Informational Interaction of Insider Trading and Share Repurchases: A Theoretical and Empirical Analysis

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All errors are our own.

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Abstract

We theoretically and empirically explore the interaction between repurchases and insider trading as signaling devices about private information on firm valuation. Our theory predicts that repurchases, when coupled with insider buying, further the signal of firm undervaluation; insider selling signals the opposite. We find that for the following quarter, repurchases generate 1.2% abnormal returns on average, while repurchase with net insider buying generate 3.7% abnormal returns, an increase of 2.5%. While coupled with insider selling, the abnormal returns are not discernable, implying strong negative insider seller effects. The implications that insider trading augments or attenuates the signal sent by share repurchases.

JEL No. G14, G35

I. Introduction

Stock repurchases have long been identified as a way for firms to signal that a firm is undervalued (Dann (1981), Vermaelen (1981)), as well as a way to enhance shareholder value (Brav et al. (2005)). It seems natural to suggest that share repurchases convey to the market private information about the underlying value of the firm. Empirical evidence supports this argument; several studies document long-term abnormal returns after share repurchases (Ikenberry, Lakonishok and Vermaelen (1995), Ikenberry, Lakonishok and Vermaelen (2000), Chan, Ikenberry and Lee (2004)).

Information is also a key component of insider trading. U.S. Securities and Exchange Commission (SEC) Rule 10b5-1 enacted in 2000 prohibits insiders from using material nonpublic information to benefit themselves at the expense of other market participants, but insider moves are also viewed as significant indicators of expected returns.

Given that insiders serve as the core decision makers of both types of transactions, it seems logical to ask if ex-post return drift to share repurchases is related in any way to the presence or absence and direction of concurrent trades made by insiders. Is it the case that the timing considerations in one transaction are related in some manner to the decision making process of the other transaction? More importantly from a market perspective, is it possible that combining the signals of share repurchase with concurrent insider trading might be more efficient in conveying information that mitigates informational asymmetries in the stock market? These are issues we address in this paper.

The potential informational interaction of strategic insider trading and share repurchases is studied with a repurchase signaling model with endogenous insider trading and asymmetric information; insiders know more about the firm than does the general market. Our model treats insiders' own trading activities as an alternative mode through which private information is conveyed to the market. Insider trading thus could potentially work with or compete with share repurchase as a signal. We investigate the issue both theoretically and empirically.

Our theoretical framework uses a signaling equilibrium where both insider trading and stock repurchases can be used as signals. Insiders are privately informed about the mean and variance of future cash flows, and can alter their exposure to risk by using one or both of the signals. We show that two types of equilibrium may emerge, depending on the parameters of the game. Although these two equilibriums have different signaling schedules they share similar comparative statistics considering the changes in insiders' holdings and share repurchases which consequently allow some testable hypotheses. In particular, share repurchases tend to be associated with insider selling among high quality firms, and more likely to be associated with insider buying among low quality firm; share repurchases should lead to positive stock responses, and the effect is expected to be larger when accompanied by insider buying.

We test the model empirically with data on actual share repurchases and insider moves. We use Compustat quarterly data to identify the actual amount of share repurchases for each firm fiscal quarter from 2000 to 2004. We use the Thomson Reuters Insiders data to identify whether or not a firm quarter is "net insider selling", "net insider buying", or neutral. Firm fiscal quarters which insider buying exceeds insider selling are classified as "net buying" firm quarters. Firm quarters with insider selling surpassing insider buying are categorized as "net selling" firm quarters. The remaining cases are labeled as neutral. The evidence, by and large, is consistent with the predictions from the theoretical model. Specifically, we find that in quarters when insiders are net sellers of their firm shares, the frequency of share repurchases is significantly larger than when they are net buyers. Though not a hard evidence of our theoretical predictions, it is consistent with the notion that some firms (high quality) with insider selling are more likely to repurchase, while others (low quality) are more likely when insiders buy. We also examine the returns after the actual repurchases and find that when repurchases were coupled with net insider buying, there were greater abnormal returns than in the net selling case. Long-term investment strategies should thus note that share repurchases might be marginally consistent with undervaluation motivation, and superior performance is available when insiders are simultaneously net buyers of their stocks.

The paper proceeds as follows. Section II reviews the related literature. Section III develops a theoretical model of repurchase signaling that includes insider transactions. We use this model to characterize empirical implications. Section IV introduces the data. Section V discusses estimation of the model and presents results. Section VI offers our conclusions.

II. Previous Literature

Insider trading before stock repurchases has been well studied, finding increased buying before an open market repurchase announcement (Babenko, Tserlukevich and Vedrashko (2012)) and self-tender offer (Lee, Mikkelson and Partch (1992)), and positive stock market responses to high levels of insider buying. Louis, Sun and White (2010) identified abnormally high net insider selling during the quarter of fixed price and Dutch-auction self-tender offer announcement and a negative relationship between concurrent insider selling and future stock performance. Chan et al. (2012) found that stock performance after repurchases differs for growth versus value firms when accounting for insider trading information; insider activity supported undervaluation of value firms but not for growth firms.

We differentiate our paper from the existing literature in several ways. First and foremost, we provide a theoretical foundation that supports earlier empirical results by constructing a signaling game that allows simultaneously for insider moves and firm repurchases. Although such a setting has been examined before (John and Lang (1991), Grinblatt and Hwang (1989)), we extend the analysis to consider the effect of firms' repurchases on insiders' risk exposure and add asymmetric information regarding cash flow variance instead of assuming symmetric information on cash flow variance as they did. With the asymmetric information, if firms differ in the ability to generate cash simple repurchases cannot fully signal undervaluation; insider buying or selling provides another signal that determines the market reaction to the repurchases.

