (2) of Table 5 present the results

of separate estimations on two subsets of the sample: firms whose GIM index is above 13 (column (1)) and firms whose GIM index is below 6 (column (2)).[17] Following Gompers et al. (2003), we label those firms with many takeover defenses as "dictatorship" firms and those with few takeover defenses as "democracy" firms. Note that these two subsamples do not include all observations in the sample. We find that the relationship between board independence and PIN is negative and significant for democracy firms, but insignificant for dictatorship firms. We conclude that the market for corporate control does have an important role to play in shaping the relation between board independence and price informativeness. Price informativeness can only substitute for the role of independent directors when the firm is open to the market for corporate control (see Proposition 2). This finding is consistent with the evidence provided by Gillan et al. (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. Our theory is thus less plausible in dispersed ownership structures where shareholders have no incentive to engage in activism. Unlike individual investors, institutional investors (especially if they hold large blocks of stock) have a clear incentive to maximize the firm value by changing the board structure when necessary. Thus, 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.

Columns (3) and (4) of Table 5 present results on this hypothesis by splitting the sample into firms with more or less concentrated institutional ownership. The high (low) institutional ownership concentration sample consists of those firms whose Herfindahl index is greater (less) than the median value. We find a negative and significant relationship between

[17] To conserve space, we only present the results of our most complete specification (column (5) in Table III), but results are consistent for other specifications.

board independence and PIN for the high institutional ownership concentration sample, but this relationship is insignificant for firms with a low concentration of institutional ownership. In other words, the probability of informed trading is only negatively related to board independence for those firms with a high concentration of institutional ownership.[18]

The results of this section suggest that price informativeness can only be an effective substitute for internal monitoring (by the board) when large institutional shareholders supervise the board themselves. Without a substantial concentration of institutional ownership the board may only play a minor role. In such cases it would be natural to find no relation between board independence and stock price informativeness.

5.3. Firm-Specific Knowledge

It is reasonable to assume that firms facing high monitoring costs have less independent boards. In particular, when firm-specific knowledge is important, a board that is too independent may fail to obtain crucial information. Perhaps there are few informed insiders (Raheja (2005)), or perhaps the CEO refuses to communicate with the board (Adams and Ferreira (2007)). We thus expect that costs associated with the acquisition of firm-specific knowledge may affect the relationship 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 relationship between board independence and price informativeness when firm-specific knowledge is less important. The idea is simply that CEOs and inside directors possess more firm-specific knowledge than outside directors (Fama and Jensen (1983)). Consequently, the trade-off between board independence and price informativeness becomes less effective when this type of knowledge is more important. This hypothesis is formally derived in Proposition 4.

Measuring the importance of firm-specific knowledge is a difficult task. Following Coles et al. (2008), we use R&D expenditures as a proxy for the importance of firm-specific knowl-

[18] We obtain similar findings when we split the sample using the institutional blockholder ownership variable.

edge. Firm-specific knowledge is harder for outsiders to acquire in firms with high levels of R&D expenditure. The kind of information that market prices convey cannot substitute for the knowledge that insiders possess, thus, empirically, the substitution effect should be weaker for firms with high R&D.

Columns (5) and (6) of Table 5 present the results of separate regressions for two subsamples that differ from each other according to their R&D expenditures. In one set of firms, the ratio of R&D expenditures to assets is above the 80th percentile (column (5)); all other firms (low R&D and firm-specific knowledge) are placed in the other category (column (6)).[19] The evidence shows that the relationship between board independence and PIN is negative and significant in low R&D firms, but statistically insignificant in high 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. No such a trade-off is possible, however, when firm-specific knowledge is important.

6. Robustness

In this section, we check the robustness of the relationship between board structure and stock price informativeness. We first present several alternative estimation methods, such as instrumental variables (2SLS) and firm fixed effects. The alternative estimation methods address several concerns with our estimates, such as omitted variables, reverse causality, and measurement errors. We then present additional robustness checks such as sample variations and additional control variables. In the two final subsections, we present results using alternative measures of price informativeness and additional board-related variables.

[19]The 80th percentile actually 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 cut-off.

6.1. Endogeneity and Alternative Estimation Methods

Endogeneity problems are ubiquitous in empirical research on corporate governance (e.g., Coles, Lemmon, and Meschke (2007)). In our setting, this problem is accentuated by recent findings showing that CEO decision-making power and board size both have direct effects on corporate performance, in particular the variability of stock returns (Adams, Almeida, and Ferreira (2005) and Cheng (2007)). Furthermore, there could be other reasons for board structure and price informativeness to be jointly determined.

We have already dealt with some of these issues in this paper. In order to be sure that our measure of price informativeness is not simply capturing the effect of stock return volatility, we have included the total stock return variance as a control variable in all specifications. More importantly, the effect of PIN is robust even when stock return variance is one of the controls. Furthermore, our analysis in Section 5 strongly supports an interpretation of the results in which price informativeness causes board structure rather than vice-versa. The reverse is difficult to reconcile with corroborating evidence on the role of takeover defenses, institutional ownership concentration, and firm-specific knowledge.

In this subsection, we first address the potential endogeneity problems using instrumental variables to control for the endogeneity of PIN; specifically, to address reverse causality issues. This two-stage least squares (2SLS) method isolates the effect of PIN on board independence. To this end, we need a good instrument 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. Since PIN is estimated using intra-day stock trading data, finding an appropriate instrument is not an easy task. We use analyst coverage, share turnover, and S&P 500 membership as instruments.

Easley, O'Hara, and Paperman (1998) suggest that analysts may serve to turn private

information into public information and do not have significant firm-specific information. Analysts may 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)). Further, Chen et al. (2007a) find a negative relation between PIN and the sensitivity of firm investment to stock prices, which suggests that information released by analysts and impounded in the stock price does not have much effect on managers' investment decisions.[20] 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 et al. (2002)). We use as an additional instrument a dummy variable that takes the value of one if a stock included in the S&P 500 index as these firms tend to attract more investor attention. Thus, our instrumental variables have been previously found to be significantly correlated with price informativeness, but have never been used as explanatory variables in board independence regressions in previous studies.[21]

The first column of Table 6 presents the results of the first stage regression that uses PIN as dependent variable. The results support the conclusion that turnover and analyst coverage are negatively and significantly related to PIN, while S&P 500 membership is positively and significantly related to PIN. Columns (2) and (3) present the 2SLS coefficients of the second-stage regression that uses board independence as 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. Assuming that our instruments are valid (i.e., we assume that all these instruments affect price informativeness but not board independence directly), the evidence suggests the existence of a causal link from price in-

[20] There are some papers that examine whether analysts serve as an additional external monitoring mechanism. Some studies argue that analysts positively impact firm performance and polices (Knyazeva (2007), Yu (2007)), while others find evidence that excess analyst coverage induce overinvestment and external financing (Doukas, Kim, and Pantzalis (2006)). In unreported results, we find that analyst coverage does not affect the negative and significant relation between board independence and price informativeness.

