

Essays on Financial Market Imperfections

by

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B.A., Economics and Mathematics
Wellesley College, 2002

Submitted to the Department of Economics
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy in Economics

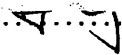
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June 2007

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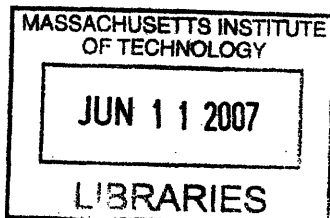
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Abstract

This dissertation consists of three chapters on financial market imperfections, in particular, information imperfections. Chapter 1 studies how the existence of a fixed cost per transaction faced by uninformed investors hampers information revelation through price and exacerbates adverse selection. The exacerbated adverse selection explains one long-standing puzzle in finance – the momentum anomaly. Properly adjusting stock returns for adverse selection by using data on trading volume substantially mitigates momentum-based arbitrage profits for the sample period from 1983 to 2004. Chapter 2 studies how information asymmetry prevents perfect risk-sharing and offers insights on stock return behavior. Chapter 3 explores the idea of Tobin's tax in the context of an emerging market and in particular examines the cost effects on speculation in the Chinese stock market.

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Acknowledgements

I thank my thesis advisors, Olivier Blanchard and Jiang Wang, who exemplify the ideal of scholarship and mentorship, for much more than words can express.

I thank Jonathan Lewellen and Andrew Lo for teaching me to see through the numbers and to think beyond the numbers. I thank Kevin Chu for numerous inspiring discussions. I also thank my fellow students at MIT for making my graduate studies a memorable experience.

I thank Chip Case and Akila Weerapana for encouraging me to attend graduate school in economics and for their continuous encouragement and mentorship.

I acknowledge financial support from the MIT economics department, the MIT Presidential Graduate Fellowship fund, and the MIT Finch Fellowship fund.

I dedicate this thesis to my family and my friends who have enriched my life, but especially my parents, Jianmin Wang and Wenyuan Wu, for their endless support and love.

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Chapter 1

An Adverse-Selection Explanation of Momentum: Theory and Evidence

This paper rationalizes momentum in a competitive market with information asymmetry and fixed transaction costs. The existence of a fixed cost per transaction faced by uninformed investors hampers information revelation through price and induces further adverse selection in quantity. The adverse selection in quantity drives a wedge between returns inferred from observable prices and returns obtained by an uninformed investor. This discrepancy becomes most pronounced when information asymmetry accompanies unbalanced non-information-driven trades. Momentum thus arises when uninformed investors accommodate sells (buys) by informed investors who unwind their positions upon the realization of strong (weak) stock performance. Properly adjusting stock returns for adverse selection by using data on trading volume substantially mitigates momentum-based arbitrage profits for the sample period from 1983 to 2004. In addition, an empirical proxy for exploitable information asymmetry forecasts the strength of momentum for extreme performers in the recent past.

1.1 Introduction

The momentum effect is one of the most enduring puzzles in asset pricing. Jegadeesh and Titman (1993) find that, when sorted on cumulative returns over the previous 3-12 months, stocks in the highest return decile continue to perform significantly better than stocks in the lowest

return decile over the ensuing period of 3-12 months.¹ Both unconditional and conditional factor models fail to explain the momentum alpha of roughly 1% per month.² The predictability of stock returns at a medium horizon of a quarter up to a year challenges the efficient market hypothesis, a keystone to classical finance theory.

Stocks that have recently experienced extreme performance are often associated with severe information asymmetry. Information asymmetry has indeed been empirically identified as an important determinant of momentum.³ However, models of information asymmetry alone cannot generate momentum as long as there are sufficiently many rational investors who are not constrained in their trading behavior.

Several recent studies argue that momentum trading strategies often require frequent trading in disproportionately high cost securities.⁴ Studies of transaction costs alone can explain how momentum persists, but cannot explain how momentum arises in the first place and why costs are particularly high for momentum stocks.

This paper investigates the implications of the simultaneous presence of information asymmetry and transaction costs, particularly a fixed cost per trade, and demonstrates how momentum arises due to adverse selection in such a competitive market setting. Take a winner stock as an example. Under information asymmetry, extreme positive stock performance usually coincides with high concentration of ownership in the hands of informed investors. After the positive shock becomes public, informed investors are expected to unload their holdings. The existence of fixed transaction costs faced by uninformed investors hampers information revelation through price and induces further adverse selection in quantity. Price soars in response to news of the fundamental, but contains a negative adjustment to compensate uninformed buyers

¹The momentum effect remains robust and pervasive. A large follow-up literature confirms and extends the original findings. See, for example, Chan, Jegadeesh and Lakonishok (1996), Fama and French (1996), Conrad and Kaul (1998), Rouwenhorst (1998), Grinblatt and Moskowitz (1999), Chan, Hameed and Tong (2000), Hong, Lim and Stein (2000), Lee and Swaminathan (2000), Grundy and Martin (2001), Jegadeesh and Titman (2001), Chordia and Shivakumar (2002), Grinblatt and Han (2002), Lewellen (2002), Ahn, Conrad and Dittmar (2003), Griffin, Ji and Martin (2003), Schwert (2003), Cooper, Gutierrez and Hameed (2004), Korajczyk and Sadka (2004), Lesmond, Schill and Zhou (2004), Liu, Warner and Zhang (2005), Frazzini (2006), Hvidkjaer (2006), Sadka (2006), and Sagi and Seasholes (2006).

²See evidence in Fama and French (1996), Grundy and Martin (2001), Ahn, Conrad and Dittmar (2003), and Lewellen and Nagel (2006).

³See evidence in Hong, Lim and Stein (2000).

⁴See, for example, Chen, Stanzl and Watanabe (2001), Korajczyk and Sadka (2004), and Lesmond, Schill and Zhou (2004).

who are subject to such adverse selection. The adjustment in price diminishes gradually with the bias in share distribution. Momentum thus follows from the dynamics of share distribution.

The adverse selection in quantity, whereby uninformed investors are most likely to own shares when the underlying asset is least desirable, is reminiscent of the winner's curse in Rock (1986). Rock (1986) studies the underpricing of initial public offerings, so his result hinges on a specific pricing mechanism. This paper extends his result to asset pricing and provides a framework in which such adverse selection arises in a competitive equilibrium without rationing.

A fixed cost per transaction results in lumpy adjustment to individual holdings. If the population of investors is sufficiently large relative to the size of a supply shock, only some investors will make a transaction. A larger supply shock involves more investors in trading, but the price remains constant. Fixed costs introduce a flat segment into the aggregate demand curve and make price less sensitive to supply shocks.

The lack of a close correspondence between price and asset allocation exacerbates adverse selection. At certain price levels, private information shifts the demand of better-informed investors and in turn alters the asset allocation, but leaves price unaffected. Less-informed investors thus face a price-independent adverse selection⁵ when passively providing liquidity. Their holdings are most likely to increase when the underlying asset is least desirable, and vice versa. As individual investors cannot directly observe contemporaneous aggregate trading activities, price does not instantaneously reflect this bias in allocation.

With price-independent adverse selection, the returns inferred from observed prices no longer coincide with the returns achieved by a marginal uninformed investor. This wedge provides a rational non-factor-based explanation of the momentum anomaly. The discrepancy can be either positive or negative and is most pronounced when information asymmetry accompanies unbalanced non-information-driven trades. In contrast, in traditional asset-pricing models of adverse selection, price immediately incorporates the part of private information revealed through trading, so returns to a marginal investor align perfectly with returns implied by prices.

Without a tight linkage between price and share distribution, private information adversely

⁵In this paper, price-independent adverse selection refers to the adverse selection in quantity with price staying fixed.

affects the probability of an uninformed investor making a transaction. An empirical proxy for this probability is trading volume. Volume thus complements price in conveying information regarding returns to a marginal investor. My model derives an empirically testable equilibrium condition that involves unsigned volume. The hypothesis testing does not require identifying trades as buyer- or seller-initiated. This simplicity enhances the power of empirical tests.

Properly adjusting returns for adverse selection using data on trading volume reduces both the economic magnitude and the statistical significance of momentum-based arbitrage profits. Over the entire sample period from 1983 to 2004, a momentum trading strategy based on cumulative returns over the past twelve months generates an average alpha⁶ of 1.27% per month over a holding period of six months. The adjustment for price-independent adverse selection reduces the momentum alpha by 0.89% per month. The momentum alpha that is actually obtainable by a marginal investor diminishes to 0.37% with t-statistic equal to 0.93. The results are robust to a variety of factor models, stock exchanges, and subperiods.

This adverse selection explanation of momentum also implies that the degree of information asymmetry should predict the magnitude of return momentum. In particular, it is the degree of exploitable information asymmetry that induces bias in share distribution and causes seemingly bias in subsequent returns. The model suggests a nonnegative (nonpositive) correlation between return and volume when non-information-driven trades are predominantly buyer- (seller-) initiated in the current period. The return-volume correlation prior to extreme stock performance thus becomes a proxy for the degree of information-induced inefficiency in share distribution. This new predictor forecasts the strength of momentum in the data.

Although my model is motivated by the momentum anomaly, the range of its applications is not limited to this particular empirical phenomenon alone. To demonstrate the versatility of the model, I also apply it to another well-known puzzle in the finance and accounting literature, the post-earnings-announcement drift⁷. The same empirical adjustment for price-independent adverse selection mitigates the drift-based arbitrage profits.

In my model, liquidity and momentum are intrinsically linked. Extreme stock performance predicts ensuing non-information-driven trades, so the liquidity cost derived from price-

⁶The alpha is based on the Fama-French three-factor model.

⁷See, for example, Foster, Olsen and Shevlin (1984), and Bernard and Thomas (1989).

independent adverse selection becomes prominent particularly for momentum stocks. This type of liquidity cost can lead to either positive or negative seemingly abnormal returns, so illiquidity does not always imply positive “return premium.”

The remainder of the paper is organized as follows. Section 2 sets up the model. Section 3 characterizes a rational expectations equilibrium. Section 4 analyzes the model and explains what causes momentum. Section 5 presents model implications and empirical findings. Section 5.1 reexamines the profitability of momentum-based and PEAD-based arbitrage. Section 5.2 develops a new predictor of momentum and also relates the theory to existing empirical findings. Section 6 discusses related literature. Section 7 concludes the paper.

1.2 Model Setup

Consider an infinite horizon model of a simple economy in discrete time. The simple economy consists of only one risky asset and two types of investors. There is a single physical good which may be allocated to consumption or savings. All values are expressed in terms of units of this good.

Each unit of the risky asset pays out a dividend d_t right before trades at time t . The dividend process is taken as exogenous. $\{d_t\}$ is a sequence of discrete random variables that are independently and identically distributed as follows:

$$d_t = \begin{cases} +d, & \text{with probability of } \frac{1}{2} \\ -d, & \text{with probability of } \frac{1}{2} \end{cases}, \text{ where } d > 0.$$

Let p_t denote the price of the risky asset at time t .

The supply of the risky asset at time t is s_{t+1} . To get around no trade theorems, this model assumes s_{t+1} to be random. s_{t+1} will not be announced to the public until time $t + 1$. In particular, $s_{t+1} = s + u_{t+1}$, where s is a positive constant and u_{t+1} is a discrete random variable. u_{t+1} takes a value of $-u$, 0 or $+u$, where $u > 0$, and satisfies the following conditional distribution: given u_t ,

$$\begin{aligned} \Pr\{u_{t+1} = u_t\} &= 0; \\ \text{and } \Pr\{u_{t+1} = x \neq u_t\} &= \frac{1}{2}, \text{ where } x \in \{0, \pm u\}. \end{aligned}$$

u_t thus follows a mean-reverting stochastic process and oscillates between the boundaries $-u$ and $+u$. Restricting the variation in u_t guarantees that the asset supply will always stay finite. The noisy supply $\{u_t\}$ and the dividend process $\{d_t\}$ are mutually independent.

The change in the random supply $(u_t - u_{t-1})$ can be interpreted literally as a random number of shares newly issued by the underlying firm. Alternatively, $(u_t - u_{t-1})$ can be interpreted as a random number of shares that some traders outside the model dump into the market. Such traders are known as noise traders.

There is a continuum of mass $(1 + n)$ of investors, indexed by $j \in [0, 1 + n]$. Among them, investor j is informed if $j \in [0, 1]$ and is uninformed if $j \in [1, 1 + n]$. The informed know d_t at time $t - 1$, one period ahead of the actual dividend payout. Both informed and uninformed investors behave competitively as price takers.

Let x_t^j denote the stock holdings of investor j before trades at time t . His total wealth w_t^j must equal $x_t^j (d_t + p_t)$, since the risky asset is the only saving vehicle in this economy. In each period, an investor consumes part of his wealth and saves the rest by investing in the risky asset. Let κ_t^j denote his consumption.

At any time t , an investor j chooses his demand of the stock x_{t+1}^j to maximize a myopic utility function:

$$U_t^j \equiv E_t^j \left[\kappa_t^j + \beta w_{t+1}^j \right],$$

where β is the time discount rate and $\beta \in [0, 1]$. w_{t+1}^j is his total wealth at time $t + 1$, and $w_{t+1}^j = x_{t+1}^j (d_{t+1} + p_{t+1})$. $E_t^j [\cdot]$ refers to the conditional expectation based on the information set available to investor j at time t including the stock price p_t .

Investor j must pay a fixed transaction cost c^j , whenever he adjusts his stock holdings, i.e., $x_{t+1}^j \neq x_t^j$. For simplicity, assume

$$c^j = \begin{cases} 0, & \text{for } j \in [0, 1] \\ c, & \text{for } j \in [1, 1 + n] \end{cases},$$

The uninformed pay a flat fee $c > 0$ per transaction, but the informed do not. The fixed cost c^j represents various costs associated with a transaction, pecuniary or non-pecuniary. For instance, an individual investor who opts to manage portfolio on his own will normally set up

an account with a discount broker who typically charges a flat fee per transaction. For an institutional investor, such as a pension fund manager, who may follow conservative investment strategies, adjusting stock holdings would incur costs in the form of extra communications or increased career risk.

This model differs from existing models in that it examines the effect of trading frictions that are imposed on investors who do not possess superior information. Previous studies in the literature on limits of arbitrage often investigate how trading frictions imposed on better-informed investors prevent the revelation of private information as investors are somewhat constrained to trade on information.

In order to generate sensible results with linear preferences, the model further imposes a carry cost h^j and a set of holdings constraints. The cost of carry h^j represents expenses incurred for every additional unit being held. They differ from variable trading costs, so a positive h^j should not be considered as an additional source of trading frictions. For simplicity, assume

$$h^j = \begin{cases} h, & \text{for } j \in [0, 1] \\ 0, & \text{for } j \in [1, 1+n] \end{cases}.$$

The informed face a cost of carry h , but the uninformed do not.

After taking into account all the costs, the budget constraint for an informed investor $j \in [0, 1]$ becomes

$$\kappa_t^j \leq x_t^j d_t - p_t (x_{t+1}^j - x_t^j) - h |x_{t+1}^j|,$$

and the budget constraint for an uninformed investor becomes

$$\kappa_t^j \leq x_t^j d_t - p_t (x_{t+1}^j - x_t^j) - c I_{x_{t+1}^j \neq x_t^j}.$$

The informed and the uninformed also differ in their holdings constraints:

$$x_t^j \in \begin{cases} [-a, a], & \text{for } j \in [0, 1] \\ [0, a], & \text{for } j \in [1, 1+n] \end{cases}.$$

The informed are allowed to sell short so that they can take advantage of both good and bad news given a linear preference. The uninformed are however prohibited from short selling. The

no-short-selling constraint helps to simplify the dynamics in the presence of a fixed transaction cost.

In the aggregate, the informed hold X_{t+1}^i shares, where

$$X_{t+1}^i \equiv \int_{j \in [0,1]} x_{t+1}^j dj.$$

Similarly, X_{t+1}^u denotes the aggregate holdings of the uninformed, and

$$X_{t+1}^u \equiv \int_{j \in [1,1+n]} x_{t+1}^j dj.$$

Both integrals are taken in the Lebesgue sense. Although investors are initially identical within each type, their holdings may diverge over time. Individual investors do not observe the aggregate trading activities at time t or the share distribution resulting from trades at time t . However, all investors can learn about X_{t+1}^i and X_{t+1}^u once u_{t+1} and d_{t+1} get revealed at time $t + 1$.

Several more assumptions are in order so that the model obtains a parsimonious closed-form solution.

$$s + u + a < na, \tag{1.1}$$

$$s - u - a > 0. \tag{1.2}$$

$$\frac{u}{a} \in \left(\frac{1}{2}, 1 \right), \tag{1.3}$$

$$\frac{c}{a} < h \ll \left(\frac{u}{a} - \frac{1}{2} \right) \beta d, \tag{1.4}$$

$$\text{and } 0 < \beta \ll 1. \tag{1.5}$$

Condition (1.1) implies a sufficiently large aggregate holdings capacity of the uninformed. The aggregate supply is bounded above by $s + u$. The aggregate holdings of the informed is bounded below by $-a$. As a result, the effective supply for the uninformed, defined as $s_t - X_t^i$, should be bounded above by $s + u + a$. Because each uninformed investor can hold a shares at most, Condition (1.1) suggests that the holdings capacity of the uninformed as a whole exceeds

the maximum effective supply. Similarly, the effective supply for the uninformed is bounded below by $s - u - a$, so Condition (1.2) ensures that the percentage of shares allocated to the uninformed never drops to zero.

Condition (1.3) implies that the holdings capacity of the informed a cannot be too large nor too small. If $a \geq 2u$, price will always reveal private information so the model will lose interesting results, given that all informed investors hold linear preference and behave competitively as price-takers in this simple model. If $a \leq u$, a larger flow of noise trades may lead to a larger number of equilibrium states and complicate the equilibrium analysis.

Condition (1.4) implies that the magnitude of exploitable information advantage is large enough to dwarf the trading or holding costs. Note that the scale of noise trades and the competition among the informed limits how much informed investors can profit from their information advantage. In this model, a larger a means there is a larger amount of “smart money” floating in the market. In addition, $\frac{c}{a} < h$, so the uninformed have a lower opportunity cost to provide liquidity than the informed in the absence of information asymmetry. Otherwise, uninformed investors will never participate in trading in this simple setup.

Finally, imposing Condition (1.5) mutes dynamic effects that are not essential to the key idea of this paper. The main driving force for dynamics of the returns process in this model is the change in share distribution. Informed investors may restrain themselves from trading aggressively on information in fear of substantial adjustment in price tomorrow due to biases in allocation. A small β thus mitigates the effect of liquidity costs tomorrow, but accentuates the effect of liquidity costs today.

1.3 Equilibrium

This section solves out a stationary rational expectations equilibrium (hereafter, REE) of the infinite-horizon model.

Trading frictions, specifically a fixed cost in this model, induce history dependence or inertia in share distribution. Therefore, the past aggregate holdings of the informed and the uninformed, respectively X_t^i and X_t^u , should characterize the equilibrium states, in addition to the current supply shock u_{t+1} and the news on the next dividend d_{t+1} . To streamline the

notations, replace X_t^u with u_t as a state variable, since the market-clearing condition implies $X_t^u = s + u_t - X_t^i$. Let $(X_t^i, u_t, u_{t+1}, d_{t+1})$ denote the state vector. A stationary equilibrium of this model is hence defined as follows.

Definition 1 *A stationary REE is characterized by a price function $p_t = p(X_t^i, u_t, u_{t+1}, d_{t+1})$, under which,*

- x_{t+1}^j maximizes the utility of investor j , for all $j \in [0, 1 + n]$;
- the asset market clears, i.e.,

$$\int_{j \in [0, 1+n]} x_{t+1}^j dj = s + u_{t+1};^8$$

- when the equilibrium asset allocation is not unique, each allocation is chosen at random with equal probability.

A fixed transaction cost introduces a kink into individual demand curve which leads to a flat portion of the aggregate demand curve. At a certain price, the optimal demand of an investor is not unique. He submits an order given the price, but is indifferent to having or not having his order filled. If the population of investors is sufficiently large relative to the supply shock, in equilibrium, only a fraction of the investors will each make a lumpy adjustment, and the rest will maintain their original holdings. Given that all investors are identical, any individual investor has a chance of adjusting his holdings. The equilibrium is thus characterized by a single equilibrium price that corresponds to multiple equilibrium allocations. Under the equilibrium price, each identical investor is indifferent to any of those possible allocations.

Combining a fixed cost with information asymmetry adds further subtlety to the equilibrium. The choice of equilibrium allocation may convey further information regarding the asset payoff. As a result, rational investors will take into consideration this additional information when deciding on their optimal demand.

The equilibrium concept in this model builds on that in Grossman (1976). The adaptation concerns the possibility that the equilibrium asset allocation is not unique. In addition to

⁸ *The integral is taken in the Lebesgue sense.*

setting a market-clearing price, the hypothetical Walrasian auctioneer in this REE randomly picks one out of many possible equilibrium asset allocations corresponding to this equilibrium price. In a symmetric equilibrium, the auctioneer assigns equal probabilities to all possible allocations.

In such an REE, given a price, investors submit their optimal demand and do not always know for sure their equilibrium holdings. An equilibrium obtains if all investors' orders are fulfilled, or if unfulfilled orders do not leave any investor worse-off. Proposition 1 states the existence of such an equilibrium.

Proposition 1 *There exists an equilibrium as is defined in Definition 1.*⁹

The state space of this stationary equilibrium, $\{(X_t^i, u_t, u_{t+1}, d_{t+1})\}$, consists of thirty-six 4×1 vectors. In particular, $\{(X_t^i, u_t, u_{t+1}, d_{t+1})\} = \chi \times U \times D$, where $\chi = \{0, \pm a\}$, $D = \{\pm d\}$ and $U = \{(0, \pm u), (\pm u, 0), (\pm u, \mp u)\}$. With a linear preference, informed investors either hold a neutral position $X_t^i = 0$ when price is fully revealing or trade aggressively on their private information $X_t^i = \pm a$, so $\chi = \{0, \pm a\}$. D is the support of the dividend shock. U is the support of the past and the current supply shocks.

The equilibrium price function is summarized in Table 1.1: $p_t = p(X_t^i, u_t, u_{t+1}, d_{t+1})$. Because informed investors behave competitively as price takers, price p_t will fully reveal the private information when the distortion in allocation is sufficiently small, i.e., when $|X_t^i + u_t| < u$. Otherwise, price will be less sensitive to the private information and will stay fixed for a pooling of different exogenous shocks (u_{t+1}, d_{t+1}) .

Define $q(X_t^i, u_t) \equiv E[p_t | X_t^i, u_t]$, the expected price conditional on the state variables X_t^i and u_t . The conditional expectation of price on average displays an upward adjustment when uninformed investors hold more than s shares as a whole and expect to sell in the current round of trading, and vice versa.

Table 1.2(a) summarizes the equilibrium holdings of an individual informed investor. When price fully reveals the private information, the informed demand zero shares, $x_{t+1}^j(p_t) = 0$, because by assumption the informed have a higher opportunity cost to provide liquidity in the absence of information asymmetry. Otherwise, if the price is not fully revealing, an informed

⁹ Appendix A provides a proof of Proposition 1.

investor will exploit his private information to the full extent, by holding a shares if $d_{t+1} = d$ and by short-selling a shares if $d_{t+1} = -d$.

Table 1.2(b) and 1.2(c) summarize the equilibrium holdings of an uninformed investor who previously holds zero and a shares, respectively. In the stationary equilibrium, an uninformed investor either holds zero or a shares. Whenever an uninformed investor adjusts his holdings, the size of the adjustment will be exactly a shares. An uninformed marginal investor is always indifferent to zero and a shares.

The market always clears, as uninformed investors passively provide market liquidity. Define the residual supply shock for the uninformed as the aggregate supply shock $u_{t+1} - u_t$ minus the change in the aggregate demand of the informed. If the residual supply shock is positive, a fraction of uninformed investors who previously hold zero shares will each buy indifferently a shares. The fraction is proportional to the size of the residual shock. Similarly, if the residual supply shock is negative, a fraction of uninformed investors who previously hold a shares will each sell indifferently a shares.

[INSERT TABLE 1.1, and 1.2 (a) - (c)]

1.4 Analysis

1.4.1 Price-Independent Adverse Selection

Imposing a fixed transaction cost excludes the possibility of infinitesimally small adjustments to an individual investor's stock holdings. When the population of marginal investors is sufficiently large relative to the size of the supply shock, only a fraction of those identical investors will make a transaction. In equilibrium, those investors must be trading indifferently. The size of the fraction, or equivalently the probability of any individual making an adjustment in holdings, correlates with the change in supply.

In this model, supply shocks of different size are absorbed by different numbers of marginal uninformed investors each of whom makes an adjustment of a fixed size, a shares. Any individual investor however does not observe the total volume of trades and cannot infer the size of a supply shock through his individual holdings. In contrast, in a standard model in

which investors face no fixed transaction cost, supply shocks are absorbed by all investors. The size of adjustment to individual holdings will vary with the size of the supply shock.

The lack of this close correspondence between individual holdings and the aggregate supply shock makes price less informative, as individual uninformed investors do not observe contemporaneous aggregate trading activities. In the current model, private information shifts the demand of the informed and in turn alters the asset allocation, but leaves price unaffected. Uninformed investors thus face a price-independent adverse selection.

For instance, when $X_t^i = -a$ and $u_t = +u$, the uninformed expect to sell in the current period to accommodate liquidity trades in the presence of adverse selection. The demand of the informed varies with their private information, so does the change in the aggregate holdings of the uninformed. However, any individual marginal uninformed seller does not observe the total volume of trades, so price does not instantaneously incorporate the relevant information contained in aggregate trading activities and stays fixed regardless of the current shock (u_{t+1}, d_{t+1}) .

The total volume of trades that involve the uninformed varies with (u_{t+1}, d_{t+1}) in the following way:

(u_{t+1}, d_{t+1})	$(0, -d)$	$(0, +d)$	$(+u, -d)$	$(+u, +d)$
$ X_{t+1}^u - X_t^u $	u	$u + 2a$	$2u$	$2u + 2a$

Consequently, the posterior of d_{t+1} conditional on an uninformed investor's selling of a shares should be:

$$d_{t+1} = \begin{cases} -d, & \text{with probability of } \frac{3u}{6u+4a} \\ +d, & \text{with probability of } \frac{3u+4a}{6u+4a} \end{cases} .$$

A marginal uninformed investor is more likely to sell a shares when the next dividend is lower. If we ignore this bias in asset allocation, the marginal investors would appear to benefit more from selling than they actually do, as the following distribution of d_{t+1} inferred from prices only is mistaken for the true posterior:

$$d_{t+1} = \begin{cases} -d, & \text{with probability of } \frac{1}{2} \\ +d, & \text{with probability of } \frac{1}{2} \end{cases} .$$

Proposition 2 and 3 summarize the model implications on return and volume as a conse-

quence of price-independent adverse selection. Define $r_t \equiv \beta(d_t + p_t) - p_{t-1}$. Let V_t^u denote the contemporaneous aggregate volume of trades that involve uninformed investors at time $t-1$. Uninformed investors do not know V_t^u until time t . $V_t^u > 0$ indicates buys by uninformed investors; and $V_t^u < 0$ indicates sells. Let π_t^u denote the ratio of $\frac{|V_t^u|}{E[|V_t^u|]}$. It is immediate that $E[\pi_t^u] = 1$.