Our basic setup is fairly simple. "Good" firms can better generate cash to pursue investment opportunities than can "bad" firms and the ability to raise cash is private information known only to the firm manager. Hence share repurchases alone cannot always be taken as a signal of undervaluation. The private information affects optimal insider moves, so the market reaction to a repurchase is affected by the direction of insider trading. Specifically, repurchases have explanatory power of undervaluation if accompanied by unusual insider buying, eliciting a positive stock price response. The market is more skeptical about a repurchase accompanied by unusual insider selling. Like previous works, the result is a separating equilibrium, but it comes from a fundamentally different signaling game than those previously modeled.

We also use a different empirical test. While most papers examine insider trading and announcements of open market repurchases (Babenko, Tserlukevich and Vedrashko (2012), Chan et al. (2012)), we look at actual share repurchase activity and net insider trading direction in the same quarter. The use of actual shares repurchased instead of open market announcements is not a trivial distinction. Share repurchase plans are frequently not fully executed in the case of open market repurchases; in fact, on average only about 75% of announced open market repurchases are fully executed (Bonaimé (2012), Stephens and Weisbach (1998)). Moreover, the timing of actual repurchases can vary dramatically from what has been stated in the announced plans. Finally, instead of approaching the problem using ordinary event-study techniques, we employ econometric approach with a panel of 2,680 firms, allowing us to control explicitly for firm-specific characteristics without constructing and continuous rebalancing a matched market portfolio.

III. Theoretical Framework

Given the same investment opportunities, firms differ, by both the mean and variance, in terms of their abilities to generate cash. Insiders know both the mean and variance of cash flows before picking up their holdings and repurchase levels, while outsiders must attempt to infer firm type from the observable actions (firm repurchases and insider buying and selling) of insiders.

At $t = 0$, the initial date, each firm, which comprises the entire and only property of the manager, has one unit of cash at hand and access to an investment opportunity, referred to as its project. Any cash not invested in the project is paid out, so the payout determines the investment level.[a] The project yields a cash flow, $I \cdot \tilde{x}$, at date $t = 1$ depending on the investment level I and a random component, $\tilde{x}$. $\tilde{x}$ is assumed to be distributed normally with mean μ and variance σ^2, $\tilde{x} \sim N(\mu, \sigma^2)$. Both the mean and variance of the project, (μ, σ^2), are assumed to be the manager's private information, not observed directly by outsiders. In other words, the manager observe the private cash flow information, (μ, σ^2), before deciding about the firm's level of investment, I, where $0 \leq I \leq 1$, and his personal holding of fraction α of the firm, where $0 \leq \alpha \leq 1$. The manager sells the residual fraction $1 - \alpha$ to outside investors.

[a] For the sake of convenience, all the following analyses relate to signaling interaction between managers' holdings and firms' levels of investment. The comparative statistics will then focus on cash payout through share repurchases, as the manager's method for determining the firm's available resources for investment.

The manager invests the portion of his wealth not tied up in the firm in riskless assets whose return is generalized to zero. Firms' cash flows are realized at date $t = 1$ and distributed pro rata to shareholders. The manger is risk averse and has negative exponential utility function and exhibits constant risk aversion with risk aversion coefficient h, $h > 0$. So the manager maximizes his expected utility depending on end-of-period wealth, $\widetilde{W}$, at date $t = 1$,

$$U(\widetilde{W}) = E(\widetilde{W}) - \frac{h}{2} var(\widetilde{W})$$

The market uses risk-neutral valuation, that is, in exchange for the fraction sold to outsiders, the manager receives $(1-\alpha)I\hat{\mu}$ where $\hat{\mu}$ denotes the market estimation of μ. The manger's wealth at date $t = 1$ can then be written as,

$$\widetilde{W} = \alpha I \tilde{x} + (1-\alpha)I\hat{\mu} + (1-I)$$

so the manager's end-of-period wealth is comprised of three elements: a random cash flow from his holdings, $\alpha I \tilde{x}$; the cash he receives in exchange for the fraction of the firm sold to outsiders, $(1-\alpha)I\hat{\mu}$; and the cash resulting from investing in a riskless asset,[b] $1 - I$. We can then substitute in $\widetilde{W}$ and write the manager's utility as,

$$U(\mu, \sigma^2, \alpha, I, \hat{\mu}) = \alpha I \mu + (1-\alpha)I\hat{\mu} + (1-I) - \frac{h}{2} I^2 \sigma^2 \alpha^2$$

The market does not know the cash flow attributes so the market estimation of μ depends on common knowledge and the manager's observed actions. Hence, the pricing function used by the market can be denoted by $\hat{\mu}(\alpha, I)$.

[b] Data on insider trading, SEC Form 4, only record transactions in securities which individuals are considered insiders, thus we choose not to specify managers' choices of diversification but assume they invest the rest of wealth in risk-free assets.

Firms randomly have access to two types of projects, high and low with attributes (μ_H, σ_H^2) and (μ_L, σ_L^2) respectively, where $\mu_H > \mu_L$.[c] For clarity, firms are labeled as high or low according to the mean of their projects, and managers of high or low firms are respectively referred as high or low managers.

We use a perfect Bayesian equilibrium to derive managers' strategies regarding their holdings and firms' levels of investment. An equilibrium is a set of strategies and beliefs, such that (a) managers' strategies are optimal given the market's beliefs and (b) the market's beliefs are derived from managers' strategies, using Bayes' rule. We restrict off-the-equilibrium by intuitive criterion (Cho and Kreps (1987)), since including it results in the unique prediction of the Pareto dominating separating equilibrium when separating equilibrium exists, and no equilibrium, otherwise.

We first consider managers' symmetric information strategies. If the project's mean, μ, is common knowledge, the market prices it according to $\hat{\mu} = \mu$, and both types of managers would maximize their utility by choosing $\alpha = 0$ and $I = 1$.