[21] Following Agarwal and O'Hara (2006), we also use lagged PIN as an instrument and obtain consistent results (not tabulated here). See Aslan, Easley, Hvidkjaer, and OŠHara (2006) for a discussion of altenative instruments for PIN.

formativeness to board structure. To formally assess the quality of the instruments, we also perform the Hansen $\mathcal{X}^2$-test of instrument orthogonality. This statistic jointly tests the null hypotheses of correct model specification and orthogonality of instruments with the errors. Our instruments perform adequately in our tests (p-value is 0.62 and 0.95 in the specifications of columns (2) and (3) respectively), indicating that we cannot reject the null hypothesis of instrument suitability.

We then use firm fixed effects that control for unobserved sources of firm heterogeneity and the endogeneity of PIN as an alternative to 2SLS. Columns (4) and (5) of Table 6 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 (5), the estimate of the PIN coefficient is -0.5812 with a significant t-statistic of -3.28. Thus, the firm fixed effects estimates suggest a casual negative relation from PIN to board independence.

A final approach to address the endogeneity concern is to use lagged PIN as explanatory variable. Columns (6) and (7) present the results of these estimations that confirm a negative relation between board independence and PIN.

All of our specifications so far have been estimated by OLS. To address the concern that outliers may drive our core results, we winsorize financial ratios at the bottom and top 1% levels. We use least-absolute deviation (median) regressions as an alternative means of addressing the difficulties associated with outliers. The results are presented in columns (1) and (2) of Table 7, and remain consistent with a negative relationship between board independence and PIN.

The presence of time dependence and cross-sectional dependence in our data is also of potential concern. Our results so far account for cross-sectional and time dependence using industry and year dummies, and by computing firm-clustered standard errors. An alternative solution is to use the procedure of Fama-MacBeth. Specifically, we estimate the relationship between board structure and PIN separately for each sample year and report the average of the yearly estimated coefficients.

Columns (3) and (4) of Table 7 present the results of the Fama-MacBeth procedure. The coefficients are qualitatively similar to those reported in Table 3. The level of economic and statistical significance is also similar to that reported in Table 3. In column (7), the PIN coefficient is -1.1203, with a t-statistic of -7.71. The coefficients of other firm characteristics are also consistent with the OLS panel regression estimates.

6.2. Additional Robustness Checks

This subsection discusses several additional robustness checks. These results appear in Table 8. With these results, we check that our findings are robust to the sample period, board independence variable definition, and control variables. To conserve space, we only present the results of our most complete specification (column (5) in Table 3), but results are consistent for other specifications.

Column (1) uses the 1996-2001 sample period, rather than 1990-2001. The 1996-2001 period corresponds to the period for which the IRRC directors data are available. Therefore, column (1) uses only IRRC directors data, rather than Compact Disclosure (1990-1995) and IRRC data (1996-2001). This issue is a potential concern because the Compact Disclosure just characterize the board in terms of executive and non-executive directors. In addition, column (2) uses board data from Compact Disclosure for the whole sample period (1990-2001) as an alternative to the IRRC directors data.

Column (3) uses the logarithm of board independence, rather than the logistic transformation, as dependent variable. Column (4) uses board independence as dependence variable. Theses check that our results are not driven by our particular transformation of board independence.

Column (5) reports results that control for blockholder ownership that considers all types of blockholders rather than only institutional investors. Column (6) reports results that control for outside blockholders ownership rather than only 13F institutional investors. These blockholder ownership is taken from Dlugosz et al. (2006) and covers 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 mechanism to eliminate managerial inefficiency. We try to capture the competitive structure of an industry using industry concentration, calculated as the sum of squared market shares of all firms in each industry (two-digit SIC) in each year (Herfindahl index). Industries with lower Herfindahl indices possess more competitive product markets. The industry concentration variable has indeed a positive coefficient but insignificant at the 5% level.

Column (8) presents results that control for earnings quality or accounting quality. 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 they increase in the magnitude of unexpected accruals. There is some evidence of a positive association between board independence and accounting quality.

Finally, column (9) includes lag board size as an additional control variable following Boone et al. (2007) and Coles et al. (2008), Gillan et al. (2006).

In all models, the probability of informed trading coefficient remains negative and strongly significant. Our basic result is confirmed: more private information trading is strongly associated with less board independence, or in other words, with less need for board monitoring.

6.3. Alternative Measures of Price Informativeness

To substantiate our informational interpretation of the board independence-PIN relationship, we next test for the relation between board independence and several alternative measures of private information flow. To begin, we use firm-specific stock return variation, or non-synchronicity of stock returns, as one alternative to the probability of informed trading in proxying for the intensity of private information flowing to a stock's market (Morck et al. (2000)). Firm-specific return variation is measured by the annual estimate of $1 - R^2$ of the

three-factor model of Fama and French (1992) model using daily return data within each year as detailed in the data section.

Trading is theoretically linked to the quality or extent of private information (e.g., Blume, Easley, and O'Hara (1994)), and is thus a natural measure of private information flow. Specifically, we investigate the illiquidity ratio of Amihud (2002). This ratio gives the absolute (percentage) price change per dollar of daily trading volume and is a proxy for the price impact of order flow.

We estimate board independence regressions similar to those in Table 3 using firm-specific return variation and the illiquidity ratio, rather than PIN, as measures of private information incorporated into stock prices. Table 9 reports the results for a specification that does not include CEO ownership and tenure as controls because these variables are not available for the 1990-1991 period and for our most complete specification in Table 3.

Columns (1) and (2) report results for the logistic transformed firm-specific return variation regression (Ψ). We find that the coefficient on Ψ is negative and significant. Thus, the evidence is that board independence is lower in stocks of firms that are less synchronized with the market or that incorporate more private information.