Proposition 2 *In equilibrium,*

$$|E[r_t \pi_t^u]| = \frac{c}{a}.^{10}$$

Proposition 3 *In equilibrium, if non-information-driven trades in the current period are predominantly buys, i.e.,*

$$\Pr[V_t^u > 0 | X_{t-1}^i, u_{t-1}] < \Pr[V_t^u < 0 | X_{t-1}^i, u_{t-1}],$$

then

$$\text{cov}[r_t, |V_t^u| | X_{t-1}^i, u_{t-1}] \geq 0;$$

otherwise, if non-information-driven trades in the current period are predominantly sells, i.e.,

$$\Pr[V_t^u > 0 | X_{t-1}^i, u_{t-1}] > \Pr[V_t^u < 0 | X_{t-1}^i, u_{t-1}],$$

then

$$\text{cov}[r_t, |V_t^u| | X_{t-1}^i, u_{t-1}] \leq 0.^{11}$$

Proposition 2 implies that, if $\frac{c}{a} \sim 0$,

$$E[r_t] = -\text{cov}(r_t, \pi_t^u).$$

The covariance between the asset payoff and the relative change in volume predicts the return observed in prices. It is the relative change in aggregate volume rather than the absolute change that matters. The magnitude of this apparent return predictability is thus potentially large and is not directly constrained by the size of the fixed cost.

¹⁰ See a proof of Proposition 2 in Appendix B.

¹¹ See a proof of Proposition 3 in Appendix B.

Proposition 3 claims that this covariance can be either positive or negative. The return predictability driven by this covariance is most pronounced when unbalanced non-information-driven trades accompany information asymmetry.

1.4.2 Momentum

The existence of price-independent adverse selection drives a wedge between the returns actually achieved by a marginal uninformed investor and the returns observed in prices. This discrepancy in returns can be either positive or negative. Momentum arises endogenously in this model.

Proposition 4

$$E [r_{t+1} | r_t > 0 \text{ and } X_t^i > 0] > 0;$$

and, similarly,

$$E [r_{t+1} | r_t < 0 \text{ and } X_t^i < 0] < 0.^{12}$$

In this model, a large positive return r_t often coincides with low concentration of ownership by the uninformed as a whole immediately before the realization of r_t . The uninformed thus expect to buy following the positive stock performance. In the presence of price-independent adverse selection, the uninformed are mostly likely to acquire the shares when the asset is least desirable. The current price p_t thus contains a downward adjustment to compensate investors for this adverse selection in quantity. The return r_{t+1} in the next period will appear to be higher than is justified. The opposite occurs for a loser stock.

The positive return autocorrelation results from information-induced biases in asset allocation. Informed investors establish large positions to exploit their information advantage and would like to rebalance their holdings after the realization of extreme stock performance. This tendency to unwind the information-induced bias in asset allocation generates unbalanced non-information-driven trades in the ensuing periods. Momentum thus arises as passive uninformed liquidity providers demand a compensation for price-independent adverse selection.

In contrast, if the informed have not managed to exploit the news before its release, returns do not display momentum. The fluctuation in price sometimes results from the variation

¹²See a proof of Proposition 4 in Appendix C.

in mean-reverting noise trades, which leads to return reversal in this model, as is stated in Proposition 5.

Proposition 5

$$E [r_{t+1} | r_t > 0 \text{ and } X_t^i = 0] < 0;$$

and, similarly,

$$E [r_{t+1} | r_t < 0 \text{ and } X_t^i = 0] > 0.^{13}$$

Extreme stock performance typically goes hand in hand with information asymmetry, so stocks that have just yielded extreme returns should in general exhibit momentum, as is demonstrated by the simulated momentum profits in Table 1.3.

Table 1.3 summarizes the simulated momentum trading profits arising in this dynamic model, when $\beta = 0.5$, $d = 1$, $\frac{\alpha}{a} = 0.6$, $h = 0.011$, and $\frac{\epsilon}{a} = 0.01$. The reported statistics are based on 100 simulations with a panel of 1000 stocks and 100 periods. The table shows the average dollar gains per period over the formation period (column 1), and one-period dollar gains over the first period up to the fifth period (column 2 through 6) ensuing the portfolio formation. Each panel includes simulated profits for the formation horizon of both one and two periods (row 1 and 3). Because it is not meaningful to report the corresponding t-statistics, I report instead a statistic defined as the sample probability of a random variable having the same sign as the respective mean (row 2 and 4).

For comparison, Table 1.3 also includes simulation results for the benchmark models.¹⁴ Panel (A) presents results for the first benchmark model with information asymmetry only. Without fixed transaction cost, price fully reveals the private signal in this model and thus eliminates exploitable information advantage. As a result, momentum profits are on average zero, for any J-K strategy. Panel (B) presents results for the second benchmark model with fixed transaction costs only. No investor knows d_{t+1} in advance. Winners are stocks that have had higher dividends and whose supplies have decreased recently, and losers are stocks that have had lower dividends and whose supplies have increased recently. Sorting on dollar gains correlates with sorting on noisy supplies. Reversals in return thus result from reversals

¹³ See a proof of Proposition 5 in Appendix C.

¹⁴ See Appendix D for the analysis of benchmark models.

in noisy supply, as is predicted by Proposition 5. In contrast, Panel (C) demonstrates the combined effect of information asymmetry and fixed transaction costs – momentum. Panel (D) shows the simulated momentum profits weighted by the volume of trades that involve uninformed investors. As is predicted by Proposition 2, the weighted momentum profits is just large enough to compensate investors for the fixed transaction cost. The return momentum in this model lasts for no more than two periods. This short duration of momentum results from the artificial assumptions of quick mean-reversion in noisy supplies and the linear utility function.

[INSERT TABLE 1.3]

1.5 Empirical Implications and Findings

1.5.1 Return and Volume

Proposition 2 provides an immediately testable empirical claim on return and volume,

$$|E[r_t \pi_t^u]| = \frac{c}{a},$$

where $\pi_t^u = \frac{|V_t^u|}{E[|V_t^u|]}$.

Any reasonable reckoning of fixed trading costs in practice suggests it is plausible to ignore the direct effect of the fixed cost $\frac{c}{a}$. Let V_t denote the unsigned aggregate trading volume and V_t^{nu} denote the unsigned volume of trades that do not involve uninformed marginal investors as are delineated in the model. Similarly, define π_t as the ratio of $\frac{V_t}{E[V_t]}$. Replacing π_t^u with π_t , we obtain that

$$|E[r_t \pi_t]| \leq |E[r_t]|$$

and, if $\frac{E[V_t^{nu}]}{E[V_t]}$ is sufficiently small,

$$|E[r_t \pi_t]| \sim 0.^{15}$$

The theory implies that for stocks that display significant return predictability after adjust-

¹⁵See Appendix B for a detailed derivation.

ment for risk, i.e., $|E[r_t]| > 0$,

$$|E[r_t]| - |E[r_t\pi_t]| > 0, \quad (1.6)$$

and

$$|E[r_t\pi_t]| \sim 0 \text{ if } \frac{E[V_t^{nu}]}{E[V_t]} \sim 0. \quad (1.7)$$

Equation (1.6) claims that the return obtainable by an uninformed marginal investor deviates from the return observed via prices when there is observed return predictability. Equation (1.7) derives from the unpredictability of return actually achievable by a marginal investor. Based on these two conditions, the remainder of this section will empirically test two null hypotheses:

$$\text{Null Hypothesis I: } E[r_t\pi_t] = 0;$$

$$\text{Null Hypothesis II: } E[r_t] - E[r_t\pi_t] = 0.$$

As is demonstrated in the literature, an equal-weighted momentum-based arbitrage portfolio delivers positive profits consistently over time, i.e., $E[r_t] > 0$. The current model argues that such an arbitrage portfolio may not be feasible in practice. For an investor who pursues momentum trading strategies but does not possess superior information, the arbitrage portfolio he actually obtains can differ from the equal-weighted portfolio. Therefore, the efficient market hypothesis should imply $E[r_t\pi_t] = 0$ instead of $E[r_t] = 0$. Given that $E[r_t] = 0$, it follows that $E[r_t] - E[r_t\pi_t] > 0$.

Data

Stock data on return, price, and trading volume come from CRSP. Data on trading volume are unavailable for NASDAQ stocks prior to November 1, 1982.¹⁶ In order to include stocks on all exchanges, the sample period starts in January 1983 and ends in December 2004. This study restricts data to all ordinary common stocks¹⁷ of non-financial firms¹⁸ that are traded on NYSE, AMEX or NASDAQ. Following Jegadeesh and Titman (2001), I exclude stocks in the smallest decile where breakpoints are determined within the NYSE stocks and stocks

¹⁶See page #110 of "Data Description Guide for CRSP US Stock and CRSP US Indices Databases."

¹⁷Stocks with a CRSP share code ("shrcd") of either 10 or 11.

¹⁸A firm is considered to be in the financial industry if its 4-digit SIC code is between 6000 and 6999. Including financial firms do not alter the results qualitatively.

with prices lower than five dollars on the formation date, which is intended to preclude issues regarding small firms and extremely low liquidity.

At the end of each month t , stocks are sorted into deciles according to their cumulative returns compounded over the prior one year, from month $(t - 12)$ through $(t - 1)$. A stock will drop out of the sample if it has at least one missing monthly return during the formation period. The momentum strategy examined in this paper takes a long position in an equal-weighted portfolio of stocks in the highest return decile (defined as the winner stocks) and a short position in an equal-weighted portfolio of stocks in the lowest return decile (defined as the loser stocks). There is a one-month interval between the twelve-month formation period and the six-month investment period, to avoid possible short-run return predictability due to microstructure issues.

As is documented in the literature, the profitability of a momentum trading strategy is measured by the difference in average first-month return between the monthly rebalanced winner and loser portfolios. I also measure the momentum profits over a longer horizon, specifically over six months, by calculating the average monthly gains on an overlapping portfolio that in any calendar month holds an equal proportion of the zero-investment momentum portfolios selected in the previous six months.

Let I_s^W and I_s^L denote respectively the winner and the loser portfolios that are formed at the end of month s . For a stock i that belongs to I_s^W or I_s^L , v_t^i refers to the sum of all daily dollar trading volumes in month t . Daily dollar volume is the product of daily volume and daily price, both of which are provided in the CRSP daily stock file. I use dollar volumes in place of share volumes to tease out artificial variations resulting from stock splits or stock dividends. Because trading volumes vary widely across stocks, the average volume $\bar{v}_t^i \equiv \sum_{\tau=s+1}^{s+6} \frac{v_\tau^i}{6}$ over the corresponding six-month investment period is applied to standardize v_t^i so that $\frac{v_t^i}{\bar{v}_t^i}$ becomes a proxy for V_t that is comparable across stocks. \bar{v}_t^i is calculated using monthly observations during the investment period, since the trading volume of momentum stocks likely behave differently before and after the formation date. The cross-sectional average $\frac{v_t^i}{\bar{v}_t^i} \equiv \frac{\sum_{i \in I_s^k} v_t^i}{N}$ of the respective winner ($k = W$) or loser ($k = L$) portfolio is used as a proxy for $E[V_t]$, assuming that the portfolio is well-diversified. I then construct weights w_t^i as a proxy for π_t , such

that $w_t^i = \left[\frac{v_t^i}{\bar{v}_t^i} \right]^{-1} \frac{v_t^i}{\bar{v}_t^i}$. Hereafter, I call this set of weights the PIAS (the acronym for price-independent adverse selection) ratios, which represent the adjustment factor on stock returns to account for price-independent correlation between asset payoff and holdings. The PIAS weights average to one by construction. Finally, the difference in $\frac{\sum_{i \in I_{t-s}^k} r_t^i w_t^i}{S}$ between the winner ($k = W$) and the loser ($k = L$) portfolios forms an empirical proxy for the momentum trading profits that are actually achieved by an uninformed investor in time t . This paper reexamines the profitability of momentum-based arbitrage, for $S = 1$ and for $S = 6$.

The results of the model are only applicable to information asymmetry regarding idiosyncratic risks only, and extending the analysis to information asymmetry regarding macro risks is out of the scope of the current paper. The empirical tests should therefore weight the idiosyncratic component of return, but I proceed with raw returns instead for the following reasons. First, to filter out excess returns by employing a factor model introduces considerable noises to the system and imposes extra restrictions on the data set. In particular, stocks with extreme returns are likely to incur large measurement errors in beta, which can be amplified through the subsequent weighting procedure. In addition, it is well known that neither the CAPM nor the Fama-French three-factor model explains return momentum. Hence, even if there exists some correlation between volume and beta, the biases should offset once we subtract the mean of the short portfolio from that of the long portfolio. There is no existing theory to my knowledge that predicts systematic difference in volume-beta correlation.

Figure (1 – 1) displays the time-variation of both the commonly-applied measure and the theory-based measure of momentum profits. The profitability measure weighted by the PIAS ratio and the standard equally-weighted average move in tandem. The two trajectories are almost identical except for a slight downward shift of the former relative to the latter. Figure (1 – 2) plots the difference between the PIAS-weighted measure and the equally-weighted measure. The return adjustment for price-independent adverse selection does not appear to spike around major episodes of market illiquidity. Unreported results suggest that macro factors, including the market, SMB¹⁹, HML²⁰, the Pástor-Stambaugh liquidity and the Sadka liquidity

¹⁹The SMB factor is also known as the size factor and is measured as the average return of small firms minus that of big firms. See Fama and French (1993) for details.

²⁰The HML factor is also known as the value factor and is measured as the average return of high-BM-ratio

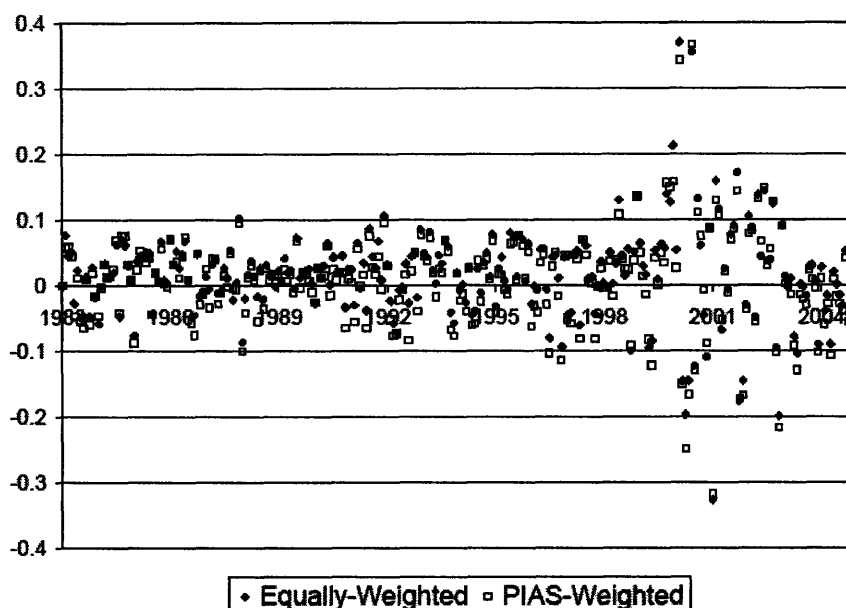


Figure 1-1: Momentum Profits, 1983-2004

factors, explain little of the variation in the PIAS adjustment, which supports that the model provides a non-factor-based explanation of return predictability.

Momentum Profits Reexamined

Table 1.4 compares the standard measure and the PIAS-adjusted measure of momentum profits for the entire sample period from 1983 to 2004. The top panel reports momentum profits without risk adjustment, and the next two panels, respectively, report risk-adjusted estimates based on the CAPM and the Fama-French three-factor model. Similarly, Table 1.5 shows the comparison for the subsample period from 1994 to 2004.

[INSERT TABLE 1.4 and 1.5]

I report simple t-statistics for all empirical estimates. The theory does not predict any autocorrelation for all time series in Table 1.4 and 1.5, which is in fact supported by unreported

firms minus that of low-BM-ratio firms. See Fama and French (1993) for details.

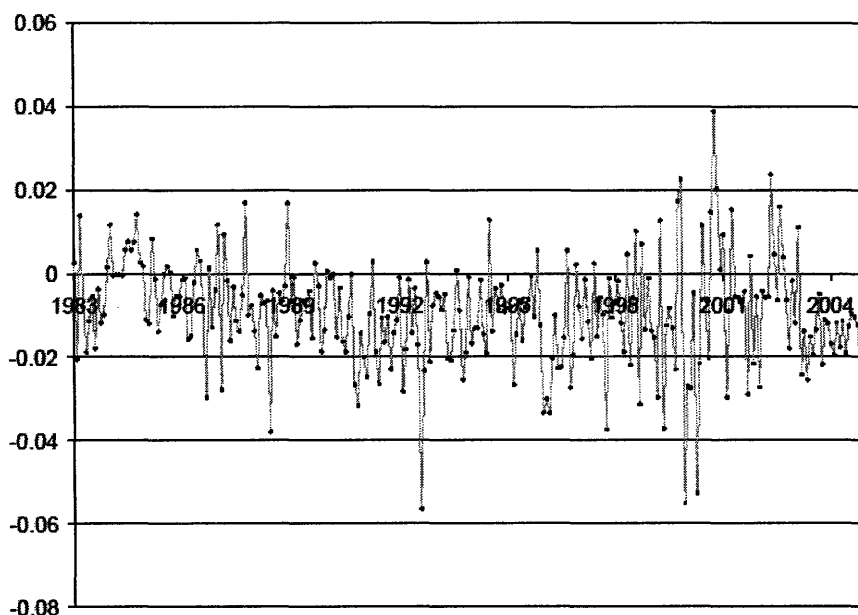


Figure 1-2: The PIAS Adjustment of Momentum Profits, 1983-2004

results. It is verified that the statistical significance does not alter with Newey-West corrections for serial correlation in errors nor with Huber-White corrections for heteroskedasticity.

It is well-documented in the literature that momentum profits have been persistently and significantly positive. Table 1.4 first replicates the standard measures of momentum profits. The estimates are consistent with previous findings. For the whole sample period of 1983 to 2004, the past winner portfolio continues to outperform the past loser portfolio by a monthly average of 1.54% over the first month of the holding period. The corresponding t-statistic is 3.59. The continuation in return stays significant, both economically and statistically, over six months. The six-month average of monthly momentum profits is 0.87%. The t-statistic is relatively low but still indicates a significance level of about 2%. For the subsample period of 1994 to 2004, which starts one year after the publication of Jegadeesh and Titman (1993), the first-month average of momentum profits becomes even higher though less significant statistically. The six-month average becomes statistically insignificant, but the alpha based on the three-factor model remains as high as 1.25% with a t-statistic of 1.95. The momentum alphas

based on the CAPM are almost identical to the raw estimates without risk adjustment. The momentum alphas based on the three-factor model are in general of slightly larger magnitude and have a higher t-statistic.

In contrast, weighting returns by the PIAS ratio eliminates both the economic significance and the statistical significance of profitability estimates. The PIAS-weighted average is 0.62% over the first month and -0.05% over a six-month holding period, and neither of the two is statistically significant. Similarly, the weighting removes significance for all risk-adjusted estimates except for one case. The first-month three-factor alpha of the entire sample period is 0.96% with t-statistic equal to 2.19, compared to the equally weighted average of 1.87% with t-statistic equal to 4.39.

As is predicted by the model, the correction is significant when $|E[r]| > 0$. Table 1.4 and 1.5 also show the magnitude and the statistical significance of return adjustment for PIAS. The PIAS adjustment is uniformly about 1% for different sample periods and for different holding horizons, either over one month or over six month. Although the momentum profits appear to be more volatile from 1994 to 2004, the t-statistic associated with the adjustment remains high and close to 10. The significant difference between the PIAS-weighted and the equally-weighted measures invalidates the possibility that data falsely support the null hypothesis owing to a lack of statistical power.

For any v_t^i , I standardize the volume measure through dividing it by the respective average \bar{v}_t^i which averages six monthly observations including v_t^i . The use of a short window potentially creates a bias that understates the relative deviation of v_t^i . Therefore, the constructed PIAS weights, if anything, tend to under-correct the bias in the standard measure.

A usual suspect of momentum is the use of positive-feedback strategies as is discussed in De-Long, Shleifer, Summers and Waldmann (1990) or in Chan, Jegadeesh and Lakonishok (1996). If positive-feedback trades push price further along the direction of its previous movement and thus cause momentum, the contemporaneous return would be positively correlated to the PIAS weight for winners and negatively for losers. Therefore, the results in Table 1.4 and 1.5 contradict this alternative explanation.

Finally, recall that the model predicts that $|E[r_t \pi_t]| \sim 0$ if and only if $\frac{E[V_t^{nu}]}{E[V_t]} \sim 0$. Given $|E[r]| > 0$, $|E[r_t \pi_t]| \sim 0$ should imply $\frac{E[V_t^{nu}]}{E[V_t]} \sim 0$. Hence, the empirical findings in Table 1.4

and 1.5 suggest little influence of $\frac{E[V_t^{nu}]}{E[V_t]}$ over a period of six months but a perhaps nontrivial role of $\frac{E[V_t^{nu}]}{E[V_t]}$ over the first month, for momentum stocks. Although the momentum profits are weaker over a period of six months, the PIAS adjustment appears the same as, if not larger than, that of the first month.

Another Application: PEAD

This paper provides a general framework to study a financial market that is subject to both fixed transaction costs and information asymmetry. Although this study is motivated by the momentum anomaly, the range of applications of this model are not limited to this particular empirical phenomenon alone. To demonstrate the versatility of the model, I therefore apply it to another well-known puzzle in the finance and accounting literature, the post-earnings-announcement drift (hereafter, PEAD).

The PEAD resembles the momentum anomaly in many aspects. Bernard and Thomas (1989) document that the PEAD lasts up to 180 trading days, or three quarters, relative to the earnings announcement, dies out around the fourth quarter and eventually disappears with a tiny reversal. The same pattern holds across different size groups. I replicate the phenomenon for the sample period from 1983 to 2004 and for the subsample period from 1994 to 2004.

I construct a PEAD-based arbitrage portfolio that assumes a long position in firms of the top decile with highest SUE²¹ in the previous quarter and a short position in firms of the bottom decile. Although the PEAD and the momentum anomaly have several traits in common, the composition of the arbitrage portfolios built upon the two empirically identified anomalies differs widely. On average, about 13% (16%) of the firms in the highest (lowest) return decile overlap with about 11% (14%) of the firms in the corresponding highest (lowest) SUE decile. This verifies that we are testing the theory with two distinctive sets of stocks, since randomly selecting a tenth of all firms will generate an average of 10% overlap between any two independent random draws.

The sample includes all firms that are traded on NYSE/AMEX or NASDAQ and have at

²¹SUE stands for standardized unexpected earnings. The unexpected earnings is estimated through a random-walk model allowing for a non-zero drift by using the latest twenty quarterly observations. The estimate is then standardized through dividing it by the standard deviation.

least ten consecutive earnings²² observations on Compustat. A further screening requires firms to have March, June, September or December fiscal-year ends, to ensure that fiscal quarters are aligned. The arbitrage portfolios are equal-weighted and are rebalanced quarterly at the end of every calendar quarter. To avoid microstructure issues, the sample excludes firms with stock price lower than \$5 at the end of the earnings quarter. Firms who announce earnings later than two months after a fiscal quarter ends are also excluded so that there is at least a one-month interval between the earnings announcement and the investment period. This screening only applies to a small fraction of firms, as normally more than 90% of the earnings announcements come out within two months after the end of a fiscal quarter. The investment strategy is examined respectively for a holding period of one and two quarters, and the latter employs an overlapping portfolio that in any calendar month holds an equal proportion of the zero-investment arbitrage portfolios selected within the previous six months.

Table 1.6 compares the standard measure and the PIAS-adjusted measure of profits on the PEAD-based arbitrage portfolio for the entire sample period from 1983 to 2004. The top panel reports monthly profits without risk adjustment, and the next two panels, respectively, report risk-adjusted profits based on the CAPM and the Fama-French three-factor model. Similarly, Table 1.7 shows the comparison for the subsample period from 1994 to 2004.

[INSERT TABLE 1.6 and 1.7]

Once adjusted for the price-independent adverse selection, the PEAD, either the raw or the risk-adjusted measure, is no longer statistically nor economically significant, for both sample periods. The correction to the standard measure is shown to stay significant even when the PEAD appears weak in the latest decade. In addition, the correction varies little with different means of risk adjustment.

The drift in this paper appears relatively weaker than in some other studies of PEAD. Firms are ranked quarterly based on the latest earnings announcement so that the top and the bottom SUE decile consist of a diverse cross-section of firms. The portfolio is formed at a quarterly frequency, because diversity is required for the empirical PIAS adjustment to be effective. In addition, this paper employs SUE as a proxy for earnings surprise. Normalizing the surprise

²²Earnings are measured before extraordinary items, i.e., Compustat data8.

by the standard deviation of earnings growth reduces the portfolio weight on small firms which tend to have noisier earnings growth and larger drift. A weaker drift however does not obscure the evidence of the return adjustment for PIAS.

Recall that the model predicts that $|E[r_t \pi_t]| \sim 0$ if and only if $\frac{E[V_t^{nu}]}{E[V_t]} \sim 0$. Given $|E[r]| > 0$, $\left|E\left[r_t \frac{V_t}{E[V_t]}\right]\right| \sim 0$ should imply $\frac{E[V_t^{nu}]}{E[V_t]} \sim 0$. Hence, the empirical findings in Table 1.6 and 1.7 suggest little influence of $\frac{E[V_t^{nu}]}{E[V_t]}$ over a period of six months but a perhaps nontrivial role of $\frac{E[V_t^{nu}]}{E[V_t]}$ over the first quarter, especially for the first half of the sample period.

1.5.2 Predictability of Excess Returns

In a standard asset-pricing model, the efficient market hypothesis permits no predictability of risk-adjusted returns, i.e., $E[r_t] = 0$. In contrast, the current model with both information asymmetry and fixed transaction costs derives that, if $\frac{\alpha}{a} \sim 0$,

$$E[r_t] = -cov(r_t, \pi_t).$$

This return predictability does not contradict the semi-strong form of market efficiency, because the return observed via prices deviates from the return obtainable by a marginal investor in the current model. The return predictability should be most pronounced when high information asymmetry accompanies unbalanced non-information-driven trades, according to Proposition 3.