When the project's mean is known only to the managers, they engage in signaling activities by choosing their fractional holdings and firms' investment levels. Both choices are observed by the market. A sequential equilibrium in this context with two possible signals can be defined as follows. Given the market pricing function $\hat{\mu}(\alpha, I)$ and private information (μ, σ^2), a manager's optimal holding $\alpha(\mu, \sigma^2)$ and the firm's investment level $I(\mu, \sigma^2)$ satisfy,

$$\left(\alpha(\mu, \sigma^2), I(\mu, \sigma^2)\right) = \underset{\substack{0 \le \alpha \le 1 \\ 0 \le I \le 1}}{\operatorname{argmax}} U\left(\mu, \sigma^2, \alpha, I, \hat{\mu}(\alpha, I)\right)$$

[c] We assume that $\mu_L = 1 + \varepsilon$, where ε is an infinitesimally small positive real number. This technical assumption greatly simplifies the analysis without impairing the generality of the results.

In turn, outside investors correctly infer the projects' expected cash flow from the manager's observable actions, that is,

$$\hat{\mu}\left(\alpha(\mu,\sigma^2), I(\mu,\sigma^2)\right) = \mu$$

Note the market is assumed to be risk-neutral, so it is concerned only with inferring μ, not σ^2. The manager, on the other hand, is risk-averse, so his utility depends on both μ and σ^2. Denote (α^L, I^L) [d]and (α^H, I^H) as the separating equilibrium strategies of low and high managers, respectively. In such equilibrium, the market identifies each firm; hence low managers maximize their utility by employing their symmetric information strategies. Given low managers' equilibrium strategies, high managers' maximization problem, incorporating incentive compatibility and participation constraint is as follows,

$$(\alpha^H,\ I^H) = \underset{\substack{0\le\alpha\le1 \\ 0\le I\le1}}{\operatorname{argmax}}\, U(\mu_H, \sigma_H^2, \alpha, I, \mu_H)$$

$$s.t.\, U(\mu_L, \sigma_L^2, \alpha^H, I^H, \mu_H)\ \le U(\mu_L, \sigma_L^2, 0{,}1, \mu_L)$$

An additional condition for $(\alpha^H,\ I^H)$ to support a separating equilibrium is that high managers are better off signaling $(\alpha^H,\ I^H)$, and receiving a high response, than being considered as low managers. That is,

$$U(\mu_H, \sigma_H^2, \alpha^H, I^H, \mu_H) > \max_{\substack{0\le\alpha\le1 \\ 0\le I\le1}} U(\mu_H, \sigma_H^2, \alpha, I, \mu_L)$$

Proposition: In the general case, a separating signaling equilibrium always exists with a unique Pareto-dominant signaling schedule in the following expressions,

[d] Low managers solve a unconstrained maximization problem, which results in their symmetric information strategy, $(\alpha^L, I^L) = (0{,}1)$. So our focus here will be on high managers.

$(\alpha^H,\, I^H)$

$$= \begin{cases} \left(\dfrac{1-\mu_H+\sqrt{\mu_H-1}\sqrt{\mu_H-1+2h\sigma_L^2}}{h\sigma_L^2}, 1\right) \text{ if } \sigma_L^2 \geq \sigma_H^2 \text{ or } \left(\sigma_L^2 < \sigma_H^2 \text{ and } h < \dfrac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}\right) \\ \left(\dfrac{2(\sigma_H^2-\sigma_L^2)}{2\sigma_H^2-\sigma_L^2}, \dfrac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2h(\sigma_H^2-\sigma_L^2)^2}\right) \text{ if } \left(\sigma_L^2 < \sigma_H^2 \text{ and } h \geq \dfrac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}\right) \end{cases}$$

Proof: see Appendix

This proposition states that a separating equilibrium always exists, and there are two types that emerge, which depends on the parameters of the game. In the first type, high projects are less risky than low projects, i.e., $\sigma_L^2 \geq \sigma_H^2$, or risk aversion is sufficiently low, so that both low and high managers choose the symmetric information investment level, i.e., $I = 1$. Separation is supported solely by high managers' fractional holdings. The second type emerges when high projects are riskier than low projects, i.e., $\sigma_L^2 < \sigma_H^2$, and risk aversion is high. In this case, high managers deviate from the symmetric information strategy and use both their holdings and firms' investment levels to separate from low managers.

We conduct comparative statistics across equilibrium types as follows:

(a) $\frac{\partial \alpha^H}{\partial \mu_H} \geq 0$, (b) $\frac{\partial \alpha^H}{\partial \sigma_H^2} \geq 0$, (c) $\frac{\partial \alpha^H}{\partial \sigma_L^2} < 0$

(d) $\frac{\partial I^H}{\partial \mu_H} \geq 0$, (e) $\frac{\partial I^H}{\partial \sigma_H^2} \leq 0$, (f) $\frac{\partial I^H}{\partial \sigma_L^2} \geq 0$

Before we form our empirical hypotheses, there is one novel prediction found in inequality (b); the fractional holdings high managers choose are positively correlated with their projects' variances. This is counter intuitive; the higher the project's variance, the higher the manager's cost of exposure to his project would be, and yet, the manager chooses to hold more of his firm. This puzzle is resolved by the fact that in this model, a higher variance leads to higher fractional holding only when it is accompanied by lower investment,[e] decreasing investment level lowers the manager's cost of fractional holding.