Columns (3) and (4) of Table 9 present estimates using the annual illiquidity ratio (ILLIQ) as measure of private information flow. ILLIQ is also negatively related to board independence, which supports our hypothesis that firms more subject to private information trading (or higher price impact) have less independent boards.

Overall, the results using alternative proxies of price informativeness confirm our basic finding of a substitute relation between corporate boards and stocks markets in their monitoring role.

6.4. Additional Board-Related Variables

The evidence of a negative relationship between board independence and the probability of informed trading is clear. We now turn to the question of whether price informativeness is

similarly related to other variables that are also related to board monitoring.

We first use the annual number of board meetings as a dependent variable. It has been argued that a board that meets more often is likely to be a better monitor (e.g. Vafeas (1999)). In Table 10, columns (1) and (2) present the estimates of OLS panel regressions in which the logarithm of the number of board meetings is the dependent variable. We find a negative relationship between the number of board meetings and the probability of informed trading. If board meetings are seen as increasing in the board's monitoring intensity, 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 number of board meetings and board committees meetings on which he served while a director. A board with a higher fraction of directors with attendance problems is likely to be a poor monitor. Columns (3) and (4) present the estimates of panel regression, where the annual fraction of directors with attendance problems is the dependent variable. We find a positive relation between the board's attendance problems and the probability of informed trading. 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. We use the log because board size is bounded below by zero. There is evidence of a negative and 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 (e.g. Boone et al. (2007) and Linck et al. (2008)).

It has been argued that larger boards are poor monitors (Lipton and Lorsch (1992), Jensen (1993)). However, some also argue that larger boards are more diverse and produce more specialized advice to managers (Coles et al. (2008), Linck et al. (2008)). Thus, although the evidence that we find is interesting, it is difficult to interpret. It should also be noted that size and independence are positively correlated in the sample.

7. Conclusion

In this paper, we add a new and important element to the list of determinants of board structure − price informativeness. We develop and test the hypothesis that the amount of private information incorporated into stock prices affects the structure of corporate boards, in particular board independence.

We find robust empirical evidence that stock price informativeness, as measured by the probability of informed trading (PIN) and other proxies, is negatively related to board independence. Consistent with the theory that we propose, this negative relationship is particularly strong for firms with few takeover defenses. We also find that effective internal monitoring such as that provided by institutional investors seems to be a condition for the existence of a trade-off between corporate boards and price informativeness. Finally, the negative relation between corporate boards and price informativeness is particularly strong for firms with less firm-specific knowledge. In this case, outside investors and independent board members are more likely to succeed as effective monitors.

We show that if stock prices are informative, stock markets are able to perform a *monitoring role* like that normally associated with the board of directors. When prices are informative it is also more likely that investors are able to monitor an ill-performing management team and directly intervene if necessary (via takeovers). For this reason, an informed stock market can also perform the *monitoring role* of the board of directors.

We thus predict that more informative prices lead to a less demanding board structure, with a lesser degree of independence, less board meetings, weaker attendance to board meetings, and smaller size.

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Table 1
Definitions of Variables

Variable	Definition
Fraction of independent directors	Ratio of number of independent directors by board size (1990-1995 data from Compact Disclosure and 1996-2001 data from IRRC).
Board size	Number of board members (IRRC).
Number of board meetings	Number of board meetings by year (EXECUCOMP).
Board attendance problems	Ratio of directors that attended less than 75% of board/committee meetings by board size (IRRC).
Probability of informed trading	Annual probability of information-based trading (PIN) of Easley, Hvidkjaer, and O'Hara (2002).
Probability of informed trading dummy (Q5 - Q1)	Dummy variable that takes the value of one if a firm-year is in the top (Q5) PIN quintile and zero in the bottom (Q1) PIN quintile.
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) price impact measure).
Firm size	Market capitalization in $ millions (COMPUSTAT: item 25 $\times$ 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 CRSP database.
Number of business segments	Number of business segments in which firm operates (COMPUSTAT).
Market-to-book	Ratio of market value of equity by book value of equity (COMPUSTAT: item 25 $\times$ item 199 / item 60).
R&D expenditures	Ratio of R&D expenditures by total assets (COMPUSTAT: item 46 / item 6).
Stock return variance	Annualized stock return variance estimated each year with daily stock returns (CRSP).
Free cash flow	Ratio of operating income before depreciation minus capital expenditures by total assets (COMPUSTAT: (item 13 $-$ item 128) / item 6).
Return-on-assets	Ratio of operating income before depreciation by total assets (COMPUSTAT: item 13 / item 6).
CEO ownership	Number of shares held by CEO divided by number of shares outstanding (EXECUCOMP).
CEO tenure	Number of years since the date the director became CEO (EXECUCOMP).
Governance index (GIM)	Governance index of Gompers, Ishii, and Metrick (2003), which is based on 24 antitakeover provisions (IRRC).
Institutional ownership	Number of shares held by institutions divided by the number of shares outstanding (Thomson 13f Holdings).
Institutional Herfindahl	Institutional Herfindahl index calculated using institutional ownership.
Institutional blockholder ownership	Number of shares held by the firm's largest institution with at least 5% of shares divided by the number of shares outstanding (Thomson 13f Holdings)
Blockholder ownership	Number of shares held by all blockholders divided by the number of shares oustanding (Dlugosz, Fahlenbrach, Gompers, and Metrick (2006)).
Outside blockholder ownership	Number of shares held by outside blockholders divided by the number of shares oustanding (Dlugosz, Fahlenbrach, Gompers, and Metrick (2006)).
Industry concentration	Industry Herfindahl index calculated as the sum of squared market shares of firms' sales (COMPUSTAT: item 12) in the firm's industry (two-digit SIC).
Earnings quality	Absolute value of firm-specific residuals from a annual industry regression (two-digit SIC) of total accruals on lagged, contemporaneous, and leading cash flow from operations; variables scaled by total assets.
Share turnover	Number of shares traded divided by the number of shares outstanding (CRSP).
Number of analysts	Number of analysts covering a firm (IBES).
S&P 500 membership	Dummy variable that takes the value of one if a firm is a member of the S&P 500 index, zero otherwise.

Table 2
Summary Statistics

This table reports the mean, median, standard deviation, maximum, minimum, and number of observations for each variable. The variables are defined in Table 1. The sample consists of IRRC firms from 1990 to 2001. Financial industries are omitted (SIC 6000-6999).