Predicting Return Momentum – New Evidence

Two attributes of stocks with extreme past performance account for momentum. First, extreme stock performance and information asymmetry go hand in hand. Even after the realization of unusual returns, the degree of information asymmetry will probably remain high. Second, privately informed investors are likely to have accumulated excessive positions in the previous period. The deviation of their holdings from a neutral position generates a subsequent flow of non-information-driven trades that are predominantly buyer- or seller-initiated. Therefore, one way to predict the strength of return momentum is to investigate to what extent informed investors manage to exploit their information advantage.

In general, informational buys induce less price impact when accompanied by liquidity sells, and vice versa. Therefore, the ratio of liquidity buy volume to liquidity sell volume before the realization of extreme stock performance, hereafter referred to as the BOS ratio, provides a proxy for the extent to which informed investors profits from their private information. In particular, the higher (lower) the BOS ratio, the stronger the momentum of a loser (winner) stock.

Proposition 3 motivates an empirical proxy for the BOS ratio, $cov\left(\frac{v_t^i}{E[v_t^i]}, r_t^i\right)$. For a stock i belonging to the monthly-rebalanced momentum portfolio that is formed in month s , the mean $E[v_t^i]$ and the covariance $cov(v_t^i, r_t^i)$ are measured using monthly observations $(v_{s-12-\tau}^i, r_{s-12-\tau}^i)$ over the twelve months immediately before the formation period, i.e., $\tau = 1, \dots, 12$.

Stocks are then sorted on the BOS ratio into three quantiles within the winner (R10) and the loser (R1) portfolios. P3 and P1, respectively, denote the subgroup that should have the strongest and the weakest momentum in return. Table 1.8 reports the risk-adjusted returns for each subportfolio after the sorting. The left panel shows the alphas based on the CAPM, and the right panel shows the alphas based on the three-factor model. Panel (A), (B) and (C) present the risk-adjusted returns over a holding period of one, three and six months, respectively.

As is predicted by the theory, the empirical proxy for the BOS ratio predicts return momentum for both the winner stocks and the loser stocks. Over the first month, P3 outperforms P1 by 0.65% for winners, and P1 underperforms P3 by 0.95% (CAPM- α) and by 0.82% (FF- α) for losers. Over a holding period of three months, P3 outperforms P1 by 0.6% per month for winners, and P1 underperforms P3 by 0.59% (CAPM- α) and by 0.45% (FF- α) per month for losers. Over a holding period of six months, P3 outperforms P1 by 0.6% per month for winners, and P1 underperforms P3 by 0.32% (CAPM- α) and by 0.18% (FF- α) per month for losers. The predicted difference remains significant and almost constant over six months for winners, but starts at a very high level and then falls gradually for losers. The different patterns suggest that informed investors are more likely to hold excessive positions of winners for longer, which probably results from the relatively high cost of short selling. In addition, the three-factor alpha of the R10-P1 subportfolio is no longer significant at the 5% level, except for being marginally significant over the first month.

[INSERT TABLE 1.8]

Table 1.9 presents the summary statistics for some characteristics of the subportfolios. In particular, the numbers shown in the table are the time-series average of respective summary statistics for the monthly-rebalanced subportfolios. For winners, the stocks with stronger momentum in fact have larger market capitalization and lower past return on average. For losers, the stocks with stronger momentum have slightly smaller market capitalization and similar past return. Therefore, it is unlikely due to correlation with size or past stock performance that the BOS ratio predicts return for momentum stocks.

[INSERT TABLE 1.9]

Predicting Return Momentum – Existing Evidence

Section 3.2.1 offers one predictor of return momentum. In principle, proxies for information asymmetry, specifically proxies for the extent of exploitable information asymmetry, and proxies for the market structure should somehow predict momentum.

Hong, Lim and Stein (2000) test the gradual-information-diffusion model of Hong and Stein (1999) and establish three key empirical results regarding the profitability of momentum strategies: momentum strategies are most profitable among firms with small market capitalization and low analyst coverage; furthermore, the marginal importance of analyst coverage is greatest among small stocks. Analyst coverage is essentially a measure of information asymmetry. Firm size is also a proxy for the degree of information imperfection and moreover is an important determinant of the underlying market structure. The dual role of size can explain why it affects both the magnitude of momentum and the first-order derivative with respect to the degree of information asymmetry. HLS (2000) also find that the effect of residual analyst coverage is entirely driven by what happens in the loser stocks. Although they argue that information problem is more severe for bad news, it should also exist for good news. What analyst coverage may not capture is to what extent the information advantage is exploitable by privately informed investors. Table 1.8 employs a different proxy and augments their findings.

Grinblatt and Han (2002) and Frazzini (2005) provide empirical evidence supporting a behavioral explanation of the momentum anomaly, which builds upon the disposition effect, the

tendency of investors to ride losses and realize gains. Both studies construct some measures of unrealized capital gains/losses by using stock market data or holdings data. The constructed proxies for capital gains/losses “overhang” subsume other predictors of short-term stock returns, such as past returns and volumes. The model in this paper provides an alternative interpretation of their results. For example, consider the overhang spread in Frazzini (2005). Good (bad) news induces high (low) returns and relatively large turnover right before the runup (rundown) when privately informed investors can exploit their information advantage. By definition, the measure of capital gains/losses overhang is mostly affected by recent returns. Given that a representative investor, or here mutual fund, is equally likely to be informed or uninformed, recent good (bad) news tends to be associated with exploitable information asymmetry when the representative investor holds a large capital gains (losses) overhang. As mutual funds are prohibited from short selling, good news with large capital losses or bad news with large capital gains implies small price movement or low trading volume around the recent news, which suggests that those stocks are probably immune to information asymmetry or that privately informed investors fail to profit from their superior information. The combination of accrued capital gains/losses overhang and recent news content conveys information on the degree of information asymmetry and the characteristics of non-information-driven trades in the current period. This paper predicts exactly the same result as is documented in Frazzini (2005): the “overhang spread” is identified as the “maximum-profits” strategy, and, what’s more, the alphas of the “negative overhang spread” are statistically insignificant, while the disposition effect fails to explain the zero “negative overhang spread.”

1.6 Related Literature

The momentum anomaly remains one of the most puzzling phenomena in asset pricing owing to its sizable magnitude and its fairly long duration.

A hypothetical portfolio of past strong performers earns a positive risk-adjusted return over the ensuing three to twelve months, while the risk-adjusted return on holding past weak performers is negative. The difference in alpha between the top- and the bottom-past-return-decile portfolio is roughly 1% per month when based on the CAPM, and the magnitude becomes

slightly larger when based on the Fama-French three-factor model.

Most empirical anomalies, such as the size or the value effect, either disappear or attenuate after their debut in the academic literature, as is surveyed by Schwert (2003). However, the momentum alpha appears most strongly over the most recent decade after the publication of the seminal paper by Jegadeesh and Titman in 1993. Moreover, Lewellen (2002) shows that this cross-sectional effect exists not only among individual stocks but also among diversified portfolios. The robustness and the pervasiveness suggest that behavioral biases are unlikely the cause of momentum.

Risk-based models have not yet been successful at explaining momentum. Fama and French (1996) claim that the three-factor model fails to explain away the momentum alpha because loser stocks load more on SMB and HML than winners. The sizable magnitude of the momentum alpha also precludes a rational explanation of the momentum anomaly through time-varying risk premium(s). Lewellen and Nagel (2006) argue that the observed fluctuation in beta(s) can hardly match the required scale of variation to explain a large unconditional alpha. Grundy and Martin (2001) show that factor models can at best explain the variation in momentum profits but not the mean.

A factor-based explanation would thus require the discovery and understanding of a new risk factor beyond those commonly accepted. Berk, Green and Naik (1999) provide a model that generates momentum over relatively long horizons as real investment decisions alter the systematic risk of firms over time with some persistence. Johnson (2002) points out that return is a convex function of the growth rate of cash flow. The curvature increases with the growth rate, and so does the growth rate risk. Both papers provide a partial-equilibrium analysis and imply a potentially highly nonlinear conditional factor model, but offer no guidance on finding a new risk factor.

This paper provides a non-factor-based rational explanation, by emphasizing the interaction between fixed transaction costs and information asymmetry. The simultaneous presence of the two market imperfections leads to potentially magnified and prolonged impacts on price and trading behavior.

Information asymmetry can be a crucial element in understanding momentum. The top past-return-decile firms earn an astonishingly high return averaging more than 100% per an-

num, and the bottom past-return-decile firms lose about 40% on average. Huge gains/losses accrued on one stock suggest that an enormous amount of information must have been disclosed about the underlying firm during the prior one year, which must have encouraged information arbitrage. High return volatility and high information asymmetry are likely to continue, though possibly to a lesser extent, following the realization of extreme stock performance.

In a market with information imperfections alone, the price before risk adjustment cannot deviate from the expected payoff based on the publicly available information set, as long as there are sufficiently many rational uninformed investors who are not constrained to trade. A model of information asymmetry hence cannot account for the momentum phenomenon without incorporating some sort of irrationality or another market imperfection.²³

A number of recent studies argue that momentum trading strategies often require frequent trading in disproportionately high cost securities. Chen, Stanzl and Watanabe (2001), Korajczyk and Sadka (2004), Lesmond, Schill and Zhou (2004) gauge various transaction costs and demonstrate that costs significantly reduce momentum profits. This paper contributes to the existing literature by inquiring as to not only why momentum persists but also how momentum comes into existence in the first place and why overall transaction costs are especially high for momentum stocks.

Liquidity and momentum are intrinsically linked in my model. Extreme stock performance predicts ensuing non-information-driven trades, so the liquidity cost derived from price-independent adverse selection becomes prominent particularly for momentum stocks. The aggravated cost of liquidity can lead to either positive or negative seemingly abnormal returns, so illiquidity does not always imply positive “return premium.”

Pástor and Stambaugh (2003) and Sadka (2006) explore several aggregate liquidity measures as proxies for a liquidity risk factor. Both papers find that adding a liquidity risk factor reduces the importance of momentum alpha. This study investigates liquidity and momentum from a different angle and provides a non-factor-based explanation.

Ahn, Conrad and Dittmar (2003) extract a stochastic discount factor from a set of industry portfolios. The nonparametric risk adjustment explains roughly half of momentum strategy

²³See DeLong, Shleifer, Summers and Waldmann (1990), Barberis, Shleifer and Vishny (1998), Daniel, Hirshleifer and Subrahmanyam (1998), and Hong and Stein (1999).

profits. Their paper may have simply shifted the focus of the pricing puzzle to industry portfolios, as in Moskowitz and Grinblatt (1999). In addition, Ahn, Conrad and Dittmar (2003) show that the dynamically weighted industry momentum portfolio lies beyond the mean-variance efficiency frontier formed by passive industry portfolios. Therefore, it is the dynamic nature of industry momentum strategy, rather than the industry component, that is crucial. Consistent with the empirical evidence, in this model, it is the adverse-selection cost of liquidity incurred in share redistribution that drives momentum.

The current model generates positive return autocorrelation through the deviation in share distribution. As the bias in share distribution corrects slowly, the return predictability will appear more strongly over a longer horizon. Examining institutional holdings of momentum stocks verifies that there is indeed strong persistence in the deviation of holdings, which explains why momentum is manifest in monthly observations over a quarter up to a year.

1.7 Conclusion

This paper combines two commonly acknowledged market imperfections, information asymmetry and fixed transaction costs, to derive a simple model of momentum. The returns achievable by a marginal investor and the average returns observed via prices can differ widely in a market with multiple trading frictions. By taking into account an extra dimension of uncertainty in investment that is suppressed in a standard asset-pricing model, this study explains away both the economic significance and the statistical significance of the momentum anomaly for the sample period from 1983 to 2004.

The theoretical analysis in this paper is confined to the impact of asymmetric information regarding idiosyncratic returns only. Although the simple model provides an adequate framework to investigate the predictability of excess returns, a generalization of the model to allow for differential information on macro factors is important from both the theoretical and the empirical point of view.

The model predicts a cost of liquidity due to price-independent adverse selection, which is jointly determined by the degree of information asymmetry and the buy/sell ratio of non-information-driven trades. Both the PIAS ratio and the BOS ratio essentially reflect certain

aspects of liquidity. These two empirical proxies might appear similar to existing liquidity measures, but the underlying theoretical motivation differs. This model suggests that liquidity might well be a firm-specific characteristic, which, however, does not falsify the concept of liquidity as an undiversifiable risk factor. The liquidity cost derived from price-independent adverse selection can lead to either positive or negative seemingly abnormal return, so illiquidity does not always imply positive “return premium.” Examining a market that is subject to both information asymmetry and fixed transaction costs may also shed light on our understanding of market liquidity.

1.8 Appendices

1.8.1 Appendix A. Equilibrium – Proof of Proposition 1

This appendix proves the existence of an REE as defined in Definition 1 by presenting such an equilibrium.

I will first propose an equilibrium characterized by the price function that is described in Table 1.1 and the equilibrium holdings that are described in Table 1.2 (a)–(c). Next I will show that the proposed equilibrium is indeed an equilibrium by looking closely at two representative states: $(0, 0, u, d)$ in which price is fully revealing and $(-a, u, 0, d)$ in which price is not revealing. The analysis for the other states is similar.

In addition, let $q(X_t^i, u_t)$ denote the conditional expectation of price $E[p_t | X_t^i, u_t]$. In the end of the proof, I will verify that the state space indeed consists of 36 states, and that the $q(X_t^i, u_t)$ function satisfies the following as $0 < \beta \ll 1$:

$$\begin{aligned} q(0, u) &= -q(0, -u) = \frac{2}{\beta}q(-a, -u) = -\frac{2}{\beta}q(a, u) = \frac{4a - u}{2(5u + a)}\beta d, \\ q(-a, 0) &= -q(a, 0) = \frac{2a - u}{4a + u}\beta d, \\ q(-a, u) &= -q(a, -u) = \frac{2a}{3u + 2a}\beta d, \\ \text{and } q(0, 0) &= 0. \end{aligned}$$

Case I. $(X_t^i, u_t, u_{t+1}, d_{t+1}) = (0, 0, u, d)$

Optimization of Informed Investors Given prices, an informed investor $j \in [0, 1]$ faces the following optimization problem:

$$\begin{aligned} &\max_{x_{t+1}^j} E_t^j \left[x_t^j (d_t + p_t) + x_{t+1}^j [\beta (d_{t+1} + p_{t+1}) - p_t] - h |x_{t+1}^j| \right] \\ &= x_t^j E_t^j [d_t + \beta (d_{t+1} + p_{t+1})] + E_t^j \left[(x_{t+1}^j - x_t^j) [\beta (d_{t+1} + p_{t+1}) - p_t] \right] - h |x_{t+1}^j| \end{aligned}$$

subject to $x_{t+1}^j \in [-a, +a]$.

Since price is fully revealing in the current state, the informed can infer u_{t+1} and X_{t+1}^i from price p_t and u_t with perfect precision. Because the informed know all the relevant information

regarding d_{t+1} and p_{t+1} that is available to the economy, his expectation of his wealth tomorrow is independent of equilibrium allocation, i.e.,

$$E_t^j [d_{t+1} + p_{t+1} | x_{t+1}^j] = E_t^j [d_{t+1} + p_{t+1}], \text{ for any } x_{t+1}^j \in [-a, +a].$$

The first-order condition with respect to x_{t+1}^j when $x_{t+1}^j \neq 0$:

$$E_t^j [\beta (d_{t+1} + p_{t+1}) - p_t] - h \frac{|x_{t+1}^j|}{x_{t+1}^j} + \theta_1 - \theta_2 = 0.$$

θ_1 and θ_2 are, respectively, the Lagrange multiplier for the holdings constraints: $x_{t+1}^j \geq -a$ and $x_{t+1}^j \leq +a$.

Given that $p(0, 0, u, d) = \beta[d + q(0, u)] - \frac{c}{a}$ and $X_{t+1}^i = 0$, $E_t^j [p_{t+1}] = E [p_{t+1} | X_{t+1}^i, u_{t+1}] = q(0, u)$, so

$$\left| \beta (d_{t+1} + E_t^j [p_{t+1}]) - p_t \right| = \frac{c}{a} < h.$$

It is immediate that $x_{t+1}^j = 0$, which also verifies that $X_{t+1}^i = 0$.

Optimization of Uninformed Investors Given p_t and p_{t+1} , an uninformed investor $j \in [1, 1 + n]$ faces the following optimization problem:

$$\begin{aligned} & \max_{x_{t+1}^j} E_t^j \left[x_t^j (d_t + p_t) + x_{t+1}^j [\beta (d_{t+1} + p_{t+1}) - p_t] - CI_{x_{t+1}^j \neq x_t^j} \right] \\ & = x_t^j E_t^j [d_t + \beta (d_{t+1} + p_{t+1})] + E_t^j \left[(x_{t+1}^j - x_t^j) [\beta (d_{t+1} + p_{t+1}) - p_t] \right] - CI_{|x_{t+1}^j - x_t^j| \neq 0}, \end{aligned}$$

subject to $x_{t+1}^j \in [0, a]$.

As all investors know u_t at time t , uninformed investors can infer X_t^i from price p_t and u_t with perfect precision. Moreover, in the current state, price is fully revealing, so the uninformed also know d_{t+1} , u_{t+1} and X_{t+1}^i . $E_t^j [d_{t+1} + p_{t+1} | x_{t+1}^j]$ is thus independent of x_{t+1}^j , and

$$E_t^j [d_{t+1} + p_{t+1} | x_{t+1}^j] = E_t^j [d_{t+1} + p_{t+1}], \text{ for any } x_{t+1}^j \in [0, a].$$

The first-order condition with respect to x_{t+1}^j when $x_{t+1}^j \neq x_t^j$:

$$E_t^j [\beta (d_{t+1} + p_{t+1}) - p_t] + \theta_1 - \theta_2 = 0.$$

θ_1 and θ_2 are, respectively, the Lagrange multiplier for the holdings constraints: $x_{t+1}^j \geq 0$ and $x_{t+1}^j \leq a$.

Facing a fixed transaction cost c , an uninformed investor would like to buy only if $p_t < E_t^j [\beta (d_{t+1} + p_{t+1})]$ and would increase holdings up to his maximum capacity a whenever he buys. Conversely, an uninformed investor would like to sell only if $p_t > E_t^j [\beta (d_{t+1} + p_{t+1})]$ and would reduce holdings all the way to zero whenever he sells.

$$\text{As } E_t^j [\beta (d_{t+1} + p_{t+1}) - p_t] = \frac{c}{a},$$

$$aE_t^j [\beta (d_{t+1} + p_{t+1}) - p_t] - c = 0.$$

Therefore, for an uninformed investor with $x_t^j = 0$, $x_{t+1}^j = 0$ or a in equilibrium. For an uninformed investor with $x_t^j = a$, $x_{t+1}^j = a$.

Market Clearing After the current round of trading, the total supply of the asset is $s + u$. The aggregate holdings of informed investors are 0. The aggregate holdings of uninformed investors who previously hold a shares per account are still $X_{t+1}^u = X_t^u = s - X_t^i = s$. A fraction of $\frac{u}{an-s}$ of uninformed investors with $x_t^j = 0$ will end up with $x_{t+1}^j = a$, and the rest of them will stay with $x_{t+1}^j = 0$. Since $na > s + u + a$, the fraction $\frac{u}{an-s}$ indeed lies in $[0, 1]$. Therefore, the market clears, i.e.,

$$s + u = 0 + s + a \times \frac{u}{an-s} \times \left(n - \frac{s}{a}\right).$$

Case II. $(X_t^i, u_t, u_{t+1}, d_{t+1}) = (-a, u, 0, d)$

Optimization of Informed Investors Given p_t and p_{t+1} , an informed investor $j \in [0, 1]$ faces the following optimization problem:

$$\begin{aligned} & \max_{x_{t+1}^j} E_t^j \left[x_t^j (d_t + p_t) + x_{t+1}^j [\beta (d_{t+1} + p_{t+1}) - p_t] - h |x_{t+1}^j| \right] \\ & = x_t^j E_t^j [d_t + \beta (d_{t+1} + p_{t+1})] + E_t^j \left[(x_{t+1}^j - x_t^j) [\beta (d_{t+1} + p_{t+1}) - p_t] - h |x_{t+1}^j| \right] \end{aligned}$$

subject to $x_{t+1}^j \in [-a, +a]$.

Because the informed know u_t and d_{t+1} and can infer X_{t+1}^j but not u_{t+1} from price p_t ,

$$E_t^j [d_{t+1} + p_{t+1} | x_{t+1}^j] = d_{t+1} + \frac{1}{2} \left[q(X_{t+1}^j, 0) + q(X_{t+1}^j, -u) \right], \text{ for any } x_{t+1}^j \in [-a, +a].$$

The first-order condition with respect to x_{t+1}^j when $x_{t+1}^j \neq 0$:

$$\beta \left[d_{t+1} + \frac{q(X_{t+1}^j, 0) + q(X_{t+1}^j, -u)}{2} \right] - p_t - h \frac{|x_{t+1}^j|}{x_{t+1}^j} + \theta_1 - \theta_2 = 0.$$

θ_1 and θ_2 are, respectively, the Lagrange multiplier for the holdings constraints: $x_{t+1}^j \geq -a$ and $x_{t+1}^j \leq +a$.

Given that

$$p(-a, u, 0, d) = \beta \left[\begin{array}{l} (\pi_2 + \pi_4 - \pi_1 - \pi_3) d + \pi_1 q(-a, 0) + \pi_2 q(a, 0) \\ + \pi_3 q(-a, -u) + \pi_4 q(a, -u) \end{array} \right] + \frac{c}{a},$$

where $\pi_1 = \frac{u}{6u+4a}$, $\pi_2 = \frac{u+2a}{6u+4a}$, $\pi_3 = \frac{2u}{6u+4a}$, and $\pi_4 = \frac{2u+2a}{6u+4a}$. If $X_{t+1}^i = a$,

$$\begin{aligned}
& \beta \left[d_{t+1} + \frac{q(X_{t+1}^j, 0) + q(X_{t+1}^j, -u)}{2} \right] - p_t \\
&= \beta \left(d + \frac{q(a, 0) + q(a, -u)}{2} \right) - \beta \left[\begin{array}{l} (\pi_2 + \pi_4 - \pi_1 - \pi_3)d + \pi_1 q(-a, 0) + \pi_2 q(a, 0) \\ + \pi_3 q(-a, -u) + \pi_4 q(a, -u) \end{array} \right] - \frac{c}{a} \\
&> 2(\pi_1 + \pi_3)\beta d - \beta \left[\left(\pi_2 - \pi_1 - \frac{1}{2} \right) q(a, 0) + \pi_3 q(-a, -u) + \left(\pi_4 - \frac{1}{2} \right) q(a, -u) \right] - \frac{c}{a} \\
&\sim 2(\pi_1 + \pi_3)\beta d > h.
\end{aligned}$$

Therefore, $x_{t+1}^j = a$, which verifies that $X_{t+1}^i = a$.

Optimization of Uninformed Investors Given p_t and p_{t+1} , an uninformed investor $j \in [1, 1+n]$ faces the following optimization problem:

$$\begin{aligned}
& \max_{x_{t+1}^j} E_t^j \left[x_{t+1}^j (d_t + p_t) + x_{t+1}^j [\beta (d_{t+1} + p_{t+1}) - p_t] - CI_{|x_{t+1}^j - x_t^j|} \right] \\
&= x_t^j E_t^j [d_t + \beta (d_{t+1} + p_{t+1})] + E_t^j \left[(x_{t+1}^j - x_t^j) [\beta (d_{t+1} + p_{t+1}) - p_t] \right] - CI_{|x_{t+1}^j - x_t^j| \neq 0},
\end{aligned}$$

subject to $x_{t+1}^j \in [0, a]$.

As all investors know u_t at time t , uninformed investors can infer X_t^i from price p_t and u_t with perfect precision. Uninformed investors take full account of available information in deciding on their optimal demand. When the equilibrium price is not fully revealing, the equilibrium allocation may convey additional information to the uninformed regarding the asset payoff. In particular,

$$E_t^j [d_t + \beta (d_{t+1} + p_{t+1})] \neq E_t^j [d_{t+1} + p_{t+1} \mid x_{t+1}^j \neq x_t^j].$$

In a symmetric equilibrium, $E_t^j [d_{t+1} + p_{t+1} \mid x_{t+1}^j \neq x_t^j]$ does not change with the size of the adjustment $|x_{t+1}^j - x_t^j|$ because the mass of individual j is infinitesimally small and the size

of any individual adjustment lies within $[0, a]$. As a result,

$$\frac{\partial E_t^j \left[d_{t+1} + p_{t+1} \mid x_{t+1}^j \neq x_t^j \right]}{\partial x_{t+1}^j} = 0.$$

The first-order condition with respect to x_{t+1}^j when $x_{t+1}^j \neq x_t^j$:

$$E_t^j \left[\beta (d_{t+1} + p_{t+1}) \mid x_{t+1}^j \neq x_t^j \right] - p_t + \theta_1 - \theta_2 = 0.$$

θ_1 and θ_2 are, respectively, the Lagrange multiplier for the holdings constraints: $x_{t+1}^j \geq 0$ and $x_{t+1}^j \leq a$.

Facing a fixed transaction cost c , an uninformed investor would like to buy only if $p_t < E_t^j \left[\beta (d_{t+1} + p_{t+1}) \mid x_{t+1}^j \neq x_t^j \right]$ and would increase holdings up to his maximum capacity a whenever he buys. Conversely, an uninformed investor would like to sell only if $p_t > E_t^j \left[\beta (d_{t+1} + p_{t+1}) \mid x_{t+1}^j \neq x_t^j \right]$ and would reduce holdings all the way to zero whenever he sells. Therefore, in a stationary equilibrium, an uninformed investor either holds zero or a shares.

In this case, price is not fully revealing. Conditional on X_t^i and u_t , price stays fixed regardless of (d_{t-1}, u_{t+1}) . For an uninformed investor with $x_t^j = a$, the conditional expectation:²⁴

$$\begin{aligned} & E_t^j \left[\beta (d_{t+1} + p_{t+1}) \mid x_{t+1}^j \neq x_t^j \right] \\ &= \pi_1 (-d + q(-a, 0)) + \pi_2 (d + q(a, 0)) + \pi_3 (-d + q(-a, -u)) + \pi_4 (d + q(a, -u)). \end{aligned}$$

It follows that

$$\begin{aligned} & E_t^j \left[\beta (d_{t+1} + p_{t+1}) \mid x_{t+1}^j \neq x_t^j \right] - p_t = -\frac{c}{a} \\ & \rightarrow -aE_t^j \left[\beta (d_{t+1} + p_{t+1}) - p_t \mid x_{t+1}^j \neq x_t^j = a \right] = c. \end{aligned}$$

Therefore, for an uninformed investor with $x_t^j = a$, $x_{t+1}^j = 0$ or a in equilibrium.

²⁴This expectation will be verified to be indeed rational after the discussion on the market-clearing condition.