We derive empirical predictions from the other comparative statistics. First recall that open market share repurchases, denoted by B, are directly related to the change in the firm's available resources for investment. Relationships between B and game parameters will be the opposite of those between I and game parameters from the identity $I = 1 - B$. Managerial holdings are monotonically increasing in quality – low managers refrain from any holdings, while high managers' holdings increase with quality. Repurchases, on the other hand, are non-monotonic in quality – low firms refrain from any stock repurchases (i.e. use all resources in investment) but, high firms' repurchases decrease with quality. Thus, stock repurchases are more likely to be associated with insider *buying* among low firms, while stock repurchases are more likely with insider *selling* among high firms. In addition, with the revelation of insiders' holdings and repurchase levels the less informed market convinces itself that an equilibrium will occur. However, prior to the announcement of signal levels, the market assigns to all firms a price based on the average projected cash flows in the market. Given, $\hat{\mu} = E_{\mu}[\hat{\mu}(\alpha(\mu), B(\mu))]$, assume insiders holdings and repurchase levels are $(\bar{\alpha}, \bar{B})$ so that $\bar{\hat{\mu}} = \hat{\mu}(\bar{\alpha}, \bar{B})$. When insiders send out signals by revealing their choices of $\alpha(\mu), B(\mu)$, the effect on stock price is a direct output of the previous signal. In particular, insiders with above average μ signal to the market by increasing their fractional holdings and repurchases, i.e., high managers' deviations from their symmetric information strategies $(\alpha^0, I^0, B^0) = (0,1,0)$, $\alpha^H > \alpha^0$, $B^H > B^0$, and $I^H < I^0$. The point is to successfully signal undervaluation, managers need to *simultaneously* increase their fractional

[e] See inequality (b) and (e).

holdings and conduct share repurchases. This is equivalent to say that stock prices would adjust and increase when repurchases are accompanied by insider buying.

It is possible that people adjust their risk attitudes as wealth changes, a feature inconsistent with constant absolute risk aversion implicit in the exponential utility function. To address this concern, we conduct comparative statistics with respect to the risk aversion coefficient, h, as follows:

(a) $\frac{\partial \alpha^H}{\partial h} \leq 0$, (b) $\frac{\partial I^H}{\partial h} \leq 0$

For both types of equilibrium, managerial holdings are decreasing with the risk aversion coefficient, and repurchases are increasing when managers are more risk averse. Experimental studies generally hold the view that absolute risk aversion declines with wealth.[f] We model the behavior of insiders who are top executives and/or large shareholders, people who normally possess high levels of wealth to start with, and hence we would not expect wealth-varying risk aversion to be evident among this group of people. If we assume that wealthier people are willing to take more risk than the average person, i.e., they have a small risk aversion coefficient, the implications in our model would be more personal holding and less firm share repurchases. However, our implication comes from the *change* of insider holding and share repurchases, not the absolute levels, so the risk aversion levels of insiders are not the crucial aspect of our model. The empirical implication that undervaluation is signaled by repurchases accompanied by insider buying holds for all levels of insider risk aversion.

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[f] Guiso and Paiella (2008), Levy (1994) and Heinemann (2008) find supported evidence of decreasing absolute risk aversion, Binswanger (1980) and Wik* et al. (2004) also find negative correlations between wealth and risk aversion but with a focus on poor individuals in developing countries.

IV. Data Construction

Insiders are defined as officers, directors, and principal stakeholders who hold more than 10% of total common stock. We construct a sample of insider trading from transactions reported in SEC Form 4 in the Thomson Reuters Insiders data for the period from January 1, 2000 to December 31, 2004. For each firm we calculate the total value of insider purchases, which includes open market and private purchases (with transaction code "P") and open market and private sales (with transaction code "S") by fiscal quarter. If total insider purchases exceed total insider sales, we label it a "net buying" quarter; if total insider sales surpass insider purchases, we classify the quarter as "net selling". Finally, if no insider transactions take place or insider sales equals insider purchases, then we classify insider trading for the quarter as "neutral".

We link our insider transaction sample to Compustat quarterly data by companies' ticker symbols. Following Billett and Xue (2007), we delete financials and utilities, as these firms operate in highly regulated industries and tend to have unreliable repurchase data. One of our key variables in analysis is actual share repurchases. We calculate share repurchase using quarterly Compustat information on net dollar spent on repurchases and retirement of the firm's own securities from cash flow statement (adjusted for the fact that this variable is cumulative),[g] minus any decrease in reported preferred stock.[h] Banyi, Dyl and Kahle (2008) identify this measure as

[g] Data item #93, Purchase of Common and Preferred stock. Compustat generally takes this information from the cash flow from financing section of the cash flow statement. The repurchase numbers are cumulative for the fiscal year ending in that fiscal quarter.

[h] We calculate "any decrease in preferred stock" as the maximum of (1) any negative change in the redemption value of preferred stock (Data item #71), (2) any negative change in the carrying value of preferred stock (Data item #55), and (3) zero. If the data on preferred stock is missing, we then assume that there was no decrease in preferred stock.

the most accurate proxy for actual common shares repurchased. Our final variable is calculated as a percentage of repurchased shares to shares outstanding, where the number of shares repurchased is defined as repurchase proxy divided by the purchase prices. We follow Banyi, Dyl and Kahle (2008) by assuming that the stock was repurchased at the average monthly closing price during the quarter.[i] If the value of the repurchase statistics is 1% or greater we consider this firm-quarter a quarter with share repurchase. Banyi, Dyl and Kahle (2008) claim that due to the fact that many small values of "Purchase of Common and Preferred Stock" are solely due to preferred repurchases, eliminating firms with common stock repurchases less than 1% of shares outstanding improves the accuracy of the repurchase measure.[j]

Although "Purchase of Common and Preferred Stock" is available for most of the firm quarters in the sample, values are flawed or missing in some cases. For instances, Compustat may fail to identify firms that record repurchases in investing rather than financing section of the cash flow statement. In other cases, firms may net stock repurchases and issuances. Also there are cases where the reductions in preferred stock are conversion to common stock. The reasons that cause incorrect (missing) values are not of particular interests, but these make calculations of the dollar value for "Purchase of Common and Preferred Stock" in quarter 2 through 4 impossible due to the fact that this variable is a year-to-date measure of stock repurchase. We thus screen our preliminary sample on certain data attributes. We identify cases where there is a positive entry in "Purchase of Common and Preferred Stock", but missing in prior quarters. We manually investigate these observations via inspecting firms' 10-Ks and 10-Qs, and we are able

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[i] We also use the minimum of the three monthly closing prices during the fiscal quarter. Our results are robust to the definition of repurchase prices.