	Mean	Median	Std Dev	Min	Max	*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 problems	0.025	0.000	0.054	0.000	0.250	4,922
Probability of informed trading	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	14,661
Illiquidity	0.165	0.009	0.706	0.000	6.881	13,957
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 ownership	0.014	0.001	0.042	0.000	0.251	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	15.000	8,404
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
Institutional blockholder ownership	0.069	0.070	0.063	0.000	0.282	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
Industry concentration	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
Share turnover	0.909	0.727	0.699	0.068	8.136	9,447
Number of analysts	8.322	6.000	8.205	0.000	31.000	9,447
S&P 500 membership	0.266	0.000	0.442	0.000	1.000	9,294

Table 3
Board Independence and Probability of Informed Trading

Estimates of OLS panel regression on the logistic transformed fraction of independent directors are shown. Refer to Table 1 for variables definition. The sample consists of IRRC firms from 1990 to 2001. Financial industries are omitted (SIC 6000-6999). Regressions include industry and year dummies. Robust t-statistics adjusted for firm-level clustering are in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
Probability of informed trading	-3.1376	-1.9860	-1.8604	-1.5294	-1.5383	-1.5299
	(-13.60)	(-7.76)	(-6.81)	(-5.08)	(-5.15)	(-5.08)
Firm size (log)		0.0259	0.0193	0.0226	0.0224	0.0226
		(1.79)	(1.34)	(1.48)	(1.44)	(1.47)
Leverage		0.4392	0.3749	0.3177	0.3214	0.3214
		(4.33)	(3.81)	(3.01)	(3.01)	(3.01)
Firm age (log)		0.1566	0.1521	0.1030	0.1063	0.1068
		(7.05)	(7.01)	(3.98)	(4.11)	(4.12)
Number of business segments (log)		0.0997	0.1059	0.0854	0.0854	0.0860
		(4.14)	(4.62)	(3.64)	(3.65)	(3.67)
Market-to-book (log)		0.0066	0.0136	0.0164	0.0171	0.0178
		(0.28)	(0.56)	(0.64)	(0.67)	(0.70)
R&D expenditures		0.1626	-0.1125	-0.1309	-0.1113	-0.1119
		(0.40)	(-0.29)	(-0.30)	(-0.25)	(-0.26)
Stock return variance		-0.0723	-0.0453	-0.0246	-0.0292	-0.0240
		(-1.27)	(-0.76)	(-0.40)	(-0.47)	(-0.39)
Free cash flow		0.3023	0.3778	0.1244	0.1178	0.1204
		(1.05)	(1.34)	(0.41)	(0.39)	(0.40)
Return-on-assets		-0.5283	-0.5507	-0.3896	-0.3930	-0.3977
		(-1.56)	(-1.67)	(-1.13)	(-1.14)	(-1.15)
CEO ownership			-2.3059	-1.8691	-1.8684	-1.8792
			(-6.54)	(-4.91)	(-4.89)	(-4.95)
CEO tenure			-0.0044	-0.0058	-0.0059	-0.0058
			(-1.73)	(-2.24)	(-2.30)	(-2.28)
Governance index (GIM)				0.0400	0.0402	0.0399
				(6.03)	(6.03)	(5.97)
Institutional ownership					0.0755	0.0390
					(1.25)	(0.53)
Institutional Herfindahl					0.1893	
					(0.74)	
Institutional blockholder ownership						0.2929
						(0.96)
R^2	0.082	0.144	0.166	0.163	0.164	0.164
N	9,447	8,610	7,504	6,740	6,740	6,740

Table 4
Board Independence and Probability of Informed Trading Quintiles

Estimates of OLS panel regression on the logistic transformed fraction of independent directors are shown. Refer to Table 1 for variables definition. The sample consists of IRRC firms from 1990 to 2001. Financial industries are omitted (SIC 6000-6999). Regressions include industry and year dummies. Robust t-statistics adjusted for firm-level clustering are in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
Probability of informed trading dummy (Q5 - Q1)	-0.5193	-0.3404	-0.3399	-0.2708	-0.2746	-0.2702
	(-13.08)	(-6.33)	(-6.12)	(-4.59)	(-4.66)	(-4.57)
Firm size (log)		0.0187	0.0115	0.0205	0.0211	0.0203
		(1.06)	(0.65)	(1.09)	(1.11)	(1.08)
Leverage		0.3937	0.3896	0.3286	0.3319	0.3328
		(3.25)	(3.07)	(2.42)	(2.42)	(2.43)
Firm age (log)		0.1965	0.1881	0.1518	0.1572	0.1576
		(7.25)	(6.76)	(4.49)	(4.60)	(4.61)
Number of business segments (log)		0.0707	0.0683	0.0418	0.0413	0.0418
		(2.48)	(2.48)	(1.53)	(1.51)	(1.53)
Market-to-book (log)		0.0084	0.0124	0.0103	0.0100	0.0112
		(0.29)	(0.42)	(0.32)	(0.32)	(0.35)
R&D expenditures		0.4071	0.3513	0.5496	0.5686	0.5564
		(0.73)	(0.64)	(0.89)	(0.92)	(0.90)
Stock return variance		-0.0606	0.0069	0.0329	0.0243	0.0302
		(-0.77)	(0.08)	(0.33)	(0.25)	(0.31)
Free cash flow		0.3559	0.4728	0.1206	0.1139	0.1219
		(1.06)	(1.36)	(0.31)	(0.30)	(0.32)
Return-on-assets		-0.6032	-0.8197	-0.6705	-0.6639	-0.6833
		(-1.58)	(-2.05)	(-1.61)	(-1.58)	(-1.64)
CEO ownership			-1.9879	-1.6861	-1.7101	-1.7090
			(-3.74)	(-3.03)	(-3.06)	(-3.06)
CEO tenure			-0.0041	-0.0066	-0.0066	-0.0066
			(-1.31)	(-2.13)	(-2.15)	(-2.15)
Governance index (GIM)				0.0396	0.0394	0.0389
				(4.93)	(4.88)	(4.83)
Institutional ownership					0.0694	0.0441
					(0.89)	(0.46)
Institutional Herfindahl					0.2539	
					(0.87)	
Institutional blockholder ownership						0.2308
						(0.58)
R^2	0.137	0.199	0.204	0.186	0.188	0.187
N	3,815	3,471	3,044	2,735	2,735	2,735

