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ESSAYS ON EXPERIMENTAL ASSET MARKET

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Executive Summary

This thesis consists of three self-contained essays on experimental asset market. The first essay investigates the impacts of a compulsory insider-trading disclosure requirement and its combination with a holding rule modeled after the *short-swing* and *restricted stock* rules, on price predictability and asset mispricing. We modify the dynamic price-adjustment model of Smith et.al (1988) to account for the variation in investors' private information. We show that informed agents produce weakly characterized price signals that undermine market learning, when they are required to reveal their transactions. This translates into less than proportional price adjustment to the revision in the expected dividend value. The introduction of illiquidity constraint aggravates asset mispricing. Market prices cease to respond to private information. This is attributable to a combination of inaccurate price signals and misleading portfolio adjustment signals delivered by the informed agents, which in turn stimulates the creation of loss-generating trade proposals and sustains price-destabilizing forces in the market.

The second essay studies the determinants of asset price movement, and the consumption smoothing behaviors across markets populated with varying proportion of traders, with and without induced motive to smooth consumption. Although the asset is overpriced compared to the risk-neutral fundamental value in all sessions, the extent of mispricing and the magnitude of price movement are significantly higher when individuals without induced motive to trade are present. We also find that the price of the asset co-moves with the dividend state, with price predictability being higher in the presence of traders with induced motive to smooth consumption. Participants with income fluctuations are able to smooth their consumptions, with the inclination being more for those with smaller asset endowment. With fixed prices, traders are able to smooth consumption not only over periods but also across the dividend states.

The third essay investigates how granting CEOs with stock ownership and the opportunity to trade influence CEOs' effort and market efficiency. We implement a two by two experimental design, where the treatments are differentiated based on: (1) whether the CEOs receive 20% of the profit as cash bonus or 20% of the stock shares as endowment, and (2) whether or not the CEOs are prohibited from participating in trading in the open market. The findings suggest that to the contrary of public beliefs, stock ownership does not significantly improve the managerial effort decisions. There is, however, a greater alignment between CEO's decisions and investors' valuation of the firm assets. Investors anticipate the growth of the asset values, utilize information of the CEO's portfolio adjustment to produce *effective* estimator of the fundamentals, and follow them closely. The *forward looking* trading strategy enhances the *actual* intrinsic value discovery process and improves market price quality. Meanwhile, we observe that granting CEO the opportunity to trade nullifies the positive growth CEO brings about to the firm values. Higher rate of change in the managerial efforts induces larger asset mispricing, greater costs of transactions and more volatile market prices.

Chapter 1. Insider Trading Disclosure Rule and Reselling Constraint in Experimental Markets

1.1. Introduction

Insider transactions in stock trading are illegal when the trades are done on the basis of non-public material information (such as merger and corporate restructuring plans) that a corporate insider possesses. As long as non-public material information is not involved, corporate insiders may buy or sell shares in their possession. However, there must be public disclosure of such trades, to protect the interests of outside investors. Insider trading remains a contentious issue in the economics and finance literature. On the one hand, the advocates of insider trading justify it on the grounds that it moderates systematic price fluctuations due to irrational noise trading, and expedites price discovery through the incorporation of new private information into market prices. On the other hand, observers often construe it as a tool for insiders to gain abnormally high returns at the expense of uninformed traders.¹ Rampant expropriation and exploitation of privileged information have led to calls for better protection of imperfectly informed investors, and stronger protection of price integrity (Thompson, 2013).

Despite tighter enforcement of punitive legislation, illegal insider transactions are still seemingly prevalent. According to the 2006 U.S. Senate Committee proceedings on insider trading, an estimated one third of takeover announcements on the stock exchange are “preceded by suspicious share price movements, suggesting insider dealing or other market

¹ For a complete discussion of the impacts of insider trading, see Jaffe (1974), Kyle (1985), Seyhun (1986), Manove (1989), Laffont and Maskin (1990), Long et al. (1990), Ausubel (1990), and Benabou and Laroque (1992).

abuses”². The difficulty of detecting illegal insider trading remains one of the major hurdles. This provides a good reason to look beyond deterrence, and explore alternative ways to strengthen the salient features of securities markets and complement the punitive approach.

The current paper addresses a set of arguments made in connection with the impacts of insider trading regulation on market performance. We chose compulsory disclosure as it is one of the most commonly implemented and widely discussed elements of insider trading regulatory frameworks. The protocol rules out the possibility of trade concealments or fraudulent disclosures (Fishman and Hagerty, 1995), allowing researchers to isolate the endogenous choices of disclosing transactions and to concentrate on the changes in the direction and price impact of insider trades. We model the post-trade disclosure mechanism after Section 16(a) of the US Securities Law of 1934. The rule requires any insider who owns at least 10% of his company’s stocks to report to the Securities and Exchange Commission (SEC) within the first 10 days of the month following a relevant transaction. Timely public access to the information in these reports is provided through internet sites such as *Yahoo! Finance* or the *SEC EDGAR Database*.