[j] We also use 0% and 2% as alternative cutoffs for the repurchase statistics. Our results are robust to the definition of non-trivial share repurchases.

to identify that repurchase did occur in the quarter with value in “Purchase of Common and Preferred Stock”, so reclassify a missing value to a repurchase. In a second screen, we inspect cases where there is a sudden decrease of shares outstanding and/or increase in treasury stock but no repurchase activities using our definition. Most of these cases are caused merely by data errors (e.g. treasury shares are not consistently subtracted from shares originally issued), or shares outstanding are not reported on the quarterly balance sheet, but we indeed reveal numerous share repurchases that occurred in a quarter based on this screen and subsequent manual inspections of firms’ 10-Ks and 10-Qs. In our final screen, we identify all cases of possible repurchase quarters suggested by “Purchase of Common and Preferred Stock”, and examine any firm that list a preferred stock balance. There are cases where preferred stock redemption explains the dollar value recorded in “Purchase of Common and Preferred Stock” even though the decline of the preferred is small. By examining 10-Ks and 10-Qs, we reclassify quarters as non-repurchase quarters when preferred stock was repurchased as opposed to common stock.

After making these adjustments for share repurchases, our final sample consists of 2,810 individual firms and 49,493 firm-quarters where a repurchase measure can be identified and prior data requirements for insider trading are met. Later when we examine market reactions to insider trading and share repurchases, sample size reduces because of missing data in stock returns.

V. Empirical results

A direct test of our hypothesis about repurchase frequency and insider trading direction is impossible due to the fact that we lack a definition of low and high firms in order to separate them in our sample. However, inferences can be drawn by examining the relative frequencies of one activity on the other.

Table 1 presents statistics that describe the general direction of insider trading conditional on whether or not a firm has a non-trivial share repurchase in the same quarter. Firms with stock repurchases represent 9.65% of our 49,493 firm-quarter observations. We also find that insiders are net sellers for 18.95% and net buyers for 6.92% of our sample. Only 1.69% of firm-quarters have concurrent insider selling and stock repurchase, and 0.54% of firm-quarters fall into the net insider buying and repurchase classification.

Table 1 Joint frequencies of insider trading and repurchase classifications

Direction of insider trading	Share repurchases		Row total
	≤1%	>1%	
Net selling	8,544	834	9,378
	17.26%	1.69%	18.95%
Neutral	33,017	3,671	36,688
	66.71%	7.42%	74.13%
Net buying	3,160	267	3,427
	6.38%	0.54%	6.92%
Column total	44,721	4,772	49,493
	90.35%	9.65%	100%

Notes: Each cell in this table presents the frequency (expressed as a number of observations and as a percentage of total observations) of the intersection of the activities represented in each row and each column.

In Table 2, we find that firms with net insider selling have repurchases 8.89% of the time, while firms with net insider buying have repurchase activity only 7.79% of the time. It seems that firms with net insider selling are more likely to repurchase shares. The 1.10% difference between the frequencies of repurchase activities conditional on insider trading is significant at 5% level. This result is still consistent with the prediction that insider trading and stock repurchase behave differently among firms. It is an indicator that we have more high quality firms in our sample.

Table 2 Share repurchases conditional on insider trading

Direction of insider trading		
Net selling	Net buying	Difference
8.89%	7.79%	1.10%
		(1.97)**

Notes: Percentage of firms with quarterly repurchases, conditional on the direction of insider trading.

*** p<0.01; ** p<0.05, * p<0.10.

Finally, we use regression to test whether the signal of undervaluation from share repurchases is stronger when accompanied by net insider buying by looking at stock reaction. For this set of empirical analysis, we employ quarterly returns as dependent variable, $QRET_{it}$. Since quarterly repurchase data may take up to three months to be reported, the information necessary for investors to implement a trading strategy should be available at the end of the quarter after the quarter for measured repurchase/insider trading, (that is insider trading/repurchase should effect on next quarter returns). Other firm characteristics that have been documented to have predictive power on future stock returns are also included. Specifically, $LOGSIZE_{it}$ is the natural logarithm of firm i's market capitalization (price times shares outstanding) at the end of quarter t. BP_{it}[k] is the book-to-price ratio of stock i at the end of quarter t. SP_{it} is the sales-to-price ratio. BP and SP are intended to capture the well-known value effects. $RET6_{it}$ is the cumulative returns of the last 6 months, which is a common momentum variable used in predicting stock returns. Finally RNS_{it} is an indicator which takes value one if in quarter t firm i has concurrent net insider selling and share repurchase; RNB_{it} takes value one if in quarter t, firm i's insiders are net buying their stocks, and the firm conducts share

[k] If book value is negative, this value is meaningless in terms of identifying stocks in portfolio management, but the ratio itself is valid.

repurchase; $REPURCHASE_{it}$ equals one if firm i repurchases more than 1% of its own stocks. Because of the limitation posed on company fundamentals, the sample has been reduced to 2,680 firms and 45,061 firm quarters.