Table 5
Board Independence and Probability of Informed Trading: The Role of Takeover Defenses, Institutions and Firm-Specific Knowledge

Estimates of OLS panel regression on the logistic transformed fraction of independent directors are shown. The Dictatorship and Democracy samples consist of those firms whose governance index (GIM) is above 13 and below 6. The High (Low) institutional ownership Herfindahl sample consists of those firms whose institutional ownership Herfindahl index is greater than the 80th percentile and smaller than the 20th percentile. The High (Low) R&D sample consists of those firms whose ratio of R&D expenditures to assets is above (below) the 80th percentile. Refer to Table 1 for variables definition. The sample consists of IRRC firms from 1990 to 2001. Financial industries are omitted (SIC 6000-6999). Regressions include industry and year dummies. Robust t-statistics adjusted for firm-level clustering are in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
	Dictatorship (high GIM)	Democracy (low GIM)	High Inst. Herfindahl	Low Inst. Herfindahl	High R&D	Low R&D
Probability of informed trading	0.1013	-1.4477	-1.2607	-0.2797	-0.7576	-1.4648
	(0.08)	(-2.08)	(-2.72)	(-0.50)	(-1.21)	(-5.05)
Firm size (log)	0.0506	0.0269	0.0164	0.0520	0.0311	0.0439
	(0.98)	(0.67)	(0.63)	(1.63)	(1.02)	(2.66)
Leverage	0.6190	0.5675	0.4331	-0.0773	-0.0648	0.3444
	(1.77)	(2.46)	(2.90)	(-0.39)	(-0.34)	(2.89)
Firm age (log)	-0.0633	0.1009	-0.0199	0.1365	0.1208	0.0945
	(-0.54)	(1.52)	(-0.46)	(2.46)	(2.00)	(3.21)
Number of business segments (log)	0.1299	0.1851	0.1720	0.0418	0.1571	0.0592
	(1.44)	(2.55)	(3.95)	(0.92)	(3.10)	(2.30)
Market-to-book (log)	0.0046	0.0324	0.0821	-0.0017	0.0275	0.0327
	(0.06)	(0.61)	(2.18)	(-0.04)	(0.69)	(1.31)
R&D expenditures	3.8049	0.2791	-0.4451	1.1160	0.1360	3.8646
	(1.81)	(0.21)	(-0.60)	(1.34)	(0.18)	(1.62)
Stock return variance	-0.0877	-0.0210	0.1380	-0.2239	-0.0423	0.0237
	(-0.24)	(-0.07)	(1.74)	(-1.49)	(-0.25)	(0.36)
Free cash flow	0.5184	-0.9381	-0.2632	0.4504	0.2941	-0.0154
	(0.48)	(-1.37)	(-0.61)	(0.84)	(0.38)	(-0.05)
Return-on-assets	-0.2561	1.1769	0.2768	-0.3990	-0.4283	-0.2363
	(-0.18)	(1.45)	(0.55)	(-0.67)	(-0.54)	(-0.60)
CEO ownership	-3.2201	-1.8107	-1.1028	-3.3888	-2.4752	-1.7124
	(-2.03)	(-2.72)	(-2.25)	(-2.38)	(-1.51)	(-4.31)
CEO tenure	-0.0043	0.0001	0.0081	0.0005	-0.0083	-0.0050
	(-0.57)	(0.02)	(1.48)	(0.09)	(-1.43)	(-1.74)
Governance index (GIM)	0.1700	0.0887	0.0636	0.0206	0.0378	0.0392
	(2.24)	(1.36)	(5.27)	(1.72)	(3.13)	(5.06)
Institutional ownership	0.3807	0.0856	0.1868	-0.2233	0.1975	0.0446
	(1.91)	(0.46)	(1.46)	(-0.80)	(1.56)	(0.66)
Institutional Herfindahl	-1.4804	-0.3847	0.4562	1.4879	0.3998	0.2157
	(-1.90)	(-0.86)	(1.77)	(0.19)	(0.88)	(0.86)
R^2	0.409	0.424	0.282	0.234	0.260	0.203
N	437	615	1,342	1,255	1,305	5,433

Table 6
Board Independence and Probability of Informed Trading: Endogeneity

Estimates of regression on the logistic transformed fraction of independent directors using alternative estimation methods are shown. The two-stage least squares (2SLS) panel regression uses share turnover, analyst coverage, and S&P 500 membership as instruments for PIN. Column (1) presents first-stage regression estimates with PIN as dependent variable. Columns (2) and (3) present second stage regression estimates with the logistic transformed fraction of independent directors as dependent variable. Columns (4) and (5) present estimates of panel regression with firm fixed effects. Columns (6) and (7) present estimates of panel regression using lagged PIN as explanatory variable. Refer to Table 1 for variables definition. The sample consists of IRRC firms from 1990 to 2001. Financial industries are omitted (SIC 6000-6999). Regressions include industry and year dummies. Robust t-statistics adjusted for firm-level clustering are in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		2SLS		Firm fixed		Lag PIN	
	First stage	Second stage	Second stage	effects			
Probability of informed trading (PIN)		-8.8139	-6.7872	-0.6940	-0.5812	-1.6905	-1.3691
		(-2.70)	(-2.37)	(-3.58)	(-2.62)	(-6.47)	(-4.76)
Firm size (log)	-0.0232	-0.1375	-0.0849	0.0738	0.0683	0.0297	0.0258
	(34.67)	(-1.75)	(-1.38)	(3.02)	(2.60)	(2.08)	(1.71)
Leverage	-0.0154	0.3395	0.2374	0.3394	0.2417	0.4344	0.3130
	(3.42)	(3.16)	(2.12)	(3.14)	(2.05)	(4.18)	(2.89)
Firm age (log)	-0.0045	0.1303	0.0937	0.4413	0.6101	0.1595	0.1042
	(4.92)	(5.02)	(3.57)	(8.09)	(6.11)	(6.97)	(3.99)
Number of business segments (log)	-0.0056	0.0645	0.0702	0.0150	0.0118	0.1024	0.0853
	(5.77)	(2.15)	(2.71)	(0.77)	(0.60)	(4.27)	(3.61)
Market-to-book (log)	0.0042	0.0370	0.0385	0.0098	-0.0120	0.0080	0.0194
	(3.64)	(1.43)	(1.42)	(0.44)	(-0.53)	(0.32)	(0.76)
R&D expenditures	0.0191	0.2163	0.0431	-0.4203	-0.5590	0.0910	-0.2403
	(1.00)	(0.51)	(0.10)	(-0.88)	(-0.83)	(0.22)	(-0.54)
Stock return variance	-0.0277	-0.3181	-0.2118	0.2085	0.1374	-0.0746	-0.0339
	(8.10)	(-2.58)	(-1.75)	(3.91)	(2.10)	(-1.23)	(-0.54)
Free cash flow	-0.0135	0.2832	0.1315	-0.1143	-0.2661	0.2094	0.0630
	(1.38)	(0.98)	(0.43)	(-0.59)	(-1.06)	(0.69)	(0.21)
Return-on-assets	0.0091	-0.5447	-0.4459	0.0063	0.1705	-0.4355	-0.3423
	(0.75)	(-1.60)	(-1.27)	(0.02)	(0.55)	(-1.23)	(-0.98)
CEO ownership			-1.8048		0.4657		-1.8711
			(-4.18)		(1.23)		(-4.86)
CEO tenure			-0.0075		-0.0051		-0.0061
			(-2.69)		(-2.34)		(-2.35)
Governance index (GIM)			0.0366		0.0416		0.0397
			(5.07)		(3.53)		(5.94)
Institutional ownership			0.0279		0.0338		0.0837
			(0.40)		(0.42)		(1.37)
Institutional Herfindahl			0.5613		0.2565		0.1218
			(1.66)		(1.61)		(0.48)
Share turnover	-0.0059						
	(5.37)						
Number of analysts	-0.0013						
	(2.10)						
S&P 500 membership	0.0034						
	(2.12)						
R^2	0.462			0.095	0.088	0.139	0.161
N	8,610	8,610	6,571	8,610	6,740	7,927	6,658