For an uninformed investor with $x_t^j = 0$, the conditional expectation,²⁵

$$\begin{aligned} E_t^j [\beta (d_{t+1} + p_{t+1}) | x_{t+1}^j \neq x_t^j] &= E_t^j [\beta (d_{t+1} + p_{t+1})] \\ &= \frac{1}{4} (-d + q(-a, 0)) + \frac{1}{4} (d + q(a, 0)) + \frac{1}{4} (-d + q(-a, -u)) + \frac{1}{4} (d + q(a, -u)). \end{aligned}$$

It follows that

$$p(-a, u, 0, d) = \beta \left[\begin{array}{l} (\pi_2 + \pi_4 - \pi_1 - \pi_3) d + \pi_1 q(-a, 0) + \pi_2 q(a, 0) \\ + \pi_3 q(-a, -u) + \pi_4 q(a, -u) \end{array} \right] + \frac{c}{a},$$

$$\begin{aligned} E_t^j [\beta (d_{t+1} + p_{t+1})] - p_t &< -(\pi_2 + \pi_4 - \pi_1 - \pi_3) \beta d + 2\beta^2 d - \frac{c}{a} \\ &\sim -(\pi_2 + \pi_4 - \pi_1 - \pi_3) \beta d < 0. \end{aligned}$$

Therefore, for an uninformed investor with $x_t^j = 0$, $x_{t+1}^j = 0$.

Market Clearing After the current round of trading, the total supply of the asset is s . The aggregate holdings of informed investors are a . The aggregate holdings of uninformed investors who previously hold zero shares remain to be zero. A fraction of $\frac{u+2a}{s+u+a}$ of uninformed investors with $x_t^j = a$ will end up with $x_{t+1}^j = 0$, and the rest of them will stay with $x_{t+1}^j = a$. Since $s - u - a > 0$, the fraction $\frac{u+2a}{s+u+a}$ indeed lies in $[0, 1]$. Therefore, the market clears, i.e.,

$$s = a + 0 + (s + u + a) \left(1 - \frac{u + 2a}{s + u + a} \right).$$

Rational Expectations As is shown above, the fraction of the uninformed investors with $x_t^j = a$ and $x_{t+1}^j = 0$ is proportional to the change in the aggregate holdings of uninformed investors. It follows that the probability of an uninformed investor with $x_t^j = a$ ending up with $x_{t+1}^j = 0$ is proportional to the aggregate volume of trades that involve the uninformed. Therefore, the posterior of a marginal uninformed investor with $x_t^j = a$ conditional on $x_{t+1}^j \neq x_t^j$

²⁵For an uninformed investor with $x_t^j = 0$, $E_t^j [\beta (d_{t+1} + p_{t+1}) | x_{t+1}^j \neq x_t^j]$ is an off-equilibrium expectation. I specify that $E_t^j [\beta (d_{t+1} + p_{t+1}) | x_{t+1}^j \neq x_t^j] = E_t^j [\beta (d_{t+1} + p_{t+1})]$. It is reasonable to assume no equilibrium state has both buy and sell orders stay unfilled. Therefore, $E_t^j [\beta (d_{t+1} + p_{t+1}) | x_{t+1}^j \neq x_t^j] = E_t^j [\beta (d_{t+1} + p_{t+1})]$.

should be:

$$(u_{t+1}, d_{t+1}) = \begin{cases} (0, -d), & \text{with probability of } \pi_1 \\ (0, +d), & \text{with probability of } \pi_2 \\ (-u, -d), & \text{with probability of } \pi_3 \\ (-u, +d), & \text{with probability of } \pi_4 \end{cases}.$$

\Rightarrow For an uninformed investor with $x_t^j = a$, given p_t , $X_t^i = -a$ and $u_t = u$,

$$\begin{aligned} E_t^j \left[\beta (d_{t+1} + p_{t+1}) \mid x_{t+1}^j \neq x_t^j \right] \\ = \pi_1 (-d + q(-a, 0)) + \pi_2 (d + q(a, 0)) + \pi_3 (-d + q(-a, -u)) + \pi_4 (d + q(a, -u)). \end{aligned}$$

The analysis for other states is similar and is hence omitted from the proof.

The function $q : \chi \times U_t \rightarrow R$, where $\chi = \{0, \pm a\}$ and $U_t = \{0, \pm u\}$, is pinned down by the following 9 conditions that are derived from Table 1.1:

$$\begin{aligned} q(0, 0) &= 0, q(a, 0) = -q(-a, 0), q(0, u) = -q(0, -u), \\ q(a, u) &= -q(-a, -u), q(a, -u) = -q(-a, u), q(a, u) = \beta \frac{q(0, -u)}{2}, \\ q(-a, 0) &= \frac{c}{a} + \frac{2a - u}{4a + u} \beta d - \frac{3u + 2a}{4u + 4a} \beta q(-a, u) + \left(\frac{1}{4} - \frac{3}{4} \frac{a - u}{u + 4a} \beta \right) \beta q(0, u), \\ q(0, u) &= \left(1 - \frac{3}{8} \frac{2u - a}{5u + a} \beta^2 \right)^{-1} \\ &\quad \left[\frac{c}{a} + \frac{4a - u}{2(5u + a)} \beta d - \frac{3}{4} \frac{u + a}{5u + a} \beta q(-a, 0) - \frac{3}{4} \frac{2u + a}{5u + a} \beta q(-a, u) \right], \\ q(-a, u) &= \left(1 + \frac{u + a}{2a + 3u} \beta \right)^{-1} \\ &\quad \left[\frac{c}{a} + \frac{2a}{3u + 2a} \beta d - \frac{a}{2a + 3u} \beta q(-a, 0) + \frac{u}{2a + 3u} \beta^2 \frac{q(0, u)}{2} \right]. \end{aligned}$$

The last three equations jointly determine $q(-a, 0)$, $q(0, u)$ and $q(-a, u)$. Given that $0 < \beta \ll$

1 and $\frac{\varepsilon}{a} \ll \beta d$,

$$q(0, u) = -q(0, -u) = \frac{2}{\beta} q(-a, -u) = -\frac{2}{\beta} q(a, u) = \frac{4a - u}{2(5u + a)} \beta d,$$

$$q(-a, 0) = -q(a, 0) = \frac{2a - u}{4a + u} \beta d,$$

$$q(-a, u) = -q(a, -u) = \frac{2a}{3u + 2a} \beta d,$$

$$\text{and } q(0, 0) = 0.$$

Finally, an informed investor in this model holds either 0 shares when price is fully revealing or $\pm a$ shares when price is not fully revealing. Therefore, X_t^i can be either 0 or $\pm a$ in equilibrium, independent of (u_t, u_{t+1}, d_{t+1}) . In addition, d_{t+1} is independent of (X_t^i, u_t, u_{t+1}) , so $\{(X_t^i, u_t, u_{t+1}, d_{t+1})\} = \chi \times U \times D$, where $\chi = \{0, \pm a\}$, $D = \{\pm d\}$ and $U = \{(0, \pm u), (\pm u, 0), (\pm u, \mp u)\}$. The state space indeed consists of 36 states.

Q.E.D.

1.8.2 Appendix B. Return and Volume

Proof of Proposition 2. As is shown in the proof of Proposition 1, whenever an uninformed investor j adjusts his stock holdings he is indifferent to an adjustment and no adjustment. Let θ_t denote $\Pr[x_{t+1}^j \neq x_t^j | p_t]$. With probability θ_t he ends up with a change of a shares, and with probability $(1 - \theta_t)$ he stays with the original holdings. His holdings vary even though the equilibrium price is held unchanged. Conditional on an individual transaction, the expected

payoff $E_t^j [r_{t+1} | p_t, x_{t+1}^j \neq x_t^j]$ for a marginal uninformed investor is:

$$\begin{aligned}
& E_t^j [r_{t+1} | p_t, x_{t+1}^j \neq x_t^j] \\
&= \sum_{(u_{t+1}, d_{t+1}) | p_t} E_t^j [r_{t+1} | p_t, x_{t+1}^j \neq x_t^j, (u_{t+1}, d_{t+1})] \Pr [(u_{t+1}, d_{t+1}) | p_t, x_{t+1}^j \neq x_t^j] \\
&= \sum_{(u_{t+1}, d_{t+1}) | p_t} E_t^j [r_{t+1} | p_t, (u_{t+1}, d_{t+1})] \frac{\Pr [(u_{t+1}, d_{t+1}) \text{ and } x_{t+1}^j \neq x_t^j | p_t]}{\Pr [x_{t+1}^j \neq x_t^j | p_t]} \\
&= \sum_{(u_{t+1}, d_{t+1}) | p_t} E_t^j [r_{t+1} | p_t, (u_{t+1}, d_{t+1})] \frac{\Pr [(u_{t+1}, d_{t+1}) | p_t] \Pr [x_{t+1}^j \neq x_t^j | p_t, (u_{t+1}, d_{t+1})]}{\theta_t} \\
&= E \left[r_{t+1} \frac{\Pr [x_{t+1}^j \neq x_t^j | p_t, (u_{t+1}, d_{t+1})]}{\theta_t} \mid p_t \right].
\end{aligned}$$

In equilibrium, there are two possible scenarios: first, a fraction of uninformed nonshareholders buy a shares to accommodate liquidity sells, and the other uninformed investors do not alter their stock holdings; second, a fraction of uninformed current shareholders sell a shares to accommodate liquidity buys, and the other uninformed investors do not alter their stock holdings. In both scenarios, given price p_t , the unsigned aggregate volume of trades that involve uninformed investors, $|V_{t+1}^u|$, is proportional to $\Pr [x_{t+1}^j \neq x_t^j | p_t, (u_{t+1}, d_{t+1})]$ in a symmetric equilibrium. Therefore,

$$E_t^j [r_{t+1} | p_t, x_{t+1}^j \neq x_t^j] = E \left[r_{t+1} \frac{|V_{t+1}^u|}{E [|V_{t+1}^u| | p_t]} \mid p_t \right].$$

Since $\left| E_t^j [r_{t+1} | p_t, x_{t+1}^j \neq x_t^j] \right| = \frac{c}{a}$,

$$\left| E \left[r_{t+1} \frac{|V_{t+1}^u|}{E [|V_{t+1}^u| | p_t]} \mid p_t \right] \right| = \frac{c}{a}.$$

\Rightarrow

$$\begin{aligned}
\left| E \left[r_t \frac{|V_t^u|}{E[|V_t^u|]} \right] \right| &= \left| \sum_{p_{t-1}} E \left[r_t \frac{|V_t^u|}{E[|V_t^u| | p_{t-1}]} \mid p_{t-1} \right] \frac{E[|V_t^u| | p_{t-1}]}{E[|V_t^u|]} \Pr[p_{t-1}] \right| \\
&\leq \sum_{p_{t-1}} \left| E \left[r_t \frac{|V_t^u|}{E[|V_t^u| | p_{t-1}]} \mid p_{t-1} \right] \right| \frac{E[|V_t^u| | p_{t-1}]}{E[|V_t^u|]} \Pr[p_{t-1}] \\
&= \frac{c}{a} \sum_{p_{t-1}} \frac{E[|V_t^u| | p_{t-1}]}{E[|V_t^u|]} \Pr[p_{t-1}] = \frac{c}{a}.
\end{aligned}$$

Q.E.D. ■

Proof of Proposition 3. The correlation between the asset payoff r_t and the demand of the informed X_t^i must be nonnegative. The flow of noise trades should not correlate with r_t , given X_{t-1}^i, u_{t-1} and the sign of V_t^u . Therefore, the effective supply for the uninformed, defined as $s + u_t - X_t^i$, must be nonpositively correlated with r_t , so is $V_t^u = s + u_t - X_t^i - X_{t-1}^u$. By definition, the positive sign of V_t^u indicate buys from uninformed marginal investors and vice versa. We thus have

$$\text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}, V_t^u > 0] \leq 0,$$

and

$$\text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}, V_t^u < 0] \geq 0.$$

\Rightarrow

$$\begin{aligned}
&\text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}] \\
&= \text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}, V_t^u > 0] \Pr [V_t^u > 0 \mid X_{t-1}^i, u_{t-1}] \\
&\quad + \text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}, V_t^u < 0] \Pr [V_t^u < 0 \mid X_{t-1}^i, u_{t-1}].
\end{aligned}$$

In equilibrium, if

$$\Pr [V_t^u > 0 \mid X_{t-1}^i, u_{t-1}] = \Pr [V_t^u < 0 \mid X_{t-1}^i, u_{t-1}],$$

then

$$\begin{aligned} \text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}] &= \text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}, V_t^u > 0] \\ &= \text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}, V_t^u < 0] = 0. \end{aligned}$$

If

$$\Pr [V_t^u > 0 \mid X_{t-1}^i, u_{t-1}] < \Pr [V_t^u < 0 \mid X_{t-1}^i, u_{t-1}],$$

then

$$\text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}, V_t^u > 0] = 0 \rightarrow \text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}] \geq 0.$$

Similarly, if

$$\Pr [V_t^u > 0 \mid X_{t-1}^i, u_{t-1}] > \Pr [V_t^u < 0 \mid X_{t-1}^i, u_{t-1}],$$

then

$$\text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}, V_t^u < 0] = 0 \rightarrow \text{cov} [r_t, |V_t^u| \mid X_{t-1}^i, u_{t-1}] \leq 0.$$

Q.E.D. ■

By Proposition 2, if $\frac{\varepsilon}{\alpha} \sim 0$,

$$\left| E \left[r_t \frac{|V_t^u|}{E[|V_t^u|]} \right] \right| = |E[r_t \pi_t^u]| = 0.$$

In reality, the indifference condition may not always hold. Without the indifference condition, $\text{cov}(r_t, \pi_t^u) = 0$. As long as there are sufficiently many investors who are uninformed but rational, $E[r_t] = 0$ after adjustment for risk, so

$$|E[r_t \pi_t^u]| = |E[r_t]| = 0.$$

Recall that $E[\pi_t^u] = 1$. Therefore, the equality holds independent of the indifference condition.

Let's check if the equality also holds if we replace $|V_t^u|$ with $V_t = |V_t^u| + V_t^{nu}$. V_t refers to the unsigned aggregate trading volume. V_t^{nu} refers to the unsigned aggregate volume of trades that do not involve indifferent uninformed traders. Similarly, $\pi_t \equiv \frac{V_t^u}{E[V_t]}$.

If either $E[|V_t^u|] = 0$ or $E[V_t^{nu}] = 0$, as is shown above, we have

$$|E[r_t \pi_t]| = 0.$$

Otherwise,

$$|E[r_t \pi_t]| = \left| E \left[r_t \frac{|V_t^u|}{E[|V_t^u|]} \right] \frac{E[|V_t^u|]}{E[V_t]} + E \left[r_t \frac{V_t^{nu}}{E[V_t^{nu}]} \right] \frac{E[V_t^{nu}]}{E[V_t]} \right|$$

Since $\text{cov} \left(r_t, \frac{V_t^{nu}}{E[V_t^{nu}]} \right) = 0$ in general,

$$\begin{aligned} |E[r_t \pi_t]| &= \left| E[r_t \pi_t^u] \frac{E[|V_t^u|]}{E[V_t]} + E[r_t] \frac{E[V_t^{nu}]}{E[V_t]} \right| \\ &= |E[r_t]| \frac{E[V_t^{nu}]}{E[V_t]}. \end{aligned}$$

The empirical analysis in this paper concerns the weighted average return of an arbitrage portfolio. To derive the weighted average return for a zero-financing portfolio, I first compute the weighted average for the long and the short portfolios separately and then subtract the latter from the former. Therefore, even if $\text{cov} \left(r_t, \frac{V_t^{nu}}{E[V_t^{nu}]} \right) \neq 0$, the biases should cancel out for the zero-investment portfolio that consists of offsetting positions in a sufficiently large number of stocks, unless there is any systematic difference in the volume-return relationship between the long and the short portfolio. Moreover, the empirical results are based on monthly data and should be exempt of high-frequency microstructure issues.

Because $\frac{E[V_t^{nu}]}{E[V_t]} \in [0, 1]$,

$$\begin{aligned} |E[r_t \pi_t]| &\leq |E[r_t]|, \\ \text{and } |E[r_t \pi_t]| &\sim 0, \text{ if } \frac{E[V_t^{nu}]}{E[V_t]} \text{ is sufficiently small.} \end{aligned}$$

1.8.3 Appendix C. Return Autocorrelation

Proof of Proposition 4. In this model, if $X_t^i > 0$ then $X_t^i = a$, so

$$E[r_{t+1} | r_t > 0 \text{ and } X_t^i > 0] = E[r_{t+1} | r_t > 0 \text{ and } X_t^i = a].$$

\Rightarrow

$$\begin{aligned} E[r_{t+1} | r_t > 0 \text{ and } X_t^i > 0] &= E[r_{t+1} | r_t > 0 \text{ and } X_t^i = a] \\ &= \sum_{\{u_t | r_t > 0 \text{ and } X_t^i = a\}} E[r_{t+1} | r_t > 0, X_t^i = a, u_t] \Pr[u_t | r_t > 0, X_t^i = a]. \end{aligned}$$

It is obvious that

$$\{u_t | r_t > 0 \text{ and } X_t^i = a\} = \{0, \pm u\}.$$

By Proposition 2 and 3, for any possible p_t conditional on $X_t^i = a$ and $u_t \neq u$,

$$E[r_{t+1} | X_t^i = a, u_t \neq u, p_t] > 0.$$

Given that

$$E[r_{t+1} | r_t > 0, X_t^i = a, u_t \neq u, p_t] = E[r_{t+1} | X_t^i = a, u_t \neq u, p_t],$$

if $u_t \neq u$ then

$$E[r_{t+1} | r_t > 0, X_t^i = a, u_t] > 0.$$

If $u_t = u$,

$$\begin{aligned} &E[r_{t+1} | r_t > 0, X_t^i = a, u_t] \\ &= \sum_{\{(u_{t+1}, d_{t+1}) | r_t > 0, X_t^i = a, u_t\}} E[r_{t+1} | X_t^i = a, u_t, u_{t+1}, d_{t+1}] \Pr[(u_{t+1}, d_{t+1}) | r_t > 0, X_t^i = a, u_t]. \end{aligned}$$

Since

$$E[r_{t+1} | X_t^i = a, u_t = u, u_{t+1} = 0] = -E[r_{t+1} | X_t^i = a, u_t = u, u_{t+1} = -u] = \frac{c}{a}$$

and under Condition (4) and (5)

$$\Pr[(u_{t+1}, d_{t+1}) | r_t > 0, X_t^i = a, u_t = u] = \Pr[(u_{t+1}, d_{t+1}) | X_t^i = a, u_t = u] = \frac{1}{4},$$

for any possible (u_{t+1}, d_{t+1}) conditional on $r_t > 0$, $X_t^i = a$ and $u_t = u$,

$$E [r_{t+1} \mid r_t > 0, X_t^i = a, u_t = u] = 0.$$

\Rightarrow

$$E [r_{t+1} \mid r_t > 0 \text{ and } X_t^i > 0] > 0.$$

As the model is constructed in a symmetric fashion, similarly, we obtain

$$E [r_{t+1} \mid r_t < 0 \text{ and } X_t^i < 0] > 0.$$

Q.E.D. ■

Proof of Proposition 5. Similar to the proof of Proposition 4,

$$\begin{aligned} & E [r_{t+1} \mid r_t > 0 \text{ and } X_t^i = 0] \\ &= \sum_{\{u_t \mid r_t > 0, X_t^i = 0\}} E [r_{t+1} \mid r_t > 0, X_t^i = 0, u_t] \Pr [u_t \mid r_t > 0, X_t^i = 0], \end{aligned}$$

and

$$\begin{aligned} & E [r_{t+1} \mid r_t > 0, X_t^i = 0, u_t] \\ &= \sum_{\{(u_{t+1}, d_{t+1}) \mid r_t > 0, X_t^i = 0, u_t\}} E [r_{t+1} \mid r_t > 0, X_t^i = 0, u_t] \Pr [(u_{t+1}, d_{t+1}) \mid r_t > 0, X_t^i = 0, u_t]. \end{aligned}$$

According to Table 1.1,

$$\begin{aligned} & \{(u_t, u_{t+1}, d_{t+1}) \mid r_t > 0 \text{ and } X_t^i = 0\} \\ &= \{(0, \pm u, d), (u, 0, d), (u, -u, \pm d), (-u, 0, d)\}. \end{aligned}$$

Since

$$\Pr [u_{t+1} = u \mid r_t > 0, X_t^i = 0, u_t = 0] = \Pr [u_{t+1} = -u \mid r_t > 0, X_t^i = 0, u_t = 0]$$

and

$$\begin{aligned} & E [r_{t+1} \mid X_t^i = 0, (u_t, u_{t+1}, d_{t+1}) = (0, u, d)] \\ &= -E [r_{t+1} \mid X_t^i = 0, (u_t, u_{t+1}, d_{t+1}) = (0, -u, d)] = \frac{c}{a}, \end{aligned}$$

$$E [r_{t+1} \mid r_t > 0, X_t^i = 0, u_t = 0] = 0.$$

It is also obvious that

$$E [r_{t+1} \mid r_t > 0, X_t^i = 0, u_t = u] < -\frac{c}{a}$$

and

$$E [r_{t+1} \mid r_t > 0, X_t^i = 0, u_t = -u] = \frac{c}{a}.$$

By symmetry,

$$\Pr [X_t^i = 0, u_t = u] = \Pr [X_t^i = 0, u_t = -u],$$

so it follows that

$$\Pr [r_t > 0, X_t^i = 0, u_t = u] > \Pr [r_t > 0, X_t^i = 0, u_t = -u].$$

\Rightarrow

$$E [r_{t+1} \mid r_t > 0 \text{ and } X_t^i = 0] < 0.$$

As the model is constructed in a symmetric fashion, similarly, we obtain

$$E [r_{t+1} \mid r_t < 0 \text{ and } X_t^i = 0] > 0.$$

Q.E.D. ■

1.8.4 Appendix D. Benchmark Models

Benchmark I. Information Asymmetry Only

With no fixed cost, equilibrium states are characterized by $(u_{t+1}, d_{t+1}) \in U \times D$, where $U = \{0, \pm u\}$ and $D = \{\pm d\}$.

Proposition 6 *There exists an equilibrium characterized by the following price function:*

$$p_t = p(u_{t+1}, d_{t+1}) = \beta d_{t+1}.$$

Proof. *Given the price function, an uninformed investor $j \in [1, 1+n]$ can infer d_{t+1} from price p_t with perfect precision, and*

$$\beta E_t^j [d_{t+1} + p_{t+1}] - p_t = 0.$$

Therefore, any uninformed investor will be willing to hold any number of shares between 0 and a .

For an informed investor $j \in [0, 1]$, $x_{t+1}^j = 0$ as price fully reveals his private information. The market always clears, as, for all t ,

$$X_t^u = s + u_t - X_t^j = s + u_t$$

and

$$0 < s + u_t < na.$$

Q.E.D. ■

Benchmark II. Fixed Transaction Costs Only

When there is a fixed transaction cost and no leakage of information regarding d_{t+1} , equilibrium states are characterized by $(u_t, u_{t+1}) \in U$, where

$$U = \{(0, \pm u), (\pm u, 0), (\pm u, \mp u)\}.$$

Proposition 7 *There exists an equilibrium characterized by the following price function:*

$$p_t = p(u_t, u_{t+1}) = \begin{cases} -\frac{3-\beta}{3+2\beta} \frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (0, +u) \\ +\frac{3-\beta}{3+2\beta} \frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (0, -u) \\ +\frac{3}{3+2\beta} \frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (+u, 0) \text{ or } (+u, -u) \\ -\frac{3}{3+2\beta} \frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (-u, 0) \text{ or } (-u, +u) \end{cases}$$

Proof. For any investor $j \in [0, 1+n]$,

$$\beta E_t^j [d_{t+1} | x_{t+1}^j \neq x_t^j] = \beta E_t^j [d_{t+1}] = 0$$

and

$$\begin{aligned} & \beta E_t^j [p_{t+1} | u_t, p_t, x_{t+1}^j \neq x_t^j] \\ = & \begin{cases} \beta p_{t+1} = +\frac{3\beta}{3+2\beta} \frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (0, +u) \\ \beta p_{t+1} = -\frac{3\beta}{3+2\beta} \frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (0, -u) \\ \beta \left(\frac{1}{3} E [p_t | u_t = 0] + \frac{2}{3} E [p_t | u_t = -u] \right) = -\frac{2\beta}{3+2\beta} \frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (+u, 0) \text{ or } (+u, -u) \\ \beta \left(\frac{1}{3} E [p_t | u_t = 0] + \frac{2}{3} E [p_t | u_t = +u] \right) = +\frac{2\beta}{3+2\beta} \frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (-u, 0) \text{ or } (-u, +u) \end{cases}, \end{aligned}$$

so

$$\beta E_t^j [d_{t+1} + p_{t+1} | u_t, p_t, x_{t+1}^j \neq x_t^j] - p_t = \begin{cases} +\frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (0, +u) \\ -\frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (0, -u) \\ -\frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (+u, 0) \text{ or } (+u, -u) \\ +\frac{c}{a}, & \text{if } (u_t, u_{t+1}) = (-u, 0) \text{ or } (-u, +u) \end{cases}$$

Therefore, an “informed” investor $j \in [0, 1]$ always holds zero shares, because

$$\left| \beta E_t^j [d_{t+1} + p_{t+1} | u_t, p_t, x_{t+1}^j \neq x_t^j] - p_t \right| = \frac{c}{a} < h.$$

For an “uninformed” investor $j \in [1, 1 + n]$ with $x_t^j = 0$,

$$x_{t+1}^j = \begin{cases} 0 \text{ or } a, & \text{if } (u_t, u_{t+1}) = (0, +u) \\ 0, & \text{if } (u_t, u_{t+1}) = (0, -u) \\ 0, & \text{if } (u_t, u_{t+1}) = (+u, 0) \text{ or } (+u, -u) \\ 0 \text{ or } a, & \text{if } (u_t, u_{t+1}) = (-u, 0) \text{ or } (-u, +u) \end{cases} .$$

For an “uninformed” investor $j \in [1, 1 + n]$ with $x_t^j = a$,

$$x_{t+1}^j = \begin{cases} a, & \text{if } (u_t, u_{t+1}) = (0, +u) \\ 0 \text{ or } a, & \text{if } (u_t, u_{t+1}) = (0, -u) \\ 0 \text{ or } a, & \text{if } (u_t, u_{t+1}) = (+u, 0) \text{ or } (+u, -u) \\ a, & \text{if } (u_t, u_{t+1}) = (-u, 0) \text{ or } (-u, +u) \end{cases} .$$

The market always clears, as, for all t ,

$$X_t^u = s + u_t - X_t^j = s + u_t$$

and

$$0 < s + u_t < na.$$

Q.E.D. ■

1.9 Bibliography

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Table 1.1. Equilibrium Price Function