These data either come directly from the Center for Research in Security Prices (CRSP) and Compustat or are calculated from these sources.[1] From CRSP, we obtain monthly returns and aggregate them into quarterly returns based on firms' fiscal quarters. From Compustat, we obtain quarterly information on a variety of accounting variables. Descriptive statistics are reported in Table 3.

Table 3 Summary statistics

Variables	Mean	Standard deviation
Quarterly return (%)	4.73	36.82
ln(Market capitalization) ('000)[m]	12.64	2.12
Book-to-market ratio[n]	0.61	1.14
Sales-to-market ratio[o]	0.50	1.22
Cumulative prior returns	7.51	35.58
N=2680	Max.T=21	N*T=45,061

Notes: Panel is unbalanced. The maximum period one firm can have in the sample is 20 quarters.

The econometric specification is

$$QRET_{it} = \gamma_0 REPURCHASE_{it-1} + \gamma_1 RNB_{it-1} + \gamma_2 RNS_{it-1} + X_{it-1}\beta + \delta_t + \varepsilon_{it}$$

[1] Financial formulas used in this paper strictly follow to those published in Standard & Poor Compustat User's Guide.

[m] Price-Quarter–Close multiplied by Common Shares Outstanding (Data item #14 * Data item #61).

[n] Common Equity-Total divided by the product of Common Shares Outstanding divided by Price-Quarter-Close (Date item #59/ (Data item #61* Data item #14)).

[o] Sales (Net) dividend by the product of Price-Quarter–Close and Common Shares Outstanding (Data item #2 / (Data item #14 * Data item #61)).

where X_{it} is a vector of stock return predictors including a constant term. The signaling game implies a testable hypothesis. Holding other factors constant, undervaluation signal conveyed by share repurchase is strengthened by net insider buying and weaken by net insider selling, or equivalently, stock prices adjust upward to a larger extent when share repurchase is coupled with net insider buying, i.e., $\gamma_1 > 0$ and $\gamma_2 < 0$

A Hausman test rejects using a random effects model, so the results reported in Table 4 are from a fixed effects model.

Table 4 The effect of insider trading direction on the power of repurchase signal-Fixed effect results

Variable	Coefficient (Standard Deviation)
REPURCHASE1	0.012 (0.007)*
RNB1	0.025 (0.013)**
RNS1	-0.011 (0.010)
LOGSIZE1	-0.207 (0.006)***
BP1	0.007 (0.007)
SP1	0.011 (0.006)*
RET6	-0.005 (0.003)

Notes: Quarterly returns ($QRET$) are regressed on previous quarter values of dependent variables, natural logarithm of market capitalization ($LOGSIZE$), book-to-market (BP)and sales-to-market (SP) ratios, indicators of repurchase ($REPURCHASE$), repurchase with net insider buying (RNB), and repurchase with net insider selling (RNS) denoted by $LOGSIZE1$, $BP1$, $SP1$, $REPURCHASE1$,$RNB1$ and $RNS1$; and momentum $RET6$.

Clustered standard errors are in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

The results are consistent with hypothesis that net insider buying in same quarter reinforces share repurchase in signaling undervaluation. The coefficient on $REPURCHASE1$ is 0.012, on $RNB1$ is 0.025, and on $RNS1$ is -0.011. Both $RNB1$ and $REPURCHASE1$ reach significance at conventional levels, and the sign on $RNS1$ indicates insider selling mitigates the positive signal repurchasing sends. This implies that repurchase would signal about 250 basis points more abnormal returns when insiders simultaneously buy stocks, this incremental increase is even larger than the abnormal returns generated by repurchase signal alone. Although not significant at conventional p-values, the magnitude of the coefficient on net insider selling would completely offset the effect of repurchase as an undervaluation signal. This bolsters the implications of our theory that insider trading serves as a further signal, above and beyond the signal from repurchases, about the true valuation of a firm.

The estimated coefficients on other independent variables generally conform to expectations. $LOGSIZE$ has a significant negative effect, i.e., big stocks outperform small stocks. BP and SP positively forecast returns, only SP is significant at p-value<0.1, i.e., stocks that are undervalued by the market (with high book-to-market value) outperform other stocks. Standard momentum $RET6$ is not significant.

Overall, our empirical evidence is consistent with the signaling game predictions. The pattern of repurchase activities conditional on insider trading in our sample does not contradict our hypothesis since repurchases behave differently among high and low quality firms. While ex-post returns imply that stock prices respond to a larger extent to signals sent by repurchase with net insider buying, and by repurchase signal alone, when insiders simultaneously sell their stocks, they may use repurchase to enable management to reduce their holdings at a favorable price by supporting stock levels. Investors notice this motivation and respond accordingly.

VI. Conclusion

In this paper we explore the interaction between multiple corporate finance signaling devices of multi-dimensional private information. It models and tests a two-device two-piece private information signaling game, using actual share repurchases and insider transactions. We add to the extant literature by examining theoretically the interaction between the signaling devices, specifically about how insider trades contribute to the informative value of firm share repurchases, and by empirically testing the effect of insider trading direction on the strength of the undervaluation signal implied by a share repurchase.

We find that the odds of observing a repurchase increase when insiders are net sellers; this result, though is not a direct support of our prediction, still implies consistency with the model prediction if we in fact have more high firms in our sample. We also investigate whether repurchases accompanied by net insider buying have more power in signaling firm undervaluation. We find that repurchases tend to generate 1.2% abnormal returns, while repurchases with net insider buying outstrip by 2.5%, a 3.7% abnormal returns one quarter after the repurchase is conducted. While coupled with insider selling, the abnormal returns are offset by negative insider sell effects.