Table 7
Board Independence and Probability of Informed Trading: Alternative Estimation Methods

Estimates of regression on the logistic transformed fraction of independent directors using alternative estimation methods are shown. Columns (1) and (2) present estimates of median (least-absolute deviation) panel regression. Columns (3) and (4) presents estimates of cross-sectional regression using the Fama-MacBeth procedure. Refer to Table 1 for variables definition. The sample consists of IRRC firms from 1990 to 2001. Financial industries are omitted (SIC 6000-6999). Regressions include industry and year dummies. Robust t-statistics adjusted for firm-level clustering are in parentheses.

	(1)	(2)	(3)	(4)
	Median regression		Fama-MacBeth	
Probability of informed trading (PIN)	-2.2345	-1.8275	-1.1203	-0.8144
	(-9.36)	(-6.14)	(-7.71)	(-3.37)
Firm size (log)	0.0115	-0.0024	0.0175	0.0126
	(1.17)	(-0.20)	(2.74)	(1.60)
Leverage	0.5376	0.3759	0.4690	0.3486
	(9.04)	(5.38)	(13.19)	(7.78)
Firm age (log)	0.1736	0.1252	0.1562	0.1042
	(12.97)	(6.87)	(13.55)	(11.59)
Number of business segments (log)	0.0766	0.0638	0.0926	0.0798
	(4.54)	(3.41)	(8.70)	(6.00)
Market-to-book (log)	0.0137	0.0238	-0.0078	0.0237
	(0.79)	(1.17)	(-0.45)	(1.59)
R&D expenditures	-0.1276	-0.2050	0.7357	0.4601
	(-0.46)	(-0.61)	(4.35)	(4.53)
Stock return variance	-0.0068	-0.0229	-0.3434	-0.4132
	(-0.13)	(-0.36)	(-4.57)	(-3.69)
Free cash flow	0.0793	0.0606	-0.0061	-0.2502
	(0.45)	(0.29)	(-0.05)	(-1.38)
Return-on-assets	-0.3578	-0.5427	-0.3193	-0.2341
	(-1.78)	(-2.26)	(-2.33)	(-1.83)
CEO ownership		-2.0375		-1.9228
		(-7.31)		(-6.79)
CEO tenure		-0.0066		-0.0063
		(-3.60)		(-4.97)
Governance index (GIM)		0.0359		0.0393
		(8.03)		(18.56)
Institutional ownership		0.0865		-0.0046
		(1.88)		(-0.12)
Institutional Herfindahl		0.0661		-0.0798
		(0.36)		(-0.41)
R^2			0.105	0.156
N	8,610	6,740	8,610	6,740

Table 8
Board Independence and Probability of Informed Trading: Additional Robustness Checks