	$u_{t+1} = +u$		$u_{t+1} = -u$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0 0	$\beta[-d + q(0, u)] - \frac{c}{a}$	$\beta[d + q(0, u)] - \frac{c}{a}$	$\beta[-d + q(0, -u)] + \frac{c}{a}$	$\beta[d + q(0, -u)] + \frac{c}{a}$
+a 0	p_a	p_a	p_a	$\beta[d + q(0, -u)] - \frac{c}{a}$
-a 0	$\beta[-d + q(0, u)] + \frac{c}{a}$	$-p_a$	$-p_a$	$-p_a$
	$u_{t+1} = 0$		$u_{t+1} = -u$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0 +u	$-\beta d + \frac{c}{a}$	$-p_u$	$-p_u$	$-p_u$
+a +u	$-\beta d - \frac{c}{a}$	$+\beta d - \frac{c}{a}$	$\beta[-d + q(0, -u)] + \frac{c}{a}$	$\beta[d + q(0, -u)] + \frac{c}{a}$
-a +u	$-p_{au}$	$-p_{au}$	$-p_{au}$	$-p_{au}$
	$u_{t+1} = +u$		$u_{t+1} = 0$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0 -u	p_u	p_u	p_u	$\beta d - \frac{c}{a}$
+a -u	p_{au}	p_{au}	p_{au}	p_{au}
-a -u	$\beta[-d + q(0, u)] - \frac{c}{a}$	$\beta[d + q(0, u)] - \frac{c}{a}$	$-\beta d + \frac{c}{a}$	$+\beta d + \frac{c}{a}$

Table 1.1 summarizes the equilibrium price function of the infinite-horizon model, $p_t = p(X_t^i, u_t, u_{t+1}, d_{t+1})$. X_t^i refers to the aggregate stock holdings of informed investors before trades at time t . u_t and u_{t+1} refer to the supply shock at time $t - 1$ and at time t , respectively. d_{t+1} refers to the dividend payout at time $t + 1$. $q(X_t^i, u_t)$ is defined as $E[p_t | X_t^i, u_t]$. In particular, the function $q : \chi \times U_t \rightarrow R$, where $\chi = \{0, \pm a\}$ and $U_t = \{0, \pm u\}$, must satisfy:

$$\begin{aligned}
q(0, 0) &= 0, q(a, 0) = -q(-a, 0), q(0, u) = -q(0, -u), \\
q(a, u) &= -q(-a, -u), q(a, -u) = -q(-a, u), q(a, u) = \beta \frac{q(0, -u)}{2}, \\
q(-a, 0) &= \frac{c}{a} + \frac{2a - u}{4a + u} \beta d - \frac{3u + 2a}{4u + 4a} \beta q(-a, u) + \left(\frac{1}{4} - \frac{3}{4} \frac{a - u}{u + 4a} \beta \right) \beta q(0, u), \\
q(0, u) &= \left(1 - \frac{3}{8} \frac{2u - a}{5u + a} \beta^2 \right)^{-1} \left[\frac{c}{a} + \frac{4a - u}{2(5u + a)} \beta d - \frac{3}{4} \frac{u + a}{5u + a} \beta q(-a, 0) - \frac{3}{4} \frac{2u + a}{5u + a} \beta q(-a, u) \right], \\
q(-a, u) &= \left(1 + \frac{u + a}{2a + 3u} \beta \right)^{-1} \left[\frac{c}{a} + \frac{2a}{3u + 2a} \beta d - \frac{a}{2a + 3u} \beta q(-a, 0) + \frac{u}{2a + 3u} \beta^2 \frac{q(0, u)}{2} \right].
\end{aligned}$$

All 9 conditions above pin down the q function. Lastly, p_a , p_u and p_{au} are constants defined as follows:

$$\begin{aligned}
p_a &\equiv \beta \left[-\frac{4a - u}{4a + u} d + \frac{2a + u}{4a + u} q(-a, u) + \frac{u}{4a + u} q(a, u) + \frac{2a - u}{4a + u} q(-a, -u) \right] - \frac{c}{a}, \\
p_u &= \beta \left[-\frac{3a + u}{a + 5u} d + \frac{a + u}{a + 5u} q(-a, 0) + \frac{-a + 2u}{a + 5u} q(a, u) + \frac{a + 2u}{a + 5u} q(-a, u) \right] - \frac{c}{a}, \\
p_{au} &= \beta \left[-\frac{4a}{4a + 6u} d + \frac{u}{4a + 6u} q(a, 0) + \frac{2a + u}{4a + 6u} q(-a, 0) + \frac{2u}{4a + 6u} q(a, u) + \frac{2a + 2u}{4a + 6u} q(-a, u) \right] - \frac{c}{a}.
\end{aligned}$$

Table 1.2(a). Equilibrium Holdings of An Informed Investor

	$u_{t+1} = +u$		$u_{t+1} = -u$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0 0	0	0	0	0
+a 0	-a	+a	-a	0
-a 0	0	+a	-a	+a

	$u_{t+1} = 0$		$u_{t+1} = -u$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0 +u	0	+a	-a	+a
+a +u	0	0	0	0
-a +u	-a	+a	-a	+a

	$u_{t+1} = +u$		$u_{t+1} = 0$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0 -u	-a	+a	-a	0
+a -u	-a	+a	-a	+a
-a -u	0	0	0	0

Table 1.2(a) summarizes the equilibrium holdings x_{t+1}^i of an informed investor. X_t^i refers to the aggregate stock holdings of informed investors before trades at time t . u_t and u_{t+1} refer to the supply shock at time $t - 1$ and at time t , respectively. d_{t+1} refers to the dividend payout at time $t + 1$.

Table 1.2(b). Equilibrium Holdings of An Uninformed Investor with $x_t^j = 0$

	$u_{t+1} = +u$		$u_{t+1} = -u$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0 0	0 or a	0 or a	0	0
$+a$ 0	0 or a	0 or a	0 or a	0 or a
$-a$ 0	0	0	0	0
	$u_{t+1} = 0$		$u_{t+1} = -u$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0 $+u$	0	0	0	0
$+a$ $+u$	0 or a	0 or a	0	0
$-a$ $+u$	0	0	0	0
	$u_{t+1} = +u$		$u_{t+1} = 0$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0 $-u$	0 or a	0 or a	0 or a	0 or a
$+a$ $-u$	0 or a	0 or a	0 or a	0 or a
$-a$ $-u$	0 or a	0 or a	0	0

Table 1.2(b) summarizes the equilibrium holdings x_{t+1}^j of an uninformed investor with $x_t^j = 0$. X_t^i refers to the aggregate stock holdings of informed investors before trades at time t . u_t and u_{t+1} refer to the supply shock at time $t - 1$ and at time t , respectively. d_{t+1} refers to the dividend payout at time $t + 1$.

Table 1.2(c). Equilibrium Holdings of An Uninformed Investor with $x_t^j = a$

	$u_{t+1} = +u$		$u_{t+1} = -u$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0	0	a	0 or a	0 or a
$+a$	0	a	a	a
$-a$	0	0 or a	0 or a	0 or a
	$u_{t+1} = 0$		$u_{t+1} = -u$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0	$+u$	0 or a	0 or a	0 or a
$+a$	$+u$	a	0 or a	0 or a
$-a$	$+u$	0 or a	0 or a	0 or a
	$u_{t+1} = +u$		$u_{t+1} = 0$	
(X_t^i, u_t)	$d_{t+1} = -d$	$d_{t+1} = +d$	$d_{t+1} = -d$	$d_{t+1} = +d$
0	$-u$	a	a	a
$+a$	$-u$	a	a	a
$-a$	$-u$	a	0 or a	0 or a

Table 1.2(c) summarizes the equilibrium holdings x_{t+1}^j of an uninformed investor with $x_t^j = a$. X_t^i refers to the aggregate stock holdings of informed investors before trades at time t . u_t and u_{t+1} refer to the supply shock at time $t - 1$ and at time t , respectively. d_{t+1} refers to the dividend payout at time $t + 1$.

Table 1.3. Simulated Momentum Profits

<i>Panel (A). Benchmark I – IA only</i>					
<i>Past Ret</i>	<i>1st Pd</i>	<i>2nd Pd</i>	<i>3rd Pd</i>	<i>4th Pd</i>	<i>5th Pd</i>
0.5000	-0.0007	-0.0000	-0.0011	-0.0008	-0.0002
(0.00)	(0.43)	(0.54)	(0.35)	(0.36)	(0.44)
0.5000	-0.0003	-0.0004	0.0001	-0.0007	-0.0006
(0.00)	(0.52)	(0.46)	(0.48)	(0.42)	(0.39)
<i>Panel (B). Benchmark II – FTC only</i>					
<i>Past Ret</i>	<i>1st Pd</i>	<i>2nd Pd</i>	<i>3rd Pd</i>	<i>4th Pd</i>	<i>5th Pd</i>
1.0223	-0.0193	0.0126	-0.0069	0.0037	-0.0013
(0.00)	(0.02)	(0.03)	(0.14)	(0.35)	(0.42)
1.0048	-0.0096	0.0069	-0.0032	0.0021	-0.0009
(0.00)	(0.09)	(0.22)	(0.35)	(0.37)	(0.50)
<i>Panel (C). IA and FTC</i>					
<i>Past Ret</i>	<i>1st Pd</i>	<i>2nd Pd</i>	<i>3rd Pd</i>	<i>4th Pd</i>	<i>5th Pd</i>
1.5208	0.0563	0.1536	-0.0788	0.0334	-0.0159
(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
1.0240	0.0911	0.0490	-0.0254	0.0105	-0.0043
(0.00)	(0.00)	(0.00)	(0.00)	(0.05)	(0.30)
<i>Panel (D). IA and FTC (weighted by π_i^u)</i>					
<i>Past Ret</i>	<i>1st Pd</i>	<i>2nd Pd</i>	<i>3rd Pd</i>	<i>4th Pd</i>	<i>5th Pd</i>
1.5208	0.0171	0.0094	-0.0075	0.0029	-0.0016
(0.00)	(0.00)	(0.01)	(0.05)	(0.29)	(0.34)
1.0240	0.0132	0.0012	-0.0030	0.0008	-0.0001
(0.00)	(0.00)	(0.38)	(0.27)	(0.45)	(0.48)

Table 1.3 displays the simulated momentum profits arising in the dynamic model and in two benchmark models with the following set of parameter values: $\beta = 0.5$, $d = 1$, $\frac{u}{a} = 0.6$, $h = 0.011$, and $\frac{c}{a} = 0.01$. The statistics are derived from 100 simulations of a panel with 1000 stocks and 100 periods. The table reports the average dollar gains per period ($r_t = \beta(d_t + p_t) - p_{t-1}$) over the formation period (column 1), and one-period dollar gains over the first period up to the fifth period (column 2 through 6) ensuing the portfolio formation. Each panel includes simulated profits for the formation horizon of both one and two periods (row 1 and 3) and also a statistic defined as the sample probability of a random variable having the same sign as the respective mean (row 2 and 4). Panel (A) to (C), respectively, correspond to the first benchmark model with information asymmetry only, the second benchmark model with fixed transaction costs only, and the model with both information asymmetry and fixed transaction costs. Panel (D) shows the simulated π_t^u -weighted profits based on the same model as in Panel (C), where π_t^u is defined in Section 4.1 as the ratio of the aggregate volume of trades that involve uninformed investors at time $t - 1$ to the expected volume.

Table 1.4. Momentum Profits, 1983-2004

<i>Raw Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-month}</i>	1.537	0.622	0.915
<i>t-stat</i>	(3.59)	(1.42)	(11.5)
<i>W-L_{six-month-avg}</i>	0.870	-0.053	0.923
<i>t-stat</i>	(2.32)	(-0.13)	(15.0)
<i>CAPM-Adjusted Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-month}</i>	1.552	0.655	0.897
<i>t-stat</i>	(3.58)	(1.47)	(11.2)
<i>W-L_{six-month-avg}</i>	0.832	-0.093	0.925
<i>t-stat</i>	(2.19)	(-0.23)	(14.8)
<i>FF3-Factor-Adjusted Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-month}</i>	1.871	0.964	0.907
<i>t-stat</i>	(4.39)	(2.19)	(11.0)
<i>W-L_{six-month-avg}</i>	1.266	0.373	0.893
<i>t-stat</i>	(3.45)	(0.93)	(13.9)

Table 1.4 compares the standard measure and the PIAS-adjusted measure of momentum profits for the entire sample period from 1983 to 2004. The table shows monthly profits in percentage terms and the corresponding simple t-statistics. The top panel reports momentum profits without risk adjustment, and the next two panels, respectively, report risk-adjusted estimates based on the CAPM and the Fama-French three-factor model. The momentum portfolio that is formed at the end of month t takes a long (short) position in an equal-weighted portfolio of stocks in the highest (lowest) decile sorted on cumulative returns compounded over the past twelve months from month $(t - 12)$ to $(t - 1)$. The standard measure is simply the difference in returns between the monthly rebalanced winner and loser portfolios. The six-month average measures the monthly profits on a six-month rolling portfolio that in any calendar month holds an equal proportion of the zero-investment momentum portfolios selected in the previous six months. The PIAS-weighted average takes into account the adjustment for price-independent adverse selection based on Proposition 2 and represents the return obtainable by an uninformed marginal investor. Hence, the last column represents the bias in the standard measure. Refer to Section 6.1.1 for a detailed description of how to construct the PIAS weights. The sample is comprised of all ordinary common stocks of nonfinancial firms that are traded on NYSE, AMEX or NASDAQ, excluding stocks priced less than \$5 on the formation date and stocks in the smallest size decile (applying NYSE size decile breakpoints).

Table 1.5. Momentum Profits, 1994-2004

<i>Raw Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-month}</i>	1.469	0.457	1.012
<i>t-stat</i>	(1.86)	(0.57)	(8.13)
<i>W-L_{six-month-avg}</i>	0.694	-0.348	1.042
<i>t-stat</i>	(1.02)	(-0.48)	(10.7)
<i>CAPM-Adjusted Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-month}</i>	1.599	0.601	0.998
<i>t-stat</i>	(2.01)	(0.75)	(7.93)
<i>W-L_{six-month-avg}</i>	0.722	-0.326	1.049
<i>t-stat</i>	(1.05)	(-0.44)	(10.7)
<i>FF3-Factor-Adjusted Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-month}</i>	1.956	0.969	0.988
<i>t-stat</i>	(2.58)	(1.25)	(7.57)
<i>W-L_{six-month-avg}</i>	1.253	0.252	1.001
<i>t-stat</i>	(1.95)	(0.36)	(10.1)

Table 1.5 compares the standard measure and the PIAS-adjusted measure of momentum profits for the subsample period from 1994 to 2004. The table shows monthly profits in percentage terms and the corresponding simple t-statistics. The top panel reports momentum profits without risk adjustment, and the next two panels, respectively, report risk-adjusted estimates based on the CAPM and the Fama-French three-factor model. The momentum portfolio that is formed at the end of month t takes a long (short) position in an equal-weighted portfolio of stocks in the highest (lowest) decile sorted on cumulative returns compounded over the past twelve months from month $(t - 12)$ to $(t - 1)$. The standard measure is simply the difference in returns between the monthly rebalanced winner and loser portfolios. The six-month average measures the monthly profits on a six-month rolling portfolio that in any calendar month holds an equal proportion of the zero-investment momentum portfolios selected in the previous six months. The PIAS-weighted average takes into account the adjustment for price-independent adverse selection based on Proposition 2 and represents the return obtainable by an uninformed marginal investor. Hence, the last column represents the bias in the standard measure. Refer to Section 6.1.1 for a detailed description of how to construct the PIAS weights. The sample is comprised of all ordinary common stocks of nonfinancial firms that are traded on NYSE, AMEX or NASDAQ, excluding stocks priced less than \$5 on the formation date and stocks in the smallest size decile (applying NYSE size decile breakpoints).

Table 1.6. PEAD-Based Arbitrage Profits, 1983-2004

<i>Raw Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-quarter}</i>	0.588	0.231	0.357
<i>t-stat</i>	(4.31)	(1.46)	(7.69)
<i>W-L_{six-month-avg}</i>	0.430	0.016	0.415
<i>t-stat</i>	(3.38)	(0.10)	(9.36)
<i>CAPM-Adjusted Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-quarter}</i>	0.558	0.205	0.353
<i>t-stat</i>	(4.06)	(1.28)	(7.51)
<i>W-L_{six-month-avg}</i>	0.397	-0.018	0.415
<i>t-stat</i>	(3.09)	(-0.12)	(9.24)
<i>FF3-Factor-Adjusted Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-quarter}</i>	0.615	0.269	0.346
<i>t-stat</i>	(4.42)	(1.67)	(7.19)
<i>W-L_{six-month-avg}</i>	0.493	0.093	0.400
<i>t-stat</i>	(3.86)	(0.63)	(8.84)

Table 1.6 compares the standard measure and the PIAS-adjusted measure of PEAD-based arbitrage profits for the sample period from 1983 to 2004. The table shows monthly profits in percentage terms and the corresponding simple t-statistics. The top panel reports monthly profits without risk adjustment, and the next two panels, respectively, report risk-adjusted estimates based on the CAPM and the Fama-French three-factor model. The PEAD-based arbitrage portfolio that is formed at the end of the announcement quarter takes a long (short) position in an equal-weighted portfolio of stocks in the highest (lowest) decile sorted on the latest publicly available SUE. The standard measure is simply the difference in monthly returns between the quarterly rebalanced highest and lowest SUE portfolios. The six-month average measures the monthly profits on a six-month rolling portfolio that in any calendar month holds an equal proportion of the zero-investment arbitrage portfolios selected within the previous six months. The PIAS-weighted average takes into account the adjustment for price-independent adverse selection based on Proposition 2 and represents the return obtainable by an uninformed marginal investor. Hence, the last column represents the bias in the standard measure. Refer to Section 6.1.1 for a detailed description of how to construct the PIAS weights. The sample is comprised of all NYSE, AMEX or NASDAQ-traded firms that have at least ten consecutive earnings observations on Compustat and have March, June, September or December fiscal-year ends, but excludes those firm-quarter observations with earnings-announcement later than two months after a fiscal quarter ends and those with stock price lower than \$5 at the end of the earnings quarter.

Table 1.7. PEAD-Based Arbitrage Profits, 1994-2004

<i>Raw Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-quarter}</i>	0.363	-0.057	0.420
<i>t-stat</i>	(1.81)	(-0.24)	(6.21)
<i>W-L_{six-month-avg}</i>	0.217	-0.259	0.476
<i>t-stat</i>	(1.15)	(-1.17)	(7.14)
<i>CAPM-Adjusted Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-quarter}</i>	0.393	-0.023	0.416
<i>t-stat</i>	(1.94)	(-0.10)	(6.07)
<i>W-L_{six-month-avg}</i>	0.227	-0.249	0.476
<i>t-stat</i>	(1.19)	(-1.11)	(7.04)
<i>FF3-Factor-Adjusted Returns</i>			
	<i>Equally-Weighted</i>	<i>PIAS-Weighted</i>	$\Delta = EW - PW$
<i>W-L_{first-quarter}</i>	0.448	0.045	0.403
<i>t-stat</i>	(2.20)	(0.19)	(5.81)
<i>W-L_{six-month-avg}</i>	0.312	-0.152	0.464
<i>t-stat</i>	(1.63)	(-0.68)	(6.89)

Table 1.7 compares the standard measure and the PIAS-adjusted measure of PEAD-based arbitrage profits for the subsample period from 1994 to 2004. The table shows monthly profits in percentage terms and the corresponding simple t-statistics. The top panel reports monthly profits without risk adjustment, and the next two panels, respectively, report risk-adjusted estimates based on the CAPM and the Fama-French three-factor model. The PEAD-based arbitrage portfolio that is formed at the end of the announcement quarter takes a long (short) position in an equal-weighted portfolio of stocks in the highest (lowest) decile sorted on the latest publicly available SUE. The standard measure is simply the difference in monthly returns between the quarterly rebalanced highest and lowest SUE portfolios. The six-month average measures the monthly profits on a six-month rolling portfolio that in any calendar month holds an equal proportion of the zero-investment arbitrage portfolios selected within the previous six months. The PIAS-weighted average takes into account the adjustment for price-independent adverse selection based on Proposition 2 and represents the return obtainable by an uninformed marginal investor. Hence, the last column represents the bias in the standard measure. Refer to Section 6.1.1 for a detailed description of how to construct the PIAS weights. The sample is comprised of all NYSE, AMEX or NASDAQ-traded firms that have at least ten consecutive earnings observations on Compustat and have March, June, September or December fiscal-year ends, but excludes those firm-quarter observations with earnings-announcement later than two months after a fiscal quarter ends and those with stock price lower than \$5 at the end of the earnings quarter.

Table 1.8. Predicting Return Momentum, 1985-2004

<i>Panel (A). First-Month Returns</i>						
	<i>CAPM α</i>			<i>FF3 α</i>		
	<i>P1</i>	<i>P3</i>	<i>P3-P1</i>	<i>P1</i>	<i>P3</i>	<i>P3-P1</i>
<i>R1</i>	-0.736	-1.685	-0.949	-0.729	-1.550	-0.822
<i>t-stat</i>	(-2.19)	(-4.80)	(-4.62)	(-2.37)	(-5.03)	(-3.98)
<i>R10</i>	0.082	0.730	0.648	0.436	1.084	0.648
<i>t-stat</i>	(0.23)	(1.99)	(3.09)	(2.01)	(4.61)	(3.00)
<i>Panel (B). Three-Month Average Returns</i>						
	<i>CAPM α</i>			<i>FF3 α</i>		
	<i>P1</i>	<i>P3</i>	<i>P3-P1</i>	<i>P1</i>	<i>P3</i>	<i>P3-P1</i>
<i>R1</i>	-0.715	-1.302	-0.586	-0.726	-1.176	-0.450
<i>t-stat</i>	(-2.22)	(-3.78)	(-3.31)	(-2.49)	(-4.05)	(-2.59)
<i>R10</i>	-0.027	0.596	0.623	0.381	0.958	0.577
<i>t-stat</i>	(-0.08)	(1.77)	(3.55)	(1.95)	(4.61)	(3.26)
<i>Panel (C). Six-Month Average Returns</i>						
	<i>CAPM α</i>			<i>FF3 α</i>		
	<i>P1</i>	<i>P3</i>	<i>P3-P1</i>	<i>P1</i>	<i>P3</i>	<i>P3-P1</i>
<i>R1</i>	-0.656	-0.971	-0.315	-0.704	-0.881	-0.177
<i>t-stat</i>	(-2.00)	(-2.79)	(-1.94)	(-2.42)	(-3.00)	(-1.12)
<i>R10</i>	-0.251	0.358	0.609	0.153	0.748	0.595
<i>t-stat</i>	(-0.72)	(1.15)	(3.98)	(0.85)	(4.21)	(3.95)

In Table 1.8, stocks are sorted on the BOS ratio into three quantiles within the highest (R10) and the lowest (R1) deciles of cumulative returns compounded over the past twelve months. See section 6.2.1 for a detailed account of the BOS ratio. For the R1 portfolio, P3 (P1) denotes the subgroup that has the highest (lowest) BOS ratio. For the R10 portfolio, P3 (P1) denotes the subgroup that has the lowest (highest) BOS ratio. The left panel reports CAPM-adjusted returns in percentage terms, and the right panel reports Fama–French three-factor-adjusted returns in percentage terms. Panel (A), (B) and (C) present results over a holding period of one, three and six months, respectively. The sample is comprised of all ordinary common stocks of nonfinancial firms that are traded on NYSE, AMEX or NASDAQ, excluding stocks priced less than \$5 on the formation date and stocks in the smallest size decile (applying NYSE size decile breakpoints).

Table 1.9. Summary Characteristics of BOS-sorted portfolios, 1985-2004

R1 – Past-Weak-Performance Stocks						
	P1			P3		
	BOS	ME	R_{p1yr}	BOS	ME	R_{p1yr}
Mean	-2.16	0.94	-5.24	6.10	0.71	-5.17
Median	-1.50	0.29	-4.66	3.75	0.22	-4.64
Std. Dev.	2.14	2.18	1.99	8.05	1.95	1.91
R10 – Past-Strong-Performance Stocks						
	P1			P3		
	BOS	ME	R_{p1yr}	BOS	ME	R_{p1yr}
Mean	7.95	0.72	8.18	-2.04	2.07	7.54
Median	5.34	0.29	7.43	-1.27	0.51	6.83
Std. Dev.	8.31	1.51	2.67	2.50	5.54	2.29

Table 1.9 presents the summary statistics for some characteristics of the subportfolios. In particular, the numbers shown in the table are the time-series average of respective summary statistics for the monthly-rebalanced subportfolios. Stocks are sorted on the BOS ratio into three quantiles within the highest (R10) and the lowest (R1) deciles of cumulative returns compounded over the past twelve months. See section 6.2.1 for a detailed account of the BOS ratio. P3 (P1) denotes the subgroup that has the strongest (weakest) momentum within the R1 or the R10 portfolio. “BOS” stands for the BOS ratio (in percentage terms). “ME” stands for the market value of equity (in million dollars). “ R_{p1yr} ” stands for the average return over the past twelve months (in percentage terms). The entire sample is comprised of all ordinary common stocks of nonfinancial firms that are traded on NYSE, AMEX or NASDAQ, excluding stocks priced less than \$5 on the formation date and stocks in the smallest size decile (applying NYSE size decile breakpoints).

Chapter 2

Inefficient Liquidity Provision under Information Asymmetry

This paper presents a simple model that features a market with information asymmetry and imperfect competition. In particular, the model examines how the market absorbs a publicly known supply shock. The informed in this model always under-provides liquidity due to the noncompetitive nature of the market. Even when price fully reveals private information, the market does not attain perfect risk sharing. An investor appears more risk-averse than in a canonical model, as a liquidity trader faces a buy price distribution that is highly skewed toward the upper end and a sell price distribution that is highly skewed toward the lower end. Moreover, uninformed investors display the “disposition effect:” to unload shares when price is high and to load shares when price is low. The magnitude of these apparent “behavioral biases” depends on the recent performance of the individual stock, as information asymmetry induces trading frictions and causes inertia in share distribution. The history dependence at the individual stock level distinguishes this information story from existing models of heterogeneous preferences. Examining the effects of information imperfections on share allocation in addition to price behavior offers insights on stock return behavior.

2.1 Introduction

This paper investigates how information asymmetry induces inefficiency in share distribution and in turn affects stock return behavior. Previous studies on information imperfections have focused on market efficiency in collecting and revealing private information.¹ Some have further explored its implications on price volatility and risk premium. The current study contributes to the literature by extending the analysis to the quantity dimension. Examining share allocation in addition to price behavior generates interesting implications for both cross-sectional and time-series return behavior under information asymmetry.

This paper presents a simple model that features a market with information asymmetry and imperfect competition. The model focuses on how the market absorbs a publicly known supply shock. The interesting questions include whether it is informed or uninformed investors who trade to accommodate liquidity trades, how the cost of liquidity varies accordingly, and how liquidity conditions predict return.