Taken together, our findings suggest that the validity of repurchase alone as an undervaluation signal is questionable. When firm insiders are simultaneously selling their stocks, share repurchase does not necessarily indicate that a firm's stock is trading below its intrinsic value. For strategic portfolio management aimed at identifying undervalued stocks, it is suggestive to incorporate insider transactions and share repurchases. One should note that significant superior performance does not occur when insiders are simultaneously net seller of their stock, but far greater returns are available when insiders are net buyers. Also, it should be noted that a broad class of corporate signals, including such things like dividend increases or divesture, could be examined in a similar fashion, though the model and empirical tests presented in this paper are specific to share repurchase and insider holding signaling.

References

Babenko, Ilona, Yuri Tserlukevich, and Alexander Vedrashko. "The Credibility of Open Market Share Repurchase Signaling." *Journal of Financial and Quantitative Analysis* 47 05 (2012): 1059-88.

Banyi, Monica L, Edward A Dyl, and Kathleen M Kahle. "Errors in Estimating Share Repurchases." *Journal of Corporate Finance* 14 4 (2008): 460-74.

Billett, Matthew T, and Hui Xue. "The Takeover Deterrent Effect of Open Market Share Repurchases." *The Journal of Finance* 62 4 (2007): 1827-50.

Binswanger, Hans P. "Attitudes toward Risk: Experimental Measurement in Rural India." *American Journal of Agricultural Economics* 62 3 (1980): 395-407.

Bonaimé, Alice Adams. "Repurchases, Reputation, and Returns." *Journal of Financial and Quantitative Analysis* 47 02 (2012): 469-91.

Brav, Alon, et al. "Payout Policy in the 21st Century." *Journal of Financial Economics* 77 3 (2005): 483-527.

Chan, Konan, et al. "Informed Traders: Linking Legal Insider Trading and Share Repurchases." *Financial Analysts Journal* 68 1 (2012): 60-73.

Chan, Konan, David Ikenberry, and Inmoo Lee. "Economic Sources of Gain in Stock Repurchases." *Journal of Financial and Quantitative Analysis* 39 03 (2004): 461-79.

Cho, In-Koo, and David M Kreps. "Signaling Games and Stable Equilibria." *The Quarterly Journal of Economics* (1987): 179-221.

Dann, Larry Y. "Common Stock Repurchases: An Analysis of Returns to Bondholders and Stockholders." *Journal of Financial Economics* 9 2 (1981): 113-38.

Grinblatt, Mark, and Chuan Yang Hwang. "Signalling and the Pricing of New Issues." *The Journal of Finance* 44 2 (1989): 393-420.

Guiso, Luigi, and Monica Paiella. "Risk Aversion, Wealth, and Background Risk." *Journal of the European Economic Association* 6 6 (2008): 1109-50.

Heinemann, Frank. "Measuring Risk Aversion and the Wealth Effect." *Research in Experimental Economics* 12 (2008): 293-313.

Ikenberry, David, Josef Lakonishok, and Theo Vermaelen. "Market Underreaction to Open Market Share Repurchases." *Journal of Financial Economics* 39 2 (1995): 181-208.

---. "Stock Repurchases in Canada: Performance and Strategic Trading." *The Journal of Finance* 55 5 (2000): 2373-97.

John, Kose, and Larry HP Lang. "Insider Trading around Dividend Announcements: Theory and Evidence." *The Journal of Finance* 46 4 (1991): 1361-89.

Lee, D Scott, Wayne H Mikkelson, and M Megan Partch. "Managers' Trading around Stock Repurchases." *The Journal of Finance* 47 5 (1992): 1947-62.

Levy, Haim. "Absolute and Relative Risk Aversion: An Experimental Study." *Journal of Risk and Uncertainty* 8 3 (1994): 289-307.

Louis, Henock, Amy X Sun, and Hal White. "Insider Trading after Repurchase Tender Offer Announcements: Timing Versus Informed Trading." *Financial Management* 39 1 (2010): 301-22.

Stephens, Clifford P, and Michael S Weisbach. "Actual Share Reacquisitions in Open‐Market Repurchase Programs." *The Journal of Finance* 53 1 (1998): 313-33.

Vermaelen, Theo. "Common Stock Repurchases and Market Signalling: An Empirical Study." *Journal of Financial Economics* 9 2 (1981): 139-83.

Wik*, Mette, et al. "On the Measurement of Risk Aversion from Experimental Data." *Applied Economics* 36 21 (2004): 2443-51.

Appendix

Proof of proposition

Let $(\alpha^H_{\mu_L}, I^H_{\mu_L})$ denote the holding and investment level that a high manager chooses when his project is priced as μ_L. That is,

$$(1)\ (\alpha^H_{\mu_L}, I^H_{\mu_L}) = \operatorname{argmax}_{\substack{0\le\alpha\le1\\0\le I\le1}} U(\mu_H, \sigma_H^2, \alpha, I, \mu_L)$$

Solving (1) yields that,

$$(2)\ \left(\alpha^H_{\mu_L},\ I^H_{\mu_L}\right) = \begin{cases} (1,1) \text{ if } h \le \frac{(\mu_H-1)}{\sigma_H^2} \\ \left(\alpha^H_{\mu_L},\ I^H_{\mu_L}\right) \text{ such that } \alpha^H_{\mu_L} = \frac{(\mu_H-1)}{h\, I^H_{\mu_L}\sigma_H^2} \ \text{ if } \ h > \frac{(\mu_H-1)}{\sigma_H^2} \end{cases}$$

Substituting (2) into a high manger's utility function yields,

$$(3)\ U(\mu_H, \sigma_H^2, \alpha^H_{\mu_L},\ I^H_{\mu_L}, \mu_L) = \begin{cases} \mu_H - \frac{h\sigma_H^2}{2} \ \text{ if } h \le \frac{(\mu_H-1)}{\sigma_H^2} \\ 1 + \frac{(\mu_H-1)^2}{2h\sigma_H^2} \ \text{ if } \ h > \frac{(\mu_H-1)}{\sigma_H^2} \end{cases}$$