Estimates of OLS panel regression on the logistic transformed fraction of independent directors, the log fraction of independent directors (column (3)), and the fraction of independent directors (column (4)) are shown. Refer to Table 1 for variables definition. The sample consists of IRRC firms from 1990 to 2001. Financial industries are omitted (SIC 6000-6999). Regressions include industry and year dummies. Robust t-statistics adjusted for firm-level clustering are in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	IRRC 1996-2001	Compact Disclosure	Board indep. (log)	Board indep.	All blockholders	Outside blockholders	Industry Herfindahl	Earnings quality	Board size
Probability of informed trading (PIN)	-0.9069	-0.8999	-0.3606	-0.1909	-0.8460	-0.9136	-1.5469	-1.2802	-1.5258
	(-2.52)	(-3.17)	(-4.06)	(-2.86)	(-2.30)	(-2.47)	(-5.18)	(-4.43)	(-4.94)
Firm size (log)	0.0201	0.0228	0.0054	0.0055	0.0190	0.0223	0.0214	0.0254	0.0053
	(1.21)	(1.47)	(1.24)	(1.66)	(1.15)	(1.35)	(1.38)	(1.57)	(0.31)
Leverage	0.2787	0.3029	0.0879	0.0735	0.2771	0.2737	0.3264	0.4203	0.2973
	(2.52)	(2.85)	(2.75)	(3.24)	(2.51)	(2.47)	(3.06)	(3.85)	(2.63)
Firm age (log)	0.1123	0.0957	0.0205	0.0138	0.1128	0.1204	0.1066	0.1079	0.1026
	(4.01)	(3.62)	(2.59)	(2.46)	(3.96)	(4.21)	(4.13)	(3.81)	(3.60)
Number of business segments (log)	0.0684	0.1082	0.0258	0.0127	0.0683	0.0675	0.0849	0.1098	0.0988
	(2.93)	(4.30)	(4.18)	(2.55)	(2.91)	(2.88)	(3.63)	(4.38)	(4.08)
Market-to-book (log)	0.0078	0.0434	0.0081	0.0059	0.0074	0.0098	0.0185	0.0102	0.0261
	(0.28)	(1.78)	(1.17)	(1.14)	(0.26)	(0.34)	(0.73)	(0.40)	(0.98)
R&D expenditures	0.2971	0.2050	-0.0451	-0.0270	0.2939	0.2938	-0.0779	-0.0544	0.1237
	(0.64)	(0.45)	(-0.35)	(-0.28)	(0.63)	(0.63)	(-0.18)	(-0.12)	(0.29)
Stock return variance	-0.0925	-0.0869	0.0227	-0.0071	-0.0856	-0.0903	-0.0325	-0.0031	0.0320
	(-1.44)	(-1.35)	(1.30)	(-0.50)	(-1.34)	(-1.42)	(-0.52)	(-0.04)	(0.48)
Free cash flow	0.2321	-0.2222	0.0303	-0.0206	0.2401	0.2377	0.1363	0.0227	0.0833
	(0.77)	(-0.72)	(0.32)	(-0.31)	(0.79)	(0.79)	(0.45)	(0.07)	(0.27)
Return-on-assets	-0.3563	-0.1136	-0.0615	-0.0117	-0.3836	-0.3784	-0.4132	-0.1770	-0.3244
	(-1.03)	(-0.32)	(-0.57)	(-0.15)	(-1.11)	(-1.09)	(-1.20)	(-0.47)	(-0.92)
CEO ownership	-2.0585	-1.7194	-0.5215	-0.3082	-2.0476	-1.9487	-1.8687	-1.7319	-1.6205
	(-4.36)	(-4.68)	(-4.10)	(-3.74)	(-4.34)	(-4.12)	(-4.90)	(-3.83)	(-4.28)
CEO tenure	-0.0092	-0.0006	-0.0012	-0.0009	-0.0092	-0.0091	-0.0059	-0.0060	-0.0059
	(-3.05)	(-0.24)	(-1.47)	(-1.64)	(-3.08)	(-3.06)	(-2.29)	(-2.20)	(-2.27)
Governance index (GIM)	0.0392	0.0512	0.0113	0.0071	0.0386	0.0377	0.0400	0.0416	0.0396
	(5.14)	(7.64)	(5.81)	(4.95)	(5.09)	(4.93)	(6.01)	(5.90)	(5.69)
Institutional ownership	0.0120	0.0756	0.0278	0.0149			0.0741	0.1257	0.1189
	(0.19)	(1.21)	(1.81)	(1.14)			(1.22)	(1.96)	(1.85)
Institutional Herfindahl	0.2839	0.1286	0.0557	0.0655			0.1868	0.3304	0.1748
	(1.15)	(0.49)	(0.75)	(1.31)			(0.73)	(1.02)	(0.67)
Blockholders ownership					0.0195				
					(0.20)				
Outside blockholders ownership						0.3024			
						(2.73)			
Industry concentration							0.1286		
							(1.02)		
Earnings quality								-0.1665	
								(-1.99)	
Board size (lag)									0.0172
									(2.14)
R^2	0.169	0.153	0.143	0.088	0.168	0.172	0.164	0.185	0.170
N	4,504	6,029	6,896	7,034	4,504	4,504	6,740	5,710	6,175

Table 9
Board Independence and Alternative Measures of Price Informativeness

Estimates of OLS panel regression on alternative price informativeness measures are shown. Columns (1) and (2) use the logistic transformed relative firm-specific return variation as dependent variable. Columns (5) and (6) use the logarithm of the illiquidity measure of Amihud (price impact). Refer to Table 1 for variables definition. The sample consists of IRRC firms from 1990 to 2001. Financial industries are omitted (SIC 6000-6999). Regressions include industry and year dummies. Robust t-statistics adjusted for firm-level clustering are in parentheses.

	(1)	(2)	(3)	(4)
Firm-specific return variation (logistic)	-0.0877	-0.0699		
	(-4.88)	(-3.74)		
Illiquidity (log)			-0.0829	-0.0722
			(-6.96)	(-4.46)
Firm size (log)	0.0748	0.0549	-0.0208	-0.0285
	(7.23)	(4.83)	(-1.07)	(-1.25)
Leverage	0.2839	0.1913	0.3264	0.2227
	(3.79)	(2.29)	(4.46)	(2.72)
Firm age (log)	0.1417	0.0942	0.1500	0.1059
	(8.64)	(4.68)	(9.22)	(5.19)
Number of business segments (log)	0.0996	0.0676	0.1111	0.0825
	(4.92)	(3.29)	(5.42)	(4.10)
Market-to-book (log)	0.0137	0.0292	-0.0262	0.0063
	(0.85)	(1.60)	(-1.40)	(0.30)
RD expenditures	0.9549	0.6470	0.6232	0.3124
	(4.47)	(2.58)	(2.85)	(1.23)
Stock return variance			-0.0266	-0.0209
			(-0.83)	(-0.57)
Free cash flow	0.4644	0.2125	0.6486	0.4124
	(2.09)	(0.88)	(2.94)	(1.70)
Return-on-assets	-0.9283	-0.5958	-1.0350	-0.7580
	(-3.80)	(-2.28)	(-4.17)	(-2.85)
CEO ownership		-1.9371		-1.9263
		(-6.52)		(-6.28)
CEO tenure		-0.0048		-0.0056
		(-2.26)		(-2.63)
Governance index (GIM)		0.0404		0.0394
		(7.49)		(7.29)
Institutional ownership		0.0890		0.0504
		(1.76)		(0.97)
Institutional Herfindahl		0.0600		0.3010
		(0.29)		(1.41)
R^2	0.151	0.159	0.159	0.162
N	11,755	9,460	12,964	9,168

Table 10
Board Structure and Probability of Informed Trading: Number of Meetings, Director Attendance, and Board Size

Estimates of OLS panel regression on the logarithm of the number of board meetings, the fraction of directors with board attendance problems, and the logarithm of board size are shown. Refer to Table 1 for variables definition. The sample consists of IRRC firms from 1990 to 2001. Financial industries are omitted (SIC 6000-6999). Regressions include industry and year dummies. Robust t-statistics adjusted for firm-level clustering are in parentheses.