To our surprise, the informed in this model always under-provide liquidity due to the non-competitive nature of the market. Given an exogenous increase in the supply of the asset the informed buy disproportionately less relative to the uninformed in absorbing the liquidity sells; and vice versa. Even when price fully reveals private information, the market does not achieve perfect risk sharing.

For an investor who is forced to liquidate his holdings, the distribution of his liquidation price is highly skewed toward the lower end, with unbounded downside but bounded upside; and vice versa. Price falls with expected payoff and falls further at the lower end, because the uninformed bear excessively more and more risk as price falls and thus demand a higher and higher risk premium. As price rises with expected payoff, the informed will be reluctant to push the price up further as the marginal profits of informed trades diminish.

This simple model of information asymmetry offers interesting implications on investment behavior and return behavior, similar to those in the growing literature of behavioral finance.²

¹See, for example, Grossman (1976), Grossman and Stiglitz (1980), Hellwig (1980), Admati (1985), Kyle (1985), Diamond and Verrecchia (1987), Kyle (1989), Easley and O'Hara (1992), Holden and Subrahmanyam (1992), Romer (1993), Wang (1993), Caplin and Leahy (1994), Foster and Viswanathan (1996), Back, Cao and Willard (2000), Vayanos (2001), and Brunnermeier (2005).

²See, for example, Barberis, Huang and Santos (2001).

An investor appears more risk-averse than in a canonical model, as a liquidity trader faces a buy price distribution that is highly skewed toward the upper end and a sell price distribution that is highly skewed toward the lower end. Moreover, uninformed investors display the “disposition effect:” to unload shares when price is high and to load shares when price is low. The magnitude of these “behavioral biases” depends on the recent performance of the individual stock, since information asymmetry induces trading frictions and causes inertia in share distribution. The history dependence at the individual stock level distinguishes this information story from existing models of heterogeneous preferences.³

Like Wu (2007), this paper provides an information-based explanation of return autocorrelation. Unlike Wu (2007) that predicts a state-dependent positive return autocorrelation, the current model predicts a state-dependent negative return autocorrelation. The two papers however do not contradict but rather complement each other. The return predictability in Wu (2007) results from the predictability of liquidity trades under information asymmetry. Seemingly abnormal returns arise when price becomes dysfunctional in uncovering information-induced distortions in aggregate trades. In contrast, the return predictability in this paper derives from the predictability of variation in risk premium. As a result, return can appear positively or negatively autocorrelated, depending on the weight of systematic risk relative to idiosyncratic risk, the noisiness of non-information-driven trades, and etc. The relevant horizon of the autocorrelation can also vary with the nature of information.

The remainder of the paper is organized as follows. Section 2 sets up the model. Section 3 characterizes a rational expectations equilibrium. Section 4 presents novel model implications. Section 5 concludes the paper.

2.2 Model

This one-period model examines how differentially informed investors trade to absorb a publicly known liquidity shock, aiming to understand the role of liquidity provision by different types of investors under information asymmetry and its implications on asset return behavior.

A typical market structure under information asymmetry consists of three parties: informed

³See, for example, Chan and Kogan (2002).

traders, uninformed traders, and liquidity traders who trade for non-informational motives. The informed profit from trading with both uninformed and liquidity traders. The uninformed lose to the informed, but exploits liquidity traders to break even. The cost of liquidity born by liquidity traders thus depends on the specification of market structure which includes the transparency of liquidity shocks among many other things.

This model investigates a case at one extreme of the spectrum, in which the liquidity shock is perfectly known to the public before trades take place. Such specification tends to minimize the cost incurred on liquidity trades and to limit the profits of informational trades. Kyle (1989) provides analyses of the other extreme. By removing uncertainty regarding the liquidity shock, this study underscores the role of information in share reallocation. In contrast, previous studies on information asymmetry focus solely on the price dimension and investigate how efficiently price reveals private information. This study expands the previous analysis by shifting our attention to the quantity dimension. I will examine how information asymmetry affects share allocation between the informed and the uninformed and its consequences on the price behavior.

The simple economy has only two assets, one risky asset and one riskfree asset. Without loss of generality, let the riskfree rate be zero. The supply of the riskfree asset is assumed to be perfectly elastic. The risky asset pays a dividend d per share:

$$d = z + \varepsilon, \text{ where } z \sim N(0, \sigma_z^2) \text{ and } \varepsilon \sim N(0, \sigma^2).$$

z and ε are mutually independent. z follows a centered normal distribution with variance of σ_z^2 . ε follows a centered normal distribution with variance of σ^2 . The aggregate supply of the risky asset is $S + u$ number of shares, where S is a positive constant. u denotes the exogenous liquidity shock that hits the market before the current round of trading. All investors observe u perfectly before trading. A positive u represents a noise sell of u shares; while a negative u represents a noise buy. Assume $S + u > 0$ always holds.

There are two types of investors, one informed investor and N uninformed investors. The informed investor observes z before trading, but the uninformed investors do not. Each individual investor is initially endowed with $\frac{S}{1+N}$ shares of the risky asset and zero shares of the

riskfree asset.

All investors share the same CARA utility function:

$$-\exp(-\alpha W_1),$$

where W_1 refers to the total wealth at the end of the period.

Finally, all the uninformed investors behave competitively as price-takers, but the informed investor takes into account monopoly power over his private information and takes into consideration his price impact while deciding on his portfolio choice. As is discussed in Kyle (1985), it is plausible to model the informed trader as behaving strategically for the following reasons. First, stylized facts suggest best-informed traders are often large. Second, introducing imperfect competition resolves the schizophrenia problem. Otherwise, under perfect competition, equilibrium prices reveal so much of private information that profits from informational trades are small and there would be little incentive to acquire costly private information in the first place.

For simplicity, this model groups all informed investors together as one monopolist. The parameter N should not be interpreted literally as the ratio of the population of the two differentially informed investors, but it instead captures the joint effect of various factors that determines the relative risk-bearing capacity of the uninformed investors as a whole versus that of the informed.

2.3 Equilibrium

A few more notations are in order. Let p denote the price of the risky asset. x_t^k denotes the demand of the risky asset by a type- k investor at time t , $t = 0, 1$. $k = i$ if an investor is informed; otherwise, $k = u$. By assumption, $x_0^i = x_0^u = \frac{S}{1+N}$.

Definition 2 *A rational expectations equilibrium consists of a price function $p = p(z)$, the demand of the informed investor $x_1^i(z)$, the belief of an uninformed investor $g(p)$, and the demand of an uninformed investor $x_1^u(p)$, such that*

1. *given the demand of an uninformed investor $x_1^u(p)$, $x_1^i(z)$ maximizes the expected utility*

of the informed investor;

2. given the price p , an uninformed investor forms his rational belief $g(p)$, and $x_1^u(p)$ maximizes his expected utility;

3. the market clears:

$$S + u = x_1^i(z) + Nx_1^u(p(z)).$$

Proposition 8 *There exists a rational expectations equilibrium as is defined above.*

By construction, the model is symmetric for positive ($u > 0$) and negative ($u < 0$) liquidity shocks. Let us first look at the case in which $u > 0$. Assume $\frac{N(2+N)\sigma_z}{\alpha\sigma^2u} \gg 1$ so that a closed form solution can be obtained to the second-order approximation. Note that the existence of an equilibrium does not require this restriction on parameters.

Equilibrium Price

For $u > 0$ and $\frac{N(2+N)\sigma_z}{\alpha\sigma^2u} \gg 1$, there exists one equilibrium characterized by the following price function $p = p(z)$:

$$p = \begin{cases} z - \alpha\sigma^2 \frac{[S+u-f^{-1}(z)]}{N}, & \text{for } z \in (-\infty, z^R]; \\ z^R - \alpha\sigma^2 \left(\frac{S}{1+N} + \frac{u}{2+N} \right), & \text{for } z \in (z^R, +\infty). \end{cases}$$

The constant z^R and the function $f(x)$ are defined as follows:

$$z^R \equiv \frac{N(2+N)\sigma_z^2}{\alpha\sigma^2u};$$

$$f(x) \equiv z^R + \alpha\sigma^2 \frac{(2+N)}{N} [x^R - x] + \alpha\sigma^2 \frac{u}{N} \ln \left(\frac{x - x_0^i}{x^R - x_0^i} \right),$$

for $x \in (x_0^i, x^R]$ and $x^R \equiv x_0^i + \frac{u}{(2+N)} \left(1 - \sqrt{\frac{2}{2+N}} \right)$.

Note that

$$f'(x) = \alpha\sigma^2 \left(\frac{2+N}{N} \right) \left(\frac{x_0^i + \frac{u}{2+N} - x}{x - x_0^i} \right) \geq 0 \text{ if } x_0^i < x \leq x_0^i + \frac{u}{(2+N)}.$$

The function $f(x)$ is indeed invertible over $(x_0^i, x^R]$. Moreover, $f'(x)$ can be rewritten as

$$f'(x) = \alpha\sigma^2 \left(\frac{2+N}{N} \right) \left(\frac{\frac{u}{2+N}}{x-x_0^i} - 1 \right),$$

so

$$f''(x) = \alpha\sigma^2 \left(\frac{2+N}{N} \right) \frac{\frac{u}{2+N}}{(x-x_0^i)^2} > 0.$$

As $f(x)$ is convex in x , $f^{-1}(z)$ must be concave in z . Therefore, over the range of $z \in (-\infty, z^R]$, price fully reveals the private information regarding z . Price increases with z ; and furthermore price is a concave function of z .

Let p^U denote the price at which all signal $z \in (z^R, +\infty)$ pools, i.e., $p^U \equiv z^R - \alpha\sigma^2 \left(\frac{S}{1+N} + \frac{u}{2+N} \right)$. Let p^R denote the highest price at which price fully reveals the private signal, i.e., $p^R = z^R - \alpha\sigma^2 \left[\frac{S}{1+N} + \frac{(1+N) + \sqrt{\frac{2}{2+N}}}{N(2+N)} u \right]$.

It can be easily verified that p^U is higher than p^R . To sum up, the equilibrium price function consists of two regimes. Over one regime, price fully reveals the private information regarding z . Price falls as z falls and drops at a faster pace. Over the other regime, price is completely uninformative. Figure 3.1 shows the mapping from z to p .

When a liquidity sell of u shares hits the market, the equilibrium price will be perfectly informative if $z \in (-\infty, z^R]$, but will be completely insensitive to private signal over the region of $[z^R, +\infty)$. Even though the distribution of the original private signal z is normal and symmetric, the distribution of the equilibrium price is asymmetric – unbounded at the lower end and bounded at the upper end. Compared to the normal distribution of z , the price distribution should have a thicker tail at the lower end because price there is concave in z .

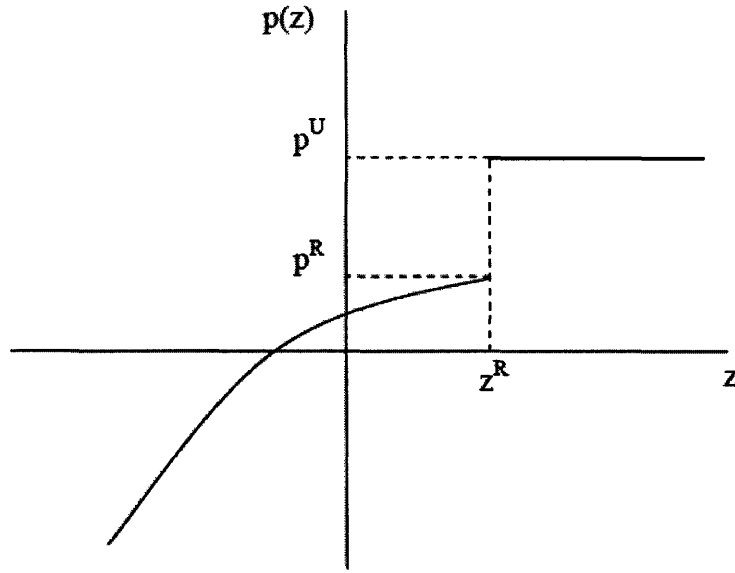


Figure 2-1: Price Function, $p(z)$

Demand of an Uninformed Investor

The uninformed investors infer others' private information from the market-clearing price. They form the following rational belief $\theta(p)$ regarding z :

$$\theta(p) = \begin{cases} z = p + \alpha\sigma^2 \frac{S+u-g^{-1}(p)}{N}, & \text{if } p \leq p^R; \\ z = p + \alpha\sigma^2 \frac{S+u-x^R}{N}, & \text{if } p \in (p^R, p^U); \\ z \sim N(0, \sigma_z^2) \text{ truncated at } z^R, & \text{if } p = p^U; \\ z \sim N(0, \sigma_z^2) \text{ truncated at } A(p) \text{ where} \\ \left(A(p) + \frac{\sigma_z^2}{A(p)}\right) = p + \alpha\sigma^2 \left(\frac{S}{N+1} + \frac{(N+1)u}{(N+2)N}\right), & \text{if } p > p^U. \end{cases}$$

The function $g(x)$ is defined as follows:

$$g(x) = z^R - \alpha\sigma^2 \frac{S+u-x^R}{N} + \alpha\sigma^2 \frac{u}{N} \ln\left(\frac{x-x_0^i}{x^R-x_0^i}\right) - \alpha\sigma^2 \frac{(1+N)}{N} (x-x^R).^4$$

⁴Note that

$$g(x^R) = z^R - \alpha\sigma^2 \frac{S+u-x^R}{N} = p^R,$$

Note that in equilibrium price either lies in $(-\infty, p^R]$ or equals p^U . For $p \in (p^R, p^U) \cup (p^U, +\infty)$, $\theta(p)$ specifies the off-equilibrium belief.

Given the belief, an uninformed investor behaves as a competitive price taker and chooses x_1^u to maximize

$$E[-\exp(-\alpha(x_1^u d - (x_1^u - x_0^u)p))].$$

If $p \leq p^R$, price fully reveals what z is, and the expected utility becomes

$$-\exp\left(-\alpha\left(x_1^u z - \frac{1}{2}\alpha\sigma^2(x_1^u)^2 - (x_1^u - x_0^u)p\right)\right).$$

It immediately follows that the optimal demand $x_1^u = \frac{S+u-g^{-1}(p)}{N}$.

If $p \in (p^R, p^U)$, the uninformed would believe $z = p + \alpha\sigma^2 \frac{S+u-x^R}{N}$, so they would choose x_1^u to maximize

$$-\exp\left(-\alpha\left(x_1^u z - \frac{1}{2}\alpha\sigma^2(x_1^u)^2 - (x_1^u - x_0^u)p\right)\right).$$

Hence, the optimal demand of an uninformed investor would be $\frac{S+u-x^R}{N}$ if price falls between p^R and p^U .

If $p = p^U$, the conditional distribution of z is a truncated normal distribution bounded

$$\lim_{x \rightarrow x_0^i} g(x) \rightarrow -\infty,$$

and

$$g'(x) = \frac{\alpha\sigma^2}{N} \left[\frac{u}{x - x_0^i} - (1 + N) \right] > 0 \text{ if } x < \frac{S+u}{1+N}.$$

Hence, $g^{-1}(p)$ is well defined for $p \leq p^R$.

below at z^R . The expected utility becomes⁵

$$\begin{aligned}
& \frac{\int_{z^R}^{\infty} -\exp\left(-\alpha\left(x_1^u z - \frac{1}{2}\alpha\sigma^2(x_1^u)^2 - (x_1^u - x_0^u)p\right)\right) \exp\left(-\frac{z^2}{2\sigma_z^2}\right) dz}{\int_{z^R}^{\infty} \exp\left(-\frac{z^2}{2\sigma_z^2}\right) dz} \\
&= -\exp\left(-\alpha\left(-\frac{1}{2}\alpha(\sigma^2 + \sigma_z^2)(x_1^u)^2 - (x_1^u - x_0^u)p\right)\right) \frac{\int_{z^R}^{\infty} \exp\left(-\frac{1}{2}\left(\frac{z}{\sigma_z} + \alpha\sigma_z x_1^u\right)^2\right) d\left(\frac{z}{\sigma_z}\right)}{\int_{z^R}^{\infty} \exp\left(-\frac{\left(\frac{z}{\sigma_z}\right)^2}{2}\right) d\left(\frac{z}{\sigma_z}\right)} \\
&\sim -\exp\left\{-\alpha\left[\left(z^R + \frac{\sigma_z^2}{z^R}\right)x_1^u - \frac{1}{2}\alpha\sigma^2(x_1^u)^2 - (x_1^u - x_0^u)p\right]\right\}.
\end{aligned}$$

Clearly, the objective function is concave in x_1^u . The optimal demand of an uninformed investor thus satisfies

$$\left(z^R + \frac{\sigma_z^2}{z^R}\right) = p^U + \alpha\sigma^2 x_1^u$$

→

$$x_1^u = \frac{z^R + \frac{\sigma_z^2}{z^R} - p^U}{\alpha\sigma^2} = \frac{S}{1+N} + \frac{u(1+N)}{N(2+N)}.$$

If $p > p^U$, the uninformed would believe the conditional distribution of z is a truncated normal distribution bounded below at $A(p)$. Recall that

$$\left(A(p) + \frac{\sigma_z^2}{A(p)}\right) = p + \alpha\sigma^2 \left(\frac{S}{N+1} + \frac{(N+1)u}{(N+2)N}\right)$$

and $1 \ll \frac{z^R}{\sigma_z}$. There exists $A(p)$ such that the condition above holds, and $A(p) > z^R$ and $A'(p) > 0$ for $p > p^U$. Similar to the case in which $p = p^U$, an uninformed investor would choose $x_1^u = \frac{S}{1+N} + \frac{u(1+N)}{N(2+N)}$.

⁵The last equality follows from $\frac{A(p)}{\sigma_z} \gg 1$. Recall the fact that, for any $a > 0$,

$$\frac{a}{1+a^2} \exp\left(-\frac{a^2}{2}\right) < \int_a^{\infty} \exp\left(-\frac{x^2}{2}\right) dx < \frac{1}{a} \exp\left(-\frac{a^2}{2}\right).$$

If a is sufficiently large,

$$\int_a^{\infty} \exp\left(-\frac{x^2}{2}\right) dx \sim \frac{1}{a} \exp\left(-\frac{a^2}{2}\right).$$

To sum up, the demand curve for an uninformed investor is as shown below:

$$x_1^u(p) = \begin{cases} \frac{S+u-g^{-1}(p)}{N}, & \text{if } p \leq p^R; \\ \frac{S+u-x^R}{N}, & \text{if } p \in (p^R, p^U); \\ \frac{S}{1+N} + \frac{u(1+N)}{N(2+N)}, & \text{if } p \geq p^U. \end{cases}$$

The demand of an uninformed investor decreases with price.

Demand of an Informed Investor

The optimal demand of the informed investor is as shown below:

$$x_1^i(z) = \begin{cases} f^{-1}(z), & \text{if } z \leq z^R; \\ x^U, & \text{if } z \in (z^R, +\infty). \end{cases}$$

Given the demand curve of uninformed investors, the residual supply for the informed should be

$$x_1^i(p) = \begin{cases} g^{-1}(p), & \text{if } p \leq p^R; \\ x^R, & \text{if } p \in (p^R, p^U); \\ x^U \equiv \frac{S}{1+N} + \frac{u}{2+N}, & \text{if } p \geq p^U. \end{cases}$$

As is discussed previously, the supply curve is upward sloping. Facing this residual supply curve, the informed investor strategically choose his demand x_1^i upon receiving private information about z . The informed who perfectly observes z decides on x_1^i to maximize his expected utility:

$$-\exp \left[-\alpha \left(x_1^i z - \frac{1}{2} \alpha \sigma^2 (x_1^i)^2 - (x_1^i - x_0^i) p \right) \right].$$

Equivalently, he decides on x_1^i to maximize

$$\pi = x_1^i z - \frac{1}{2} \alpha \sigma^2 (x_1^i)^2 - (x_1^i - x_0^i) p(x_1^i),$$

or he decides on p to maximize

$$\pi = x_1^i(p) z - \frac{1}{2} \alpha \sigma^2 [x_1^i(p)]^2 - [x_1^i(p) - x_0^i] p.$$

First of all, the informed will not choose p within $(p^R, p^U) \cup (p^U, +\infty)$, because $\frac{dx_1^i(p)}{dp} = 0$ for $p \in (p^R, p^U) \cup (p^U, +\infty)$. If $p \in (p^R, p^U)$, the informed could improve his utility by choosing $p = p^R$. Similarly, if $p \in (p^U, +\infty)$, the informed could improve his utility by choosing $p = p^U$. Therefore, in equilibrium, x^R and x^U must correspond to p^R and p^U , respectively. Rewrite the residual supply for the informed by expressing p in terms of x_1^i :

$$p(x_1^i) = \begin{cases} -\infty, & \text{if } x_1^i \leq x_0^i; \\ g(x_1^i), & \text{if } x_0^i < x_1^i \leq x^R; \\ +\infty, & \text{if } x^R < x_1^i \leq x^U; \\ p^U, & \text{if } x_1^i = x^U; \\ +\infty, & \text{if } x^U < x_1^i. \end{cases}$$

Either $p(x) = +\infty$ or $p(x) = -\infty$ implies that the informed cannot achieve the intended position x in equilibrium.

The informed takes into consideration the price impact of his demand and considers the following first-order derivative $\pi(x_1^i)$ with respect to x_1^i :

$$\pi'(x_1^i) = z - \alpha\sigma^2 x_1^i - p - (x_1^i - x_0^i) p'(x_1^i).$$

In addition, the second-order derivative of $\pi(x_1^i)$ with respect to x_1^i :

$$\pi''(x_1^i) = -\alpha\sigma^2 - 2p'(x_1^i) - (x_1^i - x_0^i) p''(x_1^i).$$

Note that, for $x_1^i \in (x_0^i, x^R]$,

$$p'(x_1^i) = g'(x_1^i) = \frac{\alpha\sigma^2}{N} \left[\frac{u}{x_1^i - x_0^i} - (1 + N) \right],$$

and

$$p''(x_1^i) = g''(x_1^i) = -\frac{\alpha\sigma^2}{N} \frac{u}{(x_1^i - x_0^i)^2}.$$

Substituting $p'(x_1^i)$ and $p''(x_1^i)$ into $\pi''(x_1^i)$, we obtain

$$\pi''(x_1^i) = -\alpha\sigma^2 \frac{2+N}{N} \frac{\left(\frac{S}{1+N} + \frac{u}{2+N}\right) - x_1^i}{x_1^i - x_0^i}.$$

That is to say, the objective function is concave in x_1^i within the range of $x_1^i \in (x_0^i, x^R]$. The informed investor would prefer to buy more shares at a higher price if $z > \alpha\sigma^2 x_1^i + p + (x_1^i - x_0^i) p'(x_1^i)$ and $p \leq p^R$, and vice versa. Any x_1^i that satisfies $z = \alpha\sigma^2 x_1^i + p + (x_1^i - x_0^i) p'(x_1^i)$ should maximize $\pi(x_1^i)$ within $(x_0^i, x^R]$. Next I show such x_1^i also maximizes $\pi(x)$ globally for the given z .

First, let us look at the case with $z = z^R$. Recall that

$$z^R \equiv \frac{N(2+N)\sigma_z^2}{\alpha\sigma^2 u}$$

and

$$g(x^R) = z^R - \alpha\sigma^2 \frac{S + u - x^R}{N}.$$

Replacing p with $g(x^R)$ in $\pi'(x^R)$, we know that the first-order condition holds, i.e., $\pi'(x) = 0$, for $z = z^R$. To verify that x^R maximizes $\pi(x)$ globally when $z = z^R$, we need to check that $\pi(x^R, z^R) \geq \pi(x^U, z^R)$.

$$\begin{aligned} & \pi(x^R, z^R) - \pi(x^U, z^R) \\ &= (x^R - x^U) z^R - \frac{1}{2} \alpha\sigma^2 [(x^R)^2 - (x^U)^2] - (x^R - x_0^i) p^R + (x^U - x_0^i) p^U \\ &= -\frac{u}{(2+N)} \sqrt{\frac{2}{2+N}} \left[z^R - \frac{1}{2} \alpha\sigma^2 (x^R + x^U) \right] - \frac{u}{(2+N)} \left(1 - \sqrt{\frac{2}{2+N}} \right) p^R + \frac{u}{2+N} p^U \\ &= -\frac{u}{(2+N)} \sqrt{\frac{2}{2+N}} \left[z^R - p^R - \frac{1}{2} \alpha\sigma^2 (x^R + x^U) \right] + \frac{u}{2+N} \alpha\sigma^2 \frac{1 + \sqrt{\frac{2}{2+N}}}{N(2+N)} u \\ &= 0 \end{aligned}$$

The informed investor is indeed indifferent between x^R and x^U . Therefore, x^R maximizes $\pi(x)$ when $z = z^R$.

$$\pi = x_1^i z - \frac{1}{2} \alpha\sigma^2 (x_1^i)^2 - (x_1^i - x_0^i) p(x_1^i),$$

Next, for any $z < z^R$, there exists a x such that $\pi'(x) = 0$ and $g(x) \leq p^R$. Since $\pi(x^R, z^R) = \pi(x^U, z^R)$,

$$\pi(x^R, z) = \pi(x^R, z^R) + x^R(z - z^R),$$

and

$$\pi(x^U, z) = \pi(x^U, z^R) + x^U(z - z^R),$$

therefore,

$$\pi(x^R, z) - \pi(x^U, z) = (x^R - x^U)(z - z^R) > 0.$$

That is to say, x maximizes $\pi(x)$ for the given z .

Finally, for any $z > z^R$, there exists no x such that $\pi'(x) = 0$ and $g(x) \leq p^R$. Either x^R or x^U maximizes $\pi(x, z)$. Since $\pi(x^R, z^R) = \pi(x^U, z^R)$,

$$\pi(x^R, z) = \pi(x^R, z^R) + x^R(z - z^R),$$

and

$$\pi(x^U, z) = \pi(x^U, z^R) + x^U(z - z^R),$$

therefore,

$$\pi(x^R, z) - \pi(x^U, z) = (x^R - x^U)(z - z^R) < 0.$$

That is to say, x^U maximizes $\pi(x)$ for the given z .

It has thus been verified that the optimal demand of the informed investor is as shown below:

$$x_1^i(z) = \begin{cases} f^{-1}(z), & \text{if } z \leq z^R; \\ x^U, & \text{if } z \in (z^R, +\infty). \end{cases}$$

To conclude the proof of the existence of an equilibrium, I show that the suggested belief $\theta(p)$ is indeed rational. The uninformed investors make correct inference based on price.

When $z \in (z^R, +\infty)$, the informed investor demands x^U shares, and each uninformed investor must have $\frac{S+u-x^U}{N} = \frac{S}{1+N} + \frac{u(1+N)}{N(2+N)}$ shares so that the market clears. The market clearing price is therefore $p = p^U$.