Let (α^H, I^H) denote the holding and investment level that a high manager chooses when his project is priced as μ_H, to maximize his utility while deterring mimicking by a low manager. That is,

$$(4)\ (\alpha^H, I^H) = \operatorname{argmax}_{\substack{0\le\alpha\le1\\0\le I\le1}} U\big(\mu_H, \sigma_H^2, \alpha, I, \hat{\mu}(\alpha, I)\big)$$

$$s.t.\ U(\mu_L, \sigma_L^2, \alpha, I, \mu_H)\ \le U(\mu_L, \sigma_L^2, 0, 1, \mu_L)$$

Solving (4) yields the optimal signaling strategy in (5)

(5)

$(\alpha^H,\ I^H)$

$$= \begin{cases} \left(\frac{1-\mu_H+\sqrt{\mu_H-1}\sqrt{\mu_H-1+2h\sigma_L^2}}{h\sigma_L^2}, 1\right) \text{ if } \sigma_L^2 > \sigma_H^2 \text{ or } \left(\ \sigma_L^2 < \sigma_H^2 \text{ and } h < \frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}\right) \\ \left(\frac{2(\sigma_H^2-\sigma_L^2)}{2\sigma_H^2-\sigma_L^2}, \frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2h(\sigma_H^2-\sigma_L^2)^2}\right) \text{ if } \left(\sigma_L^2 < \sigma_H^2 \text{ and } h \ge \frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}\right) \end{cases}$$

And the corresponding utility in (6)

$$(6)\ U(\mu_H,\sigma_H^2,\alpha^H,I^H,\mu_H)=\begin{cases}\dfrac{\sigma_H^2(\mu_H-1)(1-\mu_H+\sqrt{\mu_H-1}\sqrt{\mu_H-1+2h\sigma_L^2}+h\sigma_L^2\left(\sigma_H^2+\mu_H(\sigma_L^2-\sigma_H^2)\right)}{h\sigma_L^4}\\ \text{if } \sigma_L^2>\sigma_H^2 \text{ or } \left(\sigma_L^2<\sigma_H^2 \text{ and } h<\frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}\right)\\ 1+\frac{(\mu_H-1)^2}{2h(\sigma_H^2-\sigma_L^2)}\quad \text{if } \left(\sigma_L^2<\sigma_H^2 \text{ and } h\geq\frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}\right)\end{cases}$$

Finally it remains to verify that high managers are better off signaling $(\alpha^H,\ I^H)$ and receiving high response than being considered as low managers. Equivalently, to verify that,

$$(7)\ U(\mu_H,\sigma_H^2,\alpha^H,I^H,\mu_H)>\text{argmax}_{\substack{0\leq\alpha\leq1\\0\leq I\leq1}}U(\mu_H,\sigma_H^2,\alpha,I,\mu_L)$$

Substituting (2) and (6) into (7),

(8)

$$U(\mu_H,\sigma_H^2,\alpha^H,I^H,\mu_H)-U\left(\mu_H,\sigma_H^2,\alpha_{\mu_L}^H,\ I_{\mu_L}^H,\mu_L\right)=$$

$$\begin{cases}\dfrac{\sigma_H^2(\mu_H-1)(1-\mu_H+\sqrt{\mu_H-1}\sqrt{\mu_H-1+2h\sigma_L^2}+h\sigma_L^2\left(\sigma_H^2+\mu_H(\sigma_L^2-\sigma_H^2)\right)}{h\sigma_L^4}-\left(\mu_H-\frac{h\sigma_H^2}{2}\right)\\ \text{if } \sigma_L^2>\sigma_H^2 \text{ or } \left(\sigma_L^2<\sigma_H^2 \text{ and } h<\frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}\right) \text{ and } h\leq\frac{(\mu_H-1)}{\sigma_H^2}\\ \dfrac{\sigma_H^2(\mu_H-1)(1-\mu_H+\sqrt{\mu_H-1}\sqrt{\mu_H-1+2h\sigma_L^2})+h\sigma_L^2\left(\sigma_H^2+\mu_H(\sigma_L^2-\sigma_H^2)\right)}{h\sigma_L^4}-\left(1+\frac{(\mu_H-1)^2}{2h\sigma_H^2}\right)\\ \text{if } \sigma_L^2>\sigma_H^2 \text{ or } \left(\sigma_L^2<\sigma_H^2 \text{ and } h<\frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}\right) \text{ and } h>\frac{(\mu_H-1)}{\sigma_H^2}\\ 1+\frac{(\mu_H-1)^2}{2h(\sigma_H^2-\sigma_L^2)}-\left(1+\frac{(\mu_H-1)^2}{2h\sigma_H^2}\right)\\ \text{if } \sigma_L^2<\sigma_H^2 \text{ and } h\geq\frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}\end{cases}$$

It can be shown that in all three conditions, the right-hand side of (8) is always positive.[p]

[p] There does not exist such situation $1+\frac{(\mu_H-1)^2}{2h(\sigma_H^2-\sigma_L^2)}-\left(\mu_H-\frac{h\sigma_H^2}{2}\right)$, if $\sigma_L^2<\sigma_H^2$ and $h\geq\frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}$ and $h\leq\frac{(\mu_H-1)}{\sigma_H^2}$, since $\sigma_L^2<\sigma_H^2$ guarantees that $\frac{(\mu_H-1)(2\sigma_H^2-\sigma_L^2)}{2(\sigma_H^2-\sigma_L^2)^2}>\frac{(\mu_H-1)}{\sigma_H^2}$