	(1)	(2)	(3)	(4)	(5)	(6)
	Number of board meetings (log)		Board attendance problems		Board size (log)	
Probability of informed trading	-0.3878	-0.3773	0.0477	0.0500	-0.2942	-0.2514
	(-2.08)	(-1.99)	(2.11)	(2.12)	(-2.51)	(-1.97)
Firm size (log)	0.0415	0.0390	0.0018	0.0018	0.0844	0.0870
	(5.06)	(4.57)	(2.30)	(2.22)	(16.84)	(15.61)
Leverage	0.0965	0.0984	0.0050	0.0032	0.1183	0.0735
	(1.82)	(1.77)	(0.96)	(0.59)	(3.37)	(2.03)
Firm age (log)	0.0316	0.0147	-0.0002	-0.0008	0.0676	0.0581
	(2.87)	(1.05)	(-0.19)	(-0.61)	(8.19)	(5.86)
Number of business segments (log)	0.0272	0.0161	0.0011	0.0013	0.0295	0.0182
	(2.15)	(1.26)	(0.84)	(0.98)	(3.19)	(2.00)
Market-to-book (log)	0.0054	-0.0024	0.0001	0.0004	-0.0457	-0.0415
	(0.47)	(-0.20)	(0.10)	(0.28)	(-5.11)	(-4.43)
RD expenditures	0.0571	0.2602	0.0249	0.0370	-0.5089	-0.6790
	(0.24)	(1.06)	(0.99)	(1.34)	(-2.89)	(-3.57)
Stock return variance	0.1895	0.1618	0.0023	0.0005	-0.1330	-0.1184
	(3.98)	(3.45)	(0.52)	(0.11)	(-4.54)	(-3.59)
Free cash flow	0.0262	0.0297	0.0257	0.0253	0.0892	0.0984
	(0.17)	(0.17)	(1.97)	(1.77)	(0.86)	(0.85)
Return-on-assets	-0.4269	-0.4495	-0.0279	-0.0189	-0.3287	-0.3241
	(-2.51)	(-2.43)	(-1.78)	(-1.11)	(-2.73)	(-2.49)
CEO ownership		-0.5782		-0.0568		-0.5043
		(-2.59)		(-2.94)		(-2.95)
CEO tenure		-0.0045		0.0003		0.0006
		(-3.14)		(2.28)		(0.62)
Governance index (GIM)		0.0043		-0.0003		0.0107
		(1.17)		(-0.90)		(4.25)
Institutional ownership		-0.0878		-0.0118		-0.0486
		(-2.52)		(-3.25)		(-2.13)
Institutional Herfindahl		-0.0524		0.0331		0.1663
		(-0.36)		(2.22)		(1.79)
R^2	0.091	0.110	0.006	0.011	0.329	0.333
N	4,827	4,236	5,031	4,744	8,923	7,034

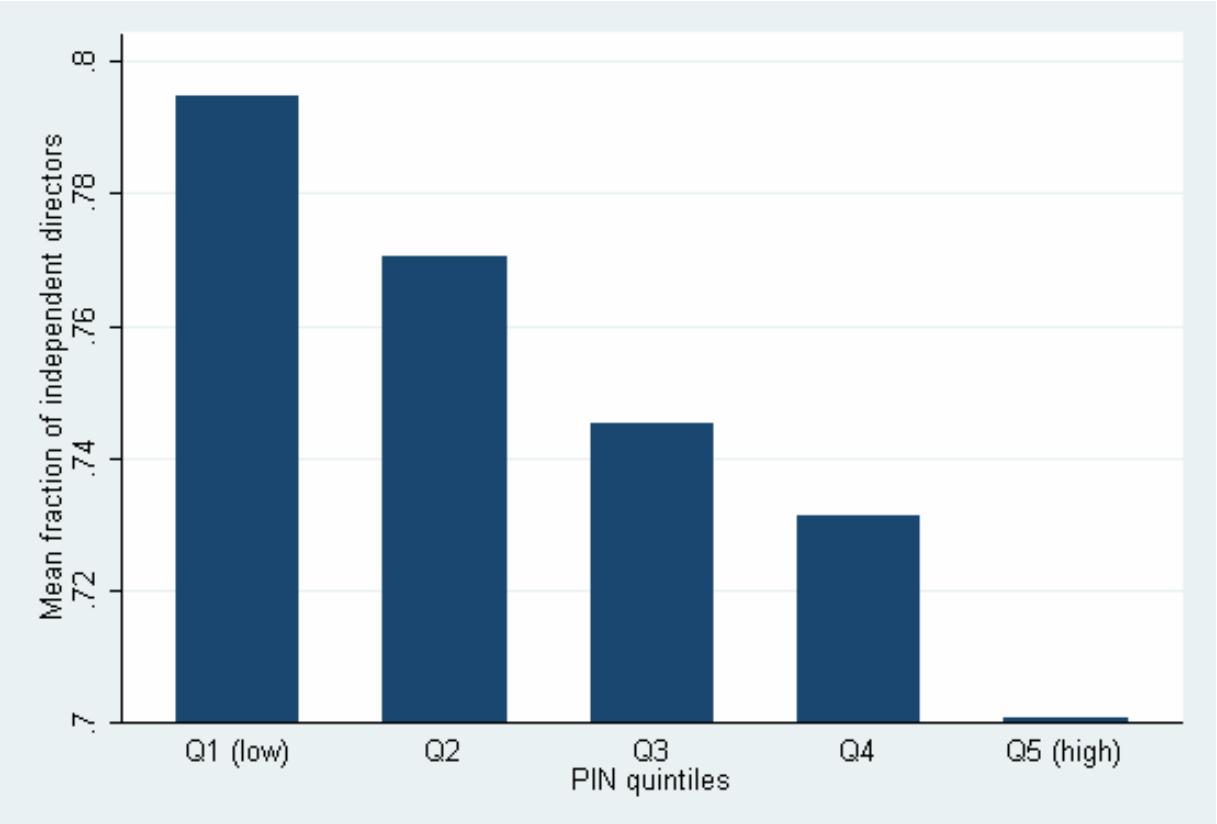

Figure 1. Board Independence by Probability of Informed Trading Quintiles. This figure plots means of fraction of independent directors by probability of informed trading (PIN) quintiles for the period from 1990 to 2001.