When $z \leq z^R$, the informed investor demands $x = f^{-1}(z) \leq x^R$ shares, and each uninformed investor must have $\frac{S+u-x}{N}$ shares so that the market clears. The market clearing price must be $p = g(x) \leq g(x^R) = p^R$. Because $f(x) - g(x) = \alpha\sigma^2 \frac{1}{N} [S + u - x]$,

$$\begin{aligned} z &= f(x) = g(x) + \alpha\sigma^2 \frac{1}{N} [S + u - x] \\ &= p + \alpha\sigma^2 \frac{1}{N} [S + u - g^{-1}(p)], \end{aligned}$$

which is indeed the conjectured belief of the uninformed for $p \leq p^R$. Hence, if $z < z^R$, the market clearing price will be lower than p^U . As a result, only if $z \geq z^R$, the market clears at price $p = p^U$. In fact, given $p = p^U$, the uninformed believes that z follows a truncated normal distribution, $N(0, \sigma_z^2)$ truncated below at z^R .

The proof of Proposition 8 is thus complete. It is worth emphasizing that although the model can have multiple equilibria there exists no equilibrium in which price fully reveals the private information regarding z . Perfect public knowledge of liquidity shock u does not guarantee perfect price revelation. To present a formal proof of this claim, I will first introduce a lemma as follows.

Lemma 1 *If price fully reveals the private information regarding z , the demand curve of an uninformed investor must be strictly downward sloping.*

Proof by Contradiction. Assume to the contrary that the demand curve is not strictly downward sloping, i.e., there exists a pair (p_1, p_2) such that $p_1 > p_2$ and $x_1^u(p_1) \geq x_1^u(p_2)$. The expectation of the uninformed must be $\theta(p) = p + \alpha\sigma^2 x_1^u$, so $\theta(p_1) > \theta(p_2)$. In equilibrium, $z = \theta(p)$. Let z_1 and z_2 denote $\theta(p_1)$ and $\theta(p_2)$, respectively. Clearly, $z_1 > z_2$.

Now consider the optimization of the informed investor. It follows that

$$\begin{aligned} \pi(p_1, z_1) &> \pi(p_2, z_1), \\ \text{and } \pi(p_1, z_2) &< \pi(p_2, z_2). \end{aligned}$$

However,

$$\begin{aligned}
\pi(p_1, z_2) &= \pi(p_1, z_1) + (z_2 - z_1)[S + u - x_1^u(p_1)] \\
&> \pi(p_2, z_1) + (z_2 - z_1)[S + u - x_1^u(p_1)] \\
&\geq \pi(p_2, z_1) + (z_2 - z_1)[S + u - x_1^u(p_2)] \\
&= \pi(p_2, z_2);
\end{aligned}$$

that is to say,

$$\pi(p_1, z_2) > \pi(p_2, z_2),$$

which contradicts

$$\pi(p_1, z_2) < \pi(p_2, z_2).$$

The initial assumption thus generates contradictory predictions. Therefore,

$$\frac{dx_1^u(p)}{dp} < 0.$$

■

Proposition 9 *The impossibility of perfect price revelation.*

Proof by Contradiction. Assume to the contrary that there is an equilibrium in which price perfectly reveals private information. According to Lemma 1, p must strictly increase with z , and x_1^u must strictly decrease with p , and p must strictly increase with x_1^i . Consider the inverse function $p(x)$ of the informed investor's demand function $x_1^i(p)$. $p(x)$ must simultaneously satisfy the following conditions:

$$\begin{aligned}
\text{Rational expectation by the uninformed:} & \quad z = p(x) + \alpha\sigma^2 \frac{S+u-x}{N}; \\
\text{FOC for the informed:} & \quad z - \alpha\sigma^2 x - p - (x - x_0^i) p'(x) = 0; \\
\text{SOC for the informed:} & \quad -\alpha\sigma^2 - 2p'(x) - (x - x_0^i) p''(x) \leq 0.
\end{aligned}$$

The first two equations above jointly pin down the functional form of $p(x)$:

$$\alpha\sigma^2 \frac{S + u - (1 + N)x}{N(x - x_0^i)} = p'(x)$$

→

$$p(x) = C + \alpha\sigma^2 \left[\frac{S + u - (1 + N)x_0^i}{N} \ln |x - x_0^i| - \frac{1 + N}{N}x \right],$$

where C is a constant determined by boundary conditions. Substitute the solution for $p(x)$ into the SOC:

$$\begin{aligned} & -\alpha\sigma^2 - 2p'(x) - (x - x_0^i)p''(x) \\ &= -\alpha\sigma^2 \left[\frac{S + u + (1 + N)x_0^i - 2(1 + N)x}{N(x - x_0^i)} + 1 \right]. \end{aligned}$$

If $\frac{S+u+(1+N)x_0^i-2(1+N)x}{N(x-x_0^i)} \geq -1$ or if $x_0^i < x \leq \frac{S+u+x_0^i}{2+N}$, the SOC holds; otherwise, $p(x)$ is not compatible with the informed investor's objective. Therefore, in the equilibrium with perfect price revelation,

$$\begin{aligned} x &\leq \frac{S + u + x_0^i}{2 + N} \text{ and} \\ p(x) &= C + \alpha\sigma^2 \left[\frac{S + u - (1 + N)x_0^i}{N} \ln |x - x_0^i| - \frac{1 + N}{N}x \right]. \end{aligned}$$

Since $z = p + \alpha\sigma^2 \frac{S+u-x}{N}$, z must be bounded above by some finite constant. However, z follows a normal distribution that does not have an upper bound. Therefore, there exists no such equilibrium in which price fully reveals private information. ■

2.4 Model Implications

2.4.1 Inefficient Liquidity Provision

Kyle (1985) characterizes and quantifies liquidity using concepts including tightness, depth, and resiliency. Liquidity nevertheless remains to be an elusive concept. Finance professionals find the Kyle concepts extremely useful in analyzing high-frequency price behavior or market microstructure issues. The concepts however fail to apply to liquidity-related issues of a relatively longer horizon. In particular, recent empirical studies suggest that market liquidity can be relevant in determining return predictability at the monthly or the quarterly frequency.

This paper employs the same framework as in Kyle (1989), which builds upon the canonical

setup in Grossman (1976). To further our understanding of liquidity, this paper interprets liquidity as the easiness of transacting shares among investors. In particular, I explore how information asymmetry prevents efficient distribution of shares among investors or in other words how information asymmetry induces frictions in trading and distorts ownership allocation. Understanding the role of information in asset reallocation contributes to our understanding of relatively longer-run market liquidity and its implications on returns.

Predicting the flow of trades, either the direction or the volume, is extremely difficult at higher frequencies, but can be less difficult at lower frequencies. The degree of uncertainty about non-information-driven trades is a key element in models of information asymmetry. This model removes the noisiness of non-information driven trades and can potentially generate results applicable to longer-run phenomena.

Proposition 10 *The informed investor under-provides liquidity, i.e.,*

$$|x_1^i - x_0^i| \leq \left| \frac{u}{2+N} \right| < \left| \frac{u}{1+N} \right|.$$

Perfect risk-sharing implies the informed investor should absorb at least a fraction of $\frac{1}{1+N}$ of the total liquidity shock u . In contrast, this model suggests that the informed at most takes in a fraction of $\frac{1}{2+N}$. The informed under-provides liquidity, while the uninformed plays a crucial role in liquidity provision. This inefficiency in share distribution worsens in low payoff state in which the uninformed trades to accommodate most of the liquidity needs.

Proposition 11 *The holdings of the informed investor x_1^i increases with z .*

Recall that for $u > 0$ the demand of the informed who observes z :

$$x_1^i(z) = \begin{cases} f^{-1}(z), & \text{if } z \leq z^R; \\ x^U, & \text{if } z \in (z^R, +\infty). \end{cases}$$

$f^{-1}(z)$ is monotonically increasing in z and is a concave function of z . If $u < 0$, the demand curve will consist of a mass point for $z \in (-\infty, z_{u<0}^R)$ and a region of $x = f_{u<0}^{-1}(z)$ for $z \geq z_{u<0}^R$, where $z_{u<0}^R$ and $f_{u<0}$ can slightly differ from z^R and f , respectively.

Under information asymmetry, high price implies a promising future payoff. However, price does not increase one for one with payoff, so the demand curve of an uninformed investor must be downward sloping. Facing an upward-sloping residual supply curve, the informed investor has to pay a higher price if he demands more shares, or he has to accept a lower price if he sells more shares. Therefore, the informed will only be willing to accommodate more of liquidity sells if z is sufficiently higher or more of liquidity buys if z is sufficiently lower. Moreover, the informed' role of liquidity provision diminishes quickly as z falls, or the former decreases faster than the latter.

This model features an economy that starts with perfect risk-sharing and ends up with non-perfect risk-sharing due to an exogenous liquidity shock. Alternatively, for an economy with imperfect risk-sharing at the outset, information asymmetry will prevent the economy from achieving the first-best allocation. In the original framework in Grossman (1976), all investors are competitive price takers. As a result, information asymmetry does not induce trading frictions, and the equilibrium is independent of initial share allocation. Kyle (1985) extends the framework to allow for noncompetitive trading behavior. Nevertheless, focusing on price informativeness and market efficiency, Kyle (1985) does not explore the role of imperfect information as a new source of trading frictions.

2.4.2 An Information Story of “Disposition Effect”

This model provides an alternative explanation of the “disposition effect.” The disposition effect refers to the tendency of investors to sell stocks that have risen in value since purchase and to buy stocks that have fallen in value. It is obvious that not all investors will display the disposition effect in equilibrium. Empirical studies have indeed documented that it is the less sophisticated investors who are more vulnerable to the apparent behavioral bias. This study shows that uninformed investors tend to take in excessively more risk in low payoff states, so the stylized fact may well arise from information asymmetry. However, note that the “disposition effect” here and that in the behavioral literature differs in a key result. The former implies a negative return autocorrelation, while the latter a positive autocorrelation.

Proposition 12 *The holdings of an uninformed investor x_1^u decreases with z .*

Recall that Proposition 11 holds for any given u . As a result, Proposition 12 follows immediately from Proposition 11. In this model, price is a monotonically increasing function of z , and price falls even further as z falls because the holdings of the uninformed tend to increase as z falls. The uninformed investors are the marginal investors in this economy. Price hence should reflect the uninformed's expectation of the asset payoff adjusted for compensation for the risk born by the uninformed. As the uninformed bears disproportionately more risk in low price state, the expected return conditional on the current price should be a decreasing function of the price.

Proposition 13

$$\frac{dE[r | p]}{dp} < 0, \text{ where } r \equiv d - p.$$

Proof.

$$E[r | p] = \begin{cases} \alpha\sigma^2 x_1^u(p), & \text{if } p \leq p^R; \\ E[z | z \geq z^R] - z^R + \alpha\sigma^2 x^U, & \text{if } p = p^U. \end{cases}$$

Moreover,

$$\begin{aligned} & E[z | z \geq z^R] - z^R + \alpha\sigma^2 x^U \\ & < \frac{\alpha\sigma^2 u}{N(2+N)} + \alpha\sigma^2 \left(\frac{S}{1+N} + \frac{u}{2+N} \right) < \alpha\sigma^2 x_1^u(p^U). \end{aligned}$$

According to Proposition 12, $x_1^u(p)$ decreases with p , and so does $E[r | p]$. ■

Proposition 13 implies a negative autocorrelation in return. Note that, the larger the initial deviation from the perfect risk-sharing distribution, the larger this negative autocorrelation. In addition, the larger the residual uncertainty regarding the payoff measured by σ^2 , the stronger the negative autocorrelation.

This model assumes non-information-motivated trades due to exogenous liquidity shock. The results discussed previously should also hold, if non-information-motivated trades results from endogenous deviation from perfect risk-sharing distribution. Suppose the informed investor starts with x_0^i shares, where x_0^i can be any positive number such that $x_0^i < x^{FB} \equiv \frac{S+u}{N+1}$. The analysis for the case in which $x_0^i > x^{FB}$ is symmetric and is thus omitted. Note that x^{FB} refers to the holdings of the informed if the economy achieves the first-best equilibrium with perfect risk-sharing.

The degree of under-risk-sharing measured by $x^{FB} - x^U$ is positively correlated with the initial degree of under-risk-sharing measured by $x^{FB} - x_0^i$. Recall that x^U denotes the largest possible holdings of the informed in this economy under information asymmetry, so $x^{FB} - x^U$ captures the degree of desirable risk-sharing that cannot be obtained with imperfect information. Note that

$$x^U = \frac{S + u + x_0^i}{2 + N},$$

hence,

$$\begin{aligned} x^{FB} - x^U &= \frac{S + u}{N + 1} - \frac{S + u + x_0^i}{2 + N} \\ &= \frac{S + u}{(N + 1)(N + 2)} - \frac{x_0^i}{N + 2} = \frac{x^{FB} - x_0^i}{N + 2}. \end{aligned}$$

It is obvious that $x^{FB} - x^U$ increases with $x^{FB} - x_0^i$.

As is pointed out previously, the uninformed investors are the marginal investors in this economy. If the informed bears relatively less risk, the uninformed must be bearing excessively more risk. As a result, the expected return will be relatively high and will increase with the degree of under-risk-sharing. The expected return not only depends on the current price as is stated in Proposition 13, but also depends on the stock performance in the recent past. Recent past poor performance tends to bias x_0^i downwards and aggravates under-risk-sharing measured by $x^{FB} - x^U$, and vice versa. The downward bias in x_0^i will increase the expected return over the subsequent periods and will enhance the negative correlation stated in Proposition 13.

Similarly, for the case in which $x_0^i > x^{FB}$, recent past poor performance tends to bias x_0^i downwards and alleviates under-risk-sharing measured by $x^{FB} - x^U$. Note that $x^{FB} - x^U < 0$ in this case. Therefore, in general, past poor performance tends to increase the expected return over the subsequent periods, but may enhance or may weaken the negative correlation stated in Proposition 13.

To sum up, this model of information asymmetry offers an alternative explanation of the fact that some investors sell at high prices and buy at low prices. Moreover, the magnitude of this effect depends on historical performance of the specific stock. Past poor stock performance will strengthen the negative return autocorrelation in a state of predominantly liquidity sells and relatively low price, but will attenuate the negative return autocorrelation in a state of pre-

dominantly liquidity buys and relatively high price; and vice versa. These model implications potentially help us understand some puzzling empirical features of time-series return behavior. Unlike behavioral models or models of heterogeneous preferences, a model of information asymmetry can generate negative return autocorrelation that takes effect at the individual stock level and that is generally state-dependent.

2.4.3 Verifiable vs. Nonverifiable Information

This simple model assumes away the uncertainty regarding non-information-driven trades. However, price still does not fully reveal private information over certain range of z . Even when price becomes perfectly informative, the economy does not obtain perfect risk-sharing.

Both equilibrium features seem counter-intuitive and result from the noncompetitive nature of a market under information asymmetry. The informed acquires private information, and the private information gets reflected in price via trades by the informed. Price therefore will not reveal further information if the informed is not willing to trade further. Moreover, the belief of the uninformed must be sustainable in the equilibrium. Price revelation needs to be incentive-compatible with the optimality of informed trading. As a result, perfect risk-sharing is not feasible in this model.

Given the inefficiency in share allocation, the next question is how long this inefficiency will last. If the value of z is verifiable then the under-risk-sharing should be corrected immediately after the information revelation via price, assuming that there is no further information asymmetry regarding future payoff. In contrast, if the value of z is nonverifiable then the imperfect risk-sharing will not be corrected until the realization of z .

This model thus predicts that the return behavior will differ depending on whether the private information is verifiable or nonverifiable. The distortion in share distribution must last longer under situations predominated by nonverifiable information. In those situations, there can be substantial inertia in share distribution. Inefficiency in allocation slowly adjusts as the fundamental develops, therefore, we can have seemingly abnormal return predictability at some fairly low frequency.

2.4.4 Return Autocorrelation: Positive or Negative

This paper underlines a negative autocorrelation in return due to the downward sloping demand curve of uninformed investors in a market under information asymmetry. Wu (2007) predicts a positive return autocorrelation as a result of information asymmetry. Are the two predictions in conflict? What do we learn about how information imperfections affect stock return behavior?

The two papers present two completely distinctive mechanisms that both lead to some sort of return autocorrelation. The two mechanisms complement rather than contradict each other. The seemingly abnormal return predictability in this paper results from predicted variation in risk premium. This predictability hinges on the systematic component of the residual risk or the non-private risk. Wu (2007) derives return predictability through the predictability of liquidity trades in a model of information asymmetry with dysfunctional price. The return predictability there does not require the risk to be systematic, however, it does require exploitable information advantage or information-induced distortion in share distribution.

The relevant horizon of return predictability associated with each of those different mechanisms also differs. In Wu (2007), the return predictability will weaken as the information-induced distortion in share allocation dissipates over time. In this paper, if the private information is verifiable, return will be predictable only over a very short horizon. If the private information is nonverifiable, the length of horizon over which return is predictable should match the frequency of fundamental news announcement.

Return therefore may be negatively autocorrelated in a very short run, but may be positively autocorrelated in a relatively short run, and may also be negatively autocorrelated in a relatively long run. The sign of return autocorrelation also depends on the weight of systematic risk relative to idiosyncratic risk, the noisiness of non-information-driven trades, and etc.

2.5 Conclusion

This study builds upon the important literature on information asymmetry. The current study contributes to the literature by shifting the focus to the quantity dimension. Examining the effects of information imperfections on share allocation in addition to price behavior offers interesting insights on both cross-sectional and time-series return behavior.

Information potentially plays a crucial role in explaining return predictability or apparent behavioral biases that are identified in the recent empirical literature. The advantage of an information-based explanation lies in its ability to explain some puzzling facts at the individual stock level that are absent in models of commonly accepted behavioral biases or heterogeneous preferences.

For the next step, it will be important to extend the current simple model to models of multiple assets and to models of multiple periods. As an overlooked source of trading frictions, information imperfections can be a key determinant of both individual and aggregate stock return behavior.

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Chapter 3

Tobin's Tax Revisited: Evidence from the Chinese Stock Market

This study explores the idea of Tobin's tax in the context of an emerging market and in particular examines the cost effects on speculation in the Chinese stock market. Inspired by the theoretical insight of Lo and Wang (2000), I construct a turnover-based empirical proxy for the aggregate level of speculative activities. Tax and brokerage fee are two major components of A-share transaction cost in China. I therefore examine how historical changes in tax or in brokerage fee affect speculative trades. Both time-series analysis of the aggregate measure and cross-sectional analysis of each policy change suggest that the best way to restrain speculation is to make the market more competitive. In the event that market is highly noncompetitive, tax is shown to be effective in curbing speculation.

3.1 Introduction

China's Ministry of Finance announced on January 23, 2005, that stamp duties levied on A-share¹ and B-share² transactions would be halved to 0.1 per cent starting from the next business

¹A-shares are issued by companies incorporated in mainland China and are traded in Shanghai and Shenzhen stock exchanges. Prices of A-shares are quoted in Renminbi. For the moment, only mainlanders and selected foreign institutional investors are allowed to trade A-shares.

²B-shares are issued by companies incorporated in mainland China and are traded in Shanghai and Shenzhen stock exchanges. Prices of B-shares are quoted in foreign currencies. In the past, only foreigners were allowed to trade B-shares. Starting from March 2001, mainlanders can also participate in the B-shares market. However,

day (Monday, January 24, 2005). The decision to reduce the stock trading tax followed the enactment of State Council guidelines early in the previous year to support the capital market development, and was thus perceived by market as another policy measure aiming at revitalizing investors' sentiment and reducing trading costs. Nevertheless, even the nine-point guideline only provided market indices with a short-lived boost. So was the outlook for the transaction tax cut.

Immature capital market and immature asset management industry lead to one major feature that distinguishes the Chinese stock market from any security market in the rest of the world – participation of a great number of individual investors with limited financial wealth. Given that a well-functioning supervision and regulation system does not yet exist, the Chinese stock market is plagued with severe information problems. As a result, there is constant information leakage, frequent informational trades, and, thus, exploitation of naïve individual investors by informed investors or speculators. Unlike investors in developed countries where they can resort to a wide variety of soundly-managed investment funds, individual investors in China have to learn their lessons through trial and loss.

Facing the status quo, has the Chinese government made the right decision on its tax policy regarding transactions in the stock market? This research will study the influences of a tax change on speculative trading activities, other than its consequences on flows in and out of the stock market. The flow effects seem to be occupying the full attention of the general public. I will provide both theoretical motivation and empirical analysis to argue for the importance of this neglected effect and will also provide policy suggestions for an emerging capital market, in particular, one characterized by extensive information asymmetry, fledgling institutional investors and a great number of small individual accounts.

The idea of throwing some sands in the wheels is not unfamiliar. James Tobin first proposed a levy on international currency transactions in 1972, immediately after the collapse of the Bretton Woods system. The idea was however born way ahead of its time and did not receive much sympathy then. Nevertheless, the debate on the Tobin's tax, or a securities transaction tax, reemerges whenever there is a disruption in financial markets. For example, the

they must trade with legal foreign currency accounts.

debate rekindled after the Black Monday on October 19, 1987.³ Studies have examined effects of securities transaction tax on market efficiency for foreign exchange markets and for stock markets in various countries. The empirical evidence was overall not conclusive.⁴ While the debate previously focuses on the developed markets, this study explores the idea of Tobin's tax in the context of an emerging market and in particular examines the cost effects on speculation.

Inspired by the theoretical insight of Lo and Wang (2000), I construct a turnover-based empirical proxy for the aggregate level of speculative activities. Tax and brokerage fee are two major components of transaction cost in the Chinese stock market. I therefore examine how historical changes in tax or in brokerage fee affect speculative trades. Both time-series analysis of the aggregate measure and cross-sectional analysis of each policy change suggest that the best way to restrain speculation is to make the market more competitive. In the event that market is highly noncompetitive, tax is shown to be effective in curbing speculation.

The remainder of the paper is organized as follows. Section 2 lays out some background on transaction costs in the Chinese stock market. Section 3 provides the theoretical motivation. Section 4 presents the empirical findings. Section 5 concludes the paper.

3.2 Background

In the Chinese stock market, stamp duties levied on A-share and B-share transactions charge both buyers and sellers per transaction an amount that is proportional to the transaction value. The securities transaction tax was first enacted on June 28, 1990, which started as a one-sided tax of 0.6% imposed on sellers only for all transactions on the Shenzhen exchange. Later in the same year on November 23, this one-sided tax changed to a two-sided transaction tax applied to both buyers and sellers. In October 1991, the Shenzhen exchange adjusted the two-sided tax downward to 0.3%, and meanwhile the Shanghai exchange adopted the same tax policy. The government raised the tax from 0.3% to 0.5% on May 12, 1997, in order to curb the growth of an overheated speculative stock market. The tax rate came back down to 0.4% on June 12,

³Summers and Summers (1989), and Stiglitz (1989) writes to advocate a transaction cost. Stiglitz (1989) in particular builds his argument upon the assumption that trading is a zero-sum game. Ross (1989) refutes his assumption and calls for evidence.

⁴See, for example, Umlauf (1993), Campbell and Froot (1994), Frankel (1996), Jones and Seguin (1997), Tyler (1999), and Habermeier and Kirilenko (2001).

1998. Later, to stimulate trading activities in the B-share market, the government reduced the tax rate on B-share transactions to 0.3%. Used as one of the measures to revitalize the market, the proportional stock transaction tax was halved to 0.2% on November 16, 2001, and was further halved to 0.1% on January 24, 2005.

Table 3.1 summarizes the historical change in the stamp duty levied on A-share transactions since its inception in 1990. Even though the Chinese stock market has experienced rapid growth in the recent past, the annual revenue due to the stock transaction tax stays below 1% of the total government tax revenue.

Table 3.1. History of A-Share Transaction Tax Changes

Date	Tax Rate	Buyers/Sellers	Exchange*
28-Jun-1990	0.6%	sellers only	Shenzhen only
23-Nov-1990	0.6%	both	Shenzhen only
Oct-1991	0.3%	both	both
12-May-1997	0.5%	both	both
12-Jun-1998	0.4%	both	both
16-Nov-2001	0.2%	both	both
24-Jan-2005	0.1%	both	both

*Note that there are two regional stock exchanges in China: the Shanghai exchange and the Shenzheng exchange.

The stamp duty is only part of the transaction costs encountered by an investor in the Chinese stock market. In addition to the stamp duty, a typical investor also faces the following costs per transaction including a brokerage fee, a supervision fee, and a servicing fee. Table 3.2 lists the most up-to-date relevant trading costs for a single transaction of share A, either sell or purchase, in the Chinese stock market. The stamp duty accounts for a significant portion of the trading costs and therefore can be an effective policy instrument in fine tuning trading activities.

Brokerage fee is another significant component of A-share transaction costs, so ignoring brokerage fee can bias our analysis of tax effects. In the past, all brokerage firms have to abide by one standard rate regulated by the government. Starting from April 4, 2002, brokerage fee is allowed to float within bounds, lower than 0.3% but higher than the sum of supervision and servicing fees. Table 3.3 displays the history of brokerage fee changes. The empirical analysis

Table 3.2. Decomposition of A-Share Transaction Costs

Cost Component	Recipient	Rate of Charge
brokerage fee	brokerage house	0.2%
stamp duty	government	0.1%
supervision fee	SEC	0.004%
servicing fee	exchange	0.015%

in this paper takes into account the historical variation in both transaction taxes and brokerage fee.

Table 3.3. History of Brokerage Fee Changes

Date	Rate
7-Jun-1990	5%
1-Jan-1993	0.7%
11-May-1993	0.4%
3-Oct-1996	0.35%
1-Aug-2001	0.2%

As fierce competition among brokerage firms drives down the transaction cost, government intervention can be necessary at the current stage of market development. First of all, a larger trading cost can better protect naïve investors and help lengthen their investment horizon. Second, the asset management industry has just come into existence recently in China and is still in its incubation period. A rapid growth by profiteering from informational trades can result in an unhealthy industry in the long run. Finally, as existing studies have shown, longer investment horizon held by investors serves as better corporate governance curbing managerial myopia. In an emerging market such as the Chinese stock market, excessive growth of speculative trading activities can exacerbate the already weak corporate governance. Therefore, the government should consider maintaining a nontrivial tax rate for the moment. It is important to establish an ethical asset management industry and to establish an effective information monitoring system before completely liberating the market. A simple convergence to the tax design in developed world may generate welfare losses in emerging markets.

3.3 Theoretical Motivation

Trading activities in financial markets consist of speculative trades and non-speculative trades. The latter includes liquidity trades and noise trades. Liquidity trades refer to rationally optimized non-information-driven trades, while noise trades refer to trades by “mistake.” Studies of differential information suggest that the noise ratio, i.e., the ratio of noise trades over liquidity trades, is a key determinant of the profitability of speculative trades. The higher the noise ratio, the lower the profitability of speculative trades. The volume of speculative trades thus increases with the noise ratio. This paper examines how changes in different components of stock transaction costs, namely the stamp duty and brokerage fee, affect the noise ratio and in turn speculative trading activities.

Lowering the transaction cost makes it more appealing to invest in the stock market, only if an investor is expected to alter his or her portfolio frequently over time. In the case of the latest tax cut, the stamp duty was reduced by 0.1%. Consider an investor who rebalances his portfolio once every year. The marginal effect on his annual portfolio return due to the tax change is about 0.2%, which is negligible compared to an average annual market return of 8% (from 1999 to 2002). Nonetheless, Feng and Seasholes (2003) have shown that portfolio turnover is surprisingly high in the Chinese stock market. They report that the average individual holds RMB 135,127 on June 1, 2000. Over the next month (June 2000) the average individual purchases RMB 64,413 of stock and sells RMB 77,351. The turnover rate is close to 50% per month. The average annual turnover rate for an average individual investor is as high as 600%.

Consider a more general case where the investor rebalances his entire portfolio N times a year, assuming the annualized gross return rate on his portfolio without trading taxes is R , the rate of return will become $R \frac{(1-\tau)^N}{(1+\tau)^N} \sim R(1-\tau)^{2N}$ where τ denotes the proportional transaction cost. The current transaction levy in China is imposed on both buyers and sellers of shares. The tax impact on the annual rate of return is approximately $-2N\tau$. When N equals 6, a decrease in stamp duty of 0.1% can generate an increase in investment return of 1.2%. Therefore, unless investors expect to trade frequently, the tax incidence will be trivial.

An increase in tax rate will deter both liquidity trades and noise trades, but will affect noise trades more than liquidity trades because noise trades take place at a higher frequency

than liquidity trades. Accordingly, the change in tax rate should matter more to the profits of noise trading. A noise trader should hence be more sensitive to the adjustment in tax rate. As a consequence of a tax increase, the overall volume of trades will decrease. Furthermore, the noise ratio will decrease with the tax rate, and so will the volume of speculative trading activities, which leads to the first test hypothesis for my empirical analysis.

Hypothesis 1 *The volume of speculative trades decreases with the rate of proportional transaction tax.*

Both brokerage fee and the stamp duty are major components of transaction costs. There is however important difference between the two. Brokerage fee is collected by brokerage firms who actively participate in trading and represent a group of relatively large and sophisticated investors in the market, while the stamp duty is collected by a third party who does not participate in the market. Therefore, the latter should discourage trades in general. In contrast, the former will not necessarily reduce aggregate trading volume, but will alter the allocation of trading profits and in turn the noise ratio.

On one hand, high brokerage fee may increase transaction costs and thus deter frequent trading. On the other hand, high fee will incentivize stock brokers to induce their clients to make excessive transactions, for example, through persistent persuasion or through transaction rebates. Brokerage firms who simultaneously play multiple roles as a broker, a speculator, and a market maker, must have a stronger incentive to encourage noise trades as opposed to liquidity trades. Therefore, this positive fee effect on trading will increase the ratio of noise trades over liquidity trades. On the contrary, a reduction in brokerage fee will decrease the noise ratio.

Finally, note that neither tax changes nor brokerage fee changes in China are exogenous. In particular, brokerage fee plays the role of a barometer indicating the competitiveness among large investors or the de factor speculators in the Chinese stock market. A decrease in brokerage fee should thus correspond to an improvement of competitiveness among speculators, which will diminish the profitability of speculation and further discourage speculation. All in all, as a consequence of a downward adjustment in brokerage fee, the ratio of noise trades relative to liquidity trades should decrease, and so should the level of speculation; and vice versa. Here

follows the second test hypothesis for my empirical analysis.

Hypothesis 2 *The volume of speculative trades increases with brokerage fee.*

This paper aims to understand and measure the policy effect on speculative trading. I therefore conduct empirical testing centered on Hypotheses 1 and 2. The empirical proxy for the volume of speculative trades derives from a theoretical insight of Lo and Wang (2000). Lo and Wang (2000) point out that when two-fund separation holds the turnover of all individual stocks must be identical. If the CAPM holds, all investors will allocate their financial wealth in two funds, the riskfree bond and the market portfolio. Different investors may assign different weights to these two funds. The weights may also vary over time. Regardless the variation in the ratio of the risky portion versus the riskless portion, the composition of the risky portfolio held by any investor stays constant and is exactly the same as the market portfolio. Therefore, the dollar trading volume of any individual stock must be proportional to its market capitalization. In other words, the turnover of all individual stocks must be identical.

In this paper, I measure the volume of speculative trades using the difference between the equally-weighted turnover and the value-weighted turnover. Given that the Chinese stock market represents only a small fraction of the domestic economy and that average small investors in China have limited access to financial market or limited investment opportunities, the CAPM should be a good approximation of the Chinese stock market in the absence of speculative trades. According to Lo and Wang (2000), average turnover with any sort of weighting scheme should be identical, so the difference should be zero without speculation. However, firms with small market capitalization tend to be more vulnerable to speculation. The discrepancy arises as the existence of speculative trades makes the turnover of small stocks relatively high. The difference between the equally-weighted turnover and the value-weighted turnover thus implies the existence of speculative activities and increases with the volume of speculative trades.

3.4 Empirical Findings

3.4.1 Data

The empirical analyses in this paper employ data on daily share volume, daily price, and tradable market capitalization for all A-share stocks.

There are two regional stock exchanges in China, the Shanghai exchange and the Shenzhen exchange. The earliest available record is dated December 19, 1990 for the former and July 3, 1991 for the latter. A public company lists in exactly one of the two exchanges. Both exchanges share nearly the same transaction costs during the entire sample period. The investor base is also similar for these two exchanges. Since there is little systematic difference between the two exchanges, the analysis will not distinguish stocks by exchange.

I exclude the first 250 daily observations for each individual stock, because the IPOs in China are subject to severe underpricing. Monthly turnover rate and market capitalization are measured as average daily turnover and market capitalization over the particular month. The sample period starts in December 1991 and ends in December 2004. The entire time series of aggregate stock data thus have 157 monthly observations.

The Chinese stock market has experienced enormous growth over the past decade. Figure 3.2 displays the rapid growth of the number of stocks covered in the sample data. There are roughly 10 stocks traded in 1991, but the number increases to more than 1200 in 2004. Investor behavior has also evolved over time. Turnover rate is significantly higher during the first half of the sample period than in the more recent years. Figure 3.3 plots the change in the average turnover weighted by market capitalization, over the whole sample period from December 1991 to December 2004. Figure 3.4 exhibits the change in the difference between the equally-weighted turnover and the value-weighted turnover. It is consistent with the theory prediction that this difference is mostly positive. The discrepancy is much higher during the earlier years and has declined over time, which suggests that speculative trades carry a heavier weight at the earlier stage of the market development but play a diminishing role at the later stage.

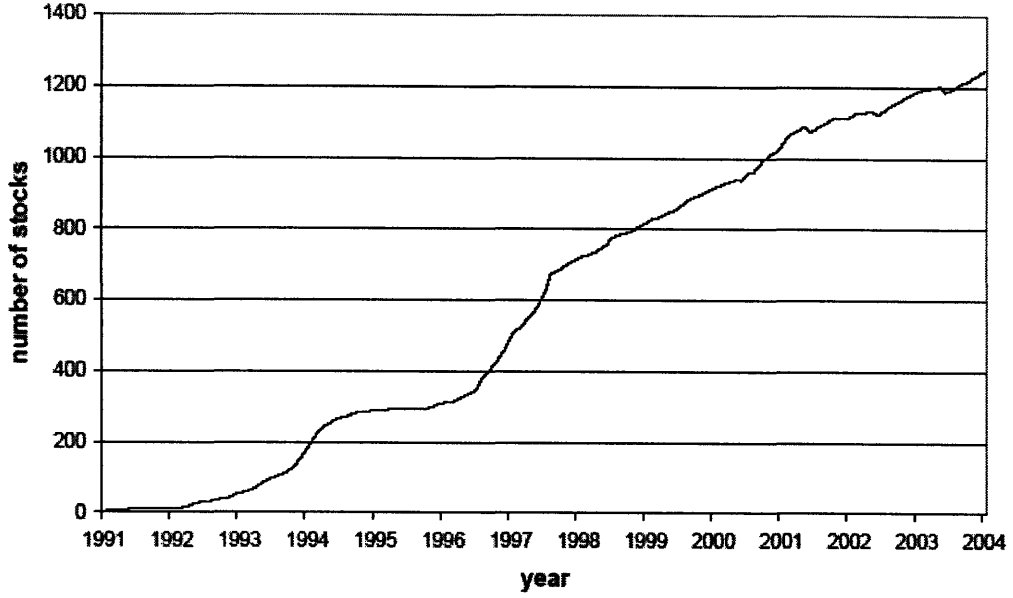


Figure 3-1: Number of Stocks in Sample, 1991 – 2004

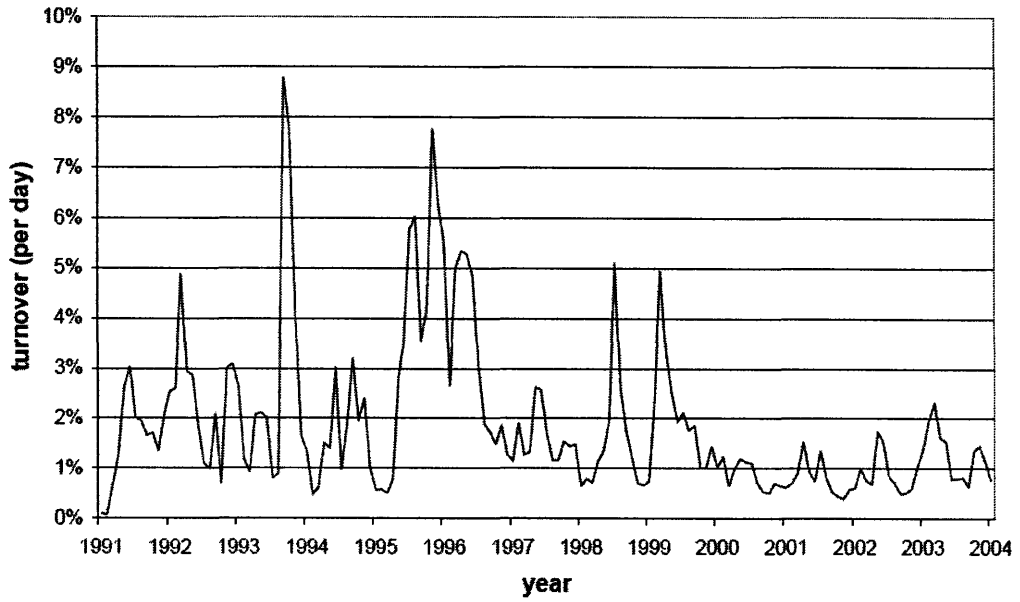


Figure 3-2: Value-Weighted Average Turnover, 1991-2004

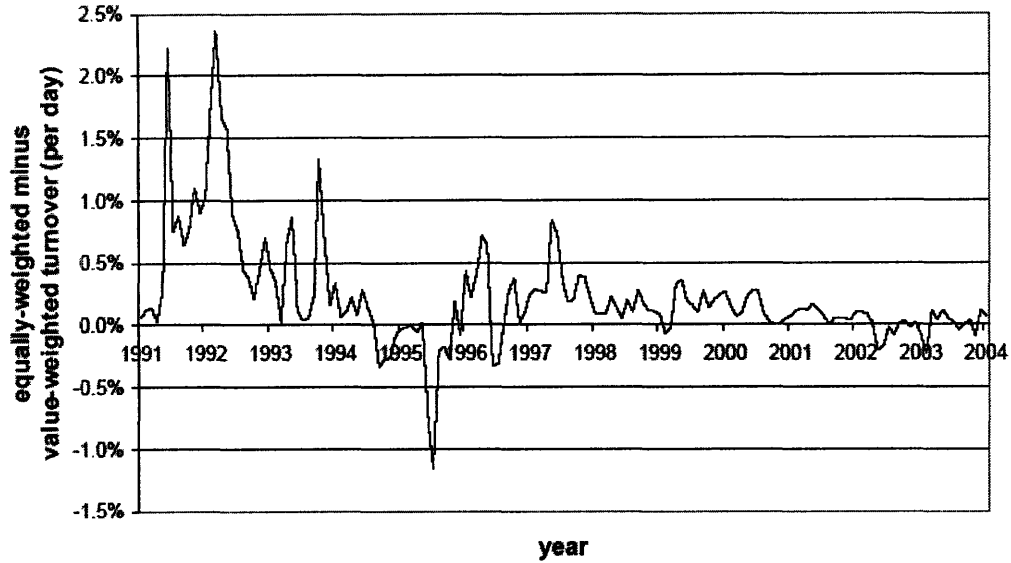


Figure 3-3: Difference between Equally-Weighted and Value-Weighted Average Turnover, 1991 – 2004

3.4.2 Time-Series Analysis

In this section, I investigate whether the variation in the aggregate measure of speculative trading, i.e. the equally-weighted average turnover minus the value-weighted average turnover, can be explained by tax change or brokerage fee change. In particular, I test the following linear model:

$$V_t = c_0 + c_1 V_{t-1} + c_2 \tau_t + c_3 \delta_t + \epsilon_t. \quad (3.1)$$

V_t and V_{t-1} represent respectively the current and the lagged measures of aggregate speculative trades. τ_t represents the tax rate levied on A-share transactions. δ_t represents the brokerage fee at time t . ϵ_t represents the noise term and can be heteroskedastic. c_0 , c_1 , c_2 , and c_3 denote the corresponding coefficients. The level of active speculation is highly persistent⁵, so the model includes a lagged term of the aggregate measure.

Note that the brokerage fee was 5% at the inception of the Chinese stock market, and the

⁵See the first column in Table 5.

rate was exponentially higher than that in the subsequent years. The linear model described by Equation (3.1) must be inadequate due to this substantial variation in brokerage fee at the outset. To fix the problem, I can amend the simple linear model by introducing a dummy variable for the period of December 1991 to December 1992 over which the huge fee was effective. Equivalently, I conduct tests excluding that period. So the empirical analyses in this section are based on 144 monthly observations from January 1993 to December 2004.

As is shown in Tables 3.1 and 3.3, and Figure 3.3, the aggregate measure of speculation, the tax rate, and the brokerage fee all exhibit a declining trend over time. To avoid spurious correlation due to cointegration, I detrend all three time series, so V_t , τ_t , and δ_t denote the detrended component after eliminating a linear trend or a constant yearly drift. Table 3.4 provides results from the detrending regressions. On average, brokerage fee falls by 0.024% per year. The tax rate falls by 0.009% every year. The level of speculation has also been decreasing by 0.044% per year in terms of daily turnover. All three time trends are significant at less than 1% level.

Table 3.4. Detrending Time Series

	Brokerage Fee	Tax Rate	EW-VW Turnover
year	-0.024 (18.29)***	-0.009 (4.09)***	-0.044 (4.84)***
Constant	0.331 (71.70)***	0.32 (43.26)***	0.186 (5.98)***
Observations	144	144	144
R-squared	0.7	0.11	0.14

Absolute value of robust t statistics are reported in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3.5 shows the regression results based on Equation (3.1). As is predicted, the level of speculative trades decreases by 1.66% for each one percentage decrease in brokerage fee. The heteroskedasticity-consistent t-statistic is about 2.4 for the coefficient estimate. The tax effect on speculation is not statistically significant, but the coefficient estimate is negative as predicted and suggests an increase of 0.34% for each one percentage of tax cut. Table 3.5 confirms that it is important to include brokerage fee in the analysis. Without accounting for brokerage fee

changes, the model would have underestimated the tax effect.⁶

Table 3.5. Cost Effects on Speculative Trades (V_t)

	V_t	V_t	V_t	V_t
V_{t-1}	0.794 (5.49)***	0.725 (7.07)***	0.637 (7.07)***	0.624 (6.65)***
V_{t-2}	-0.093 -0.9			
τ_t		-0.024 -0.1		-0.343 -1.13
δ_t			1.46 (2.42)**	1.663 (2.41)**
Observations	144	144	144	144
R-squared	0.54	0.53	0.57	0.58

Absolute value of robust t statistics are reported in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%.

The time series of the tax rate and brokerage fee must be highly autocorrelated, because those two variables change at fairly low frequency by nature. Recall that the level of speculation V_t is also highly autocorrelated. Concerns may arise that strong autocorrelation can lead to biases in estimates. To alleviate the concerns, I extract the residual from regressing V_t on its own lag V_{t-1} and denote the residual by U_t . This unpredicted component U_t has nearly zero autocorrelation.⁷ The results in Table 3.6 confirm those in Table 3.5. The estimated effects are slightly weaker. A reduction of 1% in brokerage fee coincides with a fall in speculation of 1.35% in terms of daily turnover. The estimated effect is significant at 5% level assuming heteroskedasticity. The tax effect is estimated to be negative but not statistically significant, and the effect would have been substantially underestimated without proper consideration of brokerage fee change.

As both tax and brokerage fee adjust infrequently, I further examine the robustness of the estimated cost effects by replacing τ_t and δ_t with dummy variables. The regression is based on the following linear model:

$$V_t = a_0 + a_1 V_{t-1} + a_2 ST5_t + a_3 ST4_t + a_4 ST2_t + a_5 BF4_t + a_6 BF35_t + a_7 BF2_t + \varepsilon_t. \quad (3.2)$$

⁶ Compare the second and the fourth columns of Table 5.

⁷ See the first column in Table 6.

Table 3.6. Cost Effects on Speculative Trades (U_t)

	U_t	U_t	U_t	U_t
U_{t-1}	0.068			
	-0.47			
τ_t		-0.024		-0.278
		-0.1		-0.95
δ_t			1.217	1.351
			(2.00)**	(2.00)**
Observations	144	144	144	144
R-squared	0	0	0.07	0.08

Absolute value of robust t statistics are reported in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%.

V_t is defined as previously to be the detrended level of speculation. $ST5_t$, $ST4_t$, and $ST2_t$ refer to the dummy variables for the period with the tax rate in effect being 0.5%, 0.4%, and 0.2%, respectively.⁸ Similarly, $BF4_t$, a_6BF35_t , and a_7BF2_t refer to the dummy variables for the period with the brokerage fee in effect being 0.4%, 0.35%, and 0.2%, respectively.⁹ ε_t represents the noise term and can be heteroskedastic. a_0 through a_7 denote the corresponding constant coefficients.

Table 3.7 shows the estimated cost effects derived from regression results based on Equation (3.2). I compare the coefficients corresponding to adjacent periods to illustrate the effects of tax change or brokerage fee change. These estimated policy effects are also least susceptible to biases due to missing variables. For example, turnover in January 1998 when the tax rate is 0.5% may differ widely from that in January 2003 when the tax rate is 0.2%. Over a period of 5 years, many other things could have happened that would affect turnover. The last tax cut in November 2001, from 0.4% to 0.2%, increases speculative trades by 0.07% in daily turnover, and the estimate is significant at less than the 0.1% level. Although the estimates are statistically insignificant for the first two tax changes, in May 1997 and in June 1998, the sign of the estimates is consistent with the theory prediction. The estimated effects of all three brokerage fee changes are highly significant. The first fee cut in May 1993 coincides with a drop of 0.94% in daily turnover. The last fee cut in August 2001 also coincides with a drop of

⁸The dummy variable for the period with the tax rate in effect being 0.3% is dropped from the regression.

⁹The dummy variable for the period with the brokerage fee in effect being 0.7% is dropped from the regression.

0.2% in daily turnover. However, the second fee cut in October 1996 coincides with an increase of 0.24% in daily turnover, which contradicts the theory prediction. Tables 3.5-3.7 provide overall consistent findings.

Table 3.7. Policy Effects on Speculative Trades

Event	Change in Speculative Trades (daily turnover, %)	p-value
Tax Rate:		
0.3% to 0.5% (a_2)	-0.123	0.321
0.5% to 0.4% ($a_3 - a_2$)	0.023	0.805
0.4% to 0.2% ($a_4 - a_3$)	0.066	0.000
Brokerage Fee:		
0.7% to 0.4% (a_5)	-0.941	0.000
0.4% to 0.35% ($a_6 - a_5$)	0.241	0.018
0.35% to 0.2% ($a_7 - a_6$)	-0.060	0.003

Investigating the aggregate measure of the level of speculative trades verifies the theoretical prediction in Section 3. Brokerage fee cuts are strongly correlated with decreases in the level of speculation. Tax effects are relatively weaker and statistically insignificant, nevertheless, the estimates exhibit the same sign as is predicted. We should however take these empirical findings with caveats. Since both tax change and brokerage fee change occur infrequently, the estimates based on the time-series analysis of the aggregate measure essentially reflect the relatively long-run effects. The corresponding horizon depends on the interval between adjacent policy changes. These estimates therefore may well be subject to biases due to missing variables, and possibly to different degrees. In addition, imperfect detrending may introduce further noises. The next section will conduct cross-sectional analysis immediately around the policy changes in order to reassure the robustness of the results.

3.4.3 Cross-Sectional Analysis

Since the establishment of the Shanghai exchange in 1990 and the Shenzhen exchange in 1991, the Chinese stock market has gone through considerable development in a short history of 15 years. For example, the China Securities Regulatory Commission, also known as CSRC, was enacted in October 1992. In December 1996, the government installed the 10% limit of daily

variation in closing price. Securities investment funds took off in late 1997. On November 5, 2002, the CSRC and the People's Bank of China introduced the QFII (Qualified Foreign Institutional Investor) program as a provision for foreign capital to access China's financial markets. These major regulatory changes certainly impact the operations of the stock market. It is however difficult to perfectly control for changes in macro conditions, especially given a short sample period. In response to the concerns, this section will examine policy effects in a relatively short run by running cross-sectional regressions.

Recall that Lo and Wang (2000) point out that when two-fund separation holds the turnover of all individual stocks should be identical. Without speculative trades, the change in turnover responding to a tax change or a fee adjustment should also be identical across all individual stocks. In contrast, with the existence of speculative trades, the change in turnover will vary across stocks and should be a function of the past turnover. Investors will minimize the cost effect by adjusting their trading frequency. The higher the past turnover, the larger the cost effect, and therefore the larger the change in turnover. If a policy change reduces the level of speculation, the decrease in turnover due to declining speculation should be largest for stocks with highest past turnover. It follows that the difference in turnover should diminish, and the change in turnover should be negatively correlated with the past turnover. Similarly, if a policy change turns out encouraging speculation, changes will occur in the opposite direction.

I construct my cross-sectional regressions in the following way. For each tax change or brokerage fee adjustment that occurs in month t , I measure the difference in average daily turnover between the period of 3 months before the change (month $t - 4$ to month $t - 2$) and the period of 3 months after the change (month $t + 2$ to month $t + 4$), for each single stock. I skip the month immediately preceding and the month immediately ensuing the change to avoid transitional effects. The average daily turnover over the period from month $t - 7$ to month $t - 5$ is used as the proxy for past turnover. I regress the change in turnover on past turnover. If the change results from the change in non-speculative trades, then the coefficient estimate should differ insignificantly from zero. If the change results from a fall in speculative trades, then the loadings on past turnover should be significantly negative. Finally, if the change results from a rise in speculative trades, then the loadings on past turnover should be significantly positive.

Table 3.8 provides the cross-sectional regression results for the three tax changes: an increase

**Table 3.8. Effects of Tax Change on Speculative Trades
(Cross-Sectional Regressions)**

	12-May-97 0.3% to 0.5%	12-Jun-98 0.5% to 0.4%	16-Nov-01 0.4% to 0.2%
Past Turnover	-0.223 (8.52)***	-0.368 (6.97)***	0.046 (1.44)
Observations	310	516	955
R-squared	0.19	0.09	0.00

Absolute value of t statistics are reported in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%.

of 0.2% in May 1997, a reduction of 0.1% in June 1998, and a reduction of 0.2% in November 2001. The results stay consistent with the findings in Section 4.2. The tax effects on speculation remain mixed. The increase of tax rate in 1997 is shown to have effectively curbed speculation. The cross-sectional variation in average daily turnover decreases by 22.3% ensuing the tax change. The tax cut in 1998 is nevertheless followed by a decrease of 36.8% in the cross-sectional difference in turnover, which contradicts the prediction. A possible explanation is that the government intends to revitalize the market through a tax cut, but in fact the initial slow down in transactions results from cooling speculation. Table 3.8 also suggests that the last tax cut in 2001 increases speculation marginally, and the estimate is not statistically significant.

**Table 3.9. Effects of Brokerage Fee Change on Speculative Trades
(Cross-Sectional Regressions)**

	11-May-93 0.7% to 0.4%	3-Oct-96 0.4% to 0.35%	1-Aug-01 0.35% to 0.2%
Past Turnover	-1.503 (4.71)***	-0.689 (6.19)***	-0.542 (12.43)***
Observations	13	295	931
R-squared	0.67	0.12	0.14

Absolute value of t statistics are reported in parentheses.

* significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3.9 provides the cross-sectional regression results for the three brokerage fee adjustments: a cut of 0.3% in May 1993, a cut of 0.05% in October 1996, and a cut of 0.15% in August 2001. The results firmly support the findings in Section 4.2. All three downward adjustments

in brokerage fee are shown to have effectively curbed speculation. The effects on speculative trades are highly significant both economically and statistically.

3.5 Conclusion

This paper has found weak evidence of tax effects on speculative trades in the Chinese stock market. The tax rate changes usually reflect policy responses to changing market conditions. The government can adjust the tax rate downward to stimulate a stagnating market or adjust the tax rate upward to restrain an overheated market. If the initial slowdown or speedup in trading activities is attributable to changes in speculative trades, the endogeneity of tax change will offset the tax effects on speculation and thus weaken our empirical results. Therefore, we can interpret the ambiguous findings in two ways. One possibility is that tax changes leave no effects on speculative trades in the Chinese stock market. Alternatively, it is possible that tax reductions do make small investors more vulnerable to exploitation by large investors, but the endogeneity of tax changes makes it difficult to empirically detect this tax effect.

The reduction in brokerage fee however plays an unambiguous role in explaining decreasing level of speculation. Like the tax change, the change in brokerage fee can also be endogenous. Brokerage fee cuts are often signs of increasing competitiveness among brokerage houses. The improvement in competition is proved to be an undoubtedly good protection for unsophisticated investors. On the other hand, the drop in brokerage fee should diminish the competitive edge of brokerage firms relative to other traders in the market and should enhance the competitiveness of market making, which further improves the market competition and reduces speculation. The endogeneity in this case strengthens the estimate of cost effects.

To conclude, the empirical findings in this paper suggest that the best way to restrain speculation is to make the market more competitive. In the event that market is highly noncompetitive, tax is shown to be effective in curbing speculation. It will be interesting to conduct a comparative study on how stock markets in different countries, such as Japan or Taiwan, evolve from high-securities-transaction-tax regime to low-tax regime.

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