While the theoretical research generally suggests that insiders should be obliged to disclose their transactions, a fair assessment of the empirical evidence seems to indicate mixed outcomes. In principle, a transparency protocol facilitates market learning, despite of the variation in the speed of price discovery (Huddart et al., 2001; Huang, 2008). It fosters traders’ confidence in market reliability and creates a thicker market through increased investor participation in it (Bhattacharya and Spiegel, 1991; Manove, 1989). However, disclosure is also inextricably linked to a surge in strategic executions that mislead, and exploit the poor decisions of less sophisticated investors (Benabou and

² United States Senate Committee on the Judiciary, 2006, *Illegal Insider Trading: How Widespread Is The Problem and Is There Adequate Criminal Enforcement?* in *Hearings Before the Committee on the Judiciary*, published by U.S. G.P.O.

Laroque, 1992; John and Narayanan, 1997; Zhang, 2008). Even in the absence of an insider's motive to engage in market manipulation, outsiders are still incapable of distinguishing informed trading from individual portfolio adjustment. It follows that, as the signal dissemination process is obstructed, market quality is impaired.

We focus on asset mispricing as the main indicator of market quality. One of the key challenges in the empirical work based on field data lies in the identification of asset bubbles. Measurements of price deviation often produce arbitrary outcomes, due to inaccurate specifications of the fundamentals. Non-material private information is collected and quantified separately from the actual transactions, impeding the establishment of links between the two. Moreover, data on transparency reforms are rare; there are insufficient empirical materials that compare key indicators before and after a rule is implemented.

An experimental methodology allows researchers to control the economic value of the privileged information possessed by insiders (Damodaran and Liu, 1993). Problems arising from inaccurate specification of fundamentals can be addressed with well-determined and pre-defined instruments. More importantly, the setting minimizes potential bias due to the presence of alternative investment platforms, market trends, and the behavioral traits of the agents.

We model our market after the Smith, Suchanek, and Williams (SSW) model (Smith et al., 1988). The framework has been rigorously studied because of its robust bubble and crash observations. Previous studies have examined informed trading and informational efficiency when informed agents are exogenously endowed with private information (Schnitzlein, 2002; Bossaerts et al., 2014); however, the roles of traders are not retained for the duration of the experiments. This runs contrary to actual practice, where trader identities are non-interchangeable. To the best of our knowledge, only Sutter et al. (2012) have assigned permanent identities and made the presence of insiders a matter of common knowledge in the SSW framework: insiders receive dividend clues at the start of a period

and trade with uninformed traders who are cognizant about the asymmetric information. However, insiders in that study do not have to follow any regulation. We build on the literature by making it compulsory for the insiders to reveal their transactions and hold acquired assets (which yield two possible dividend outcomes) for a minimum of two trading periods before being able to resell them. The design feature of the holding requirement is based loosely on legislation promulgated to deter insiders from flouting such elements of the transparency protocol, such as the SEC's *short-swing* and *restricted stock* rules. The spirit of provisions of this sort also manifests itself in corporate compliance programs that prohibit trading by insiders during certain *blackout* periods (Bettis et al., 2000).

Our assessment of the market performance is centered on the informational role of market prices. In particular, we examine the adherence of prices to the fundamentals and to what extent this reflects private information variability. We find no evidence of improvement in market pricing efficiency when insider trades are observable. The estimation of a modified dynamic price adjustment model, however, indicates that price adjustments are small relative to the revisions in the expected dividend values. Informed agents produce weakly characterized and less distinctive price signals in response to the changes in the *private information*, hindering the price discovery process. As insiders switch from dividend accumulating to capital appreciation realization strategies, they enjoy more superior income positions over the uninformed agents.

Price predictability suffers a complete breakdown when holding rule is introduced. Our evidence points to a surge in inaccurate *price signals* and misleading portfolio adjustment signals relayed by the informed agents, as the likely cause. Informed distortions evolve positively according to the intensity of the illiquidity constraint, suggesting what could plausibly be an imposition of price premium to mitigate the hedging inflexibility risk

involuntarily born by the insiders. The phenomenon spurs the growth of loss-generating trade proposals generated in the market, exacerbating the asset bubbles.

The organization of this paper is as follows. We present the experimental framework in section 1.2. We discuss our empirical strategy and results in section 1.3 and 1.4. Section 1.5 presents the concluding remarks.

1.2. Experimental Design and Procedure

The market structure adheres closely to the baseline parametric paradigm of Smith et al. (1988). The double continuous-auction market format demonstrates a long tradition of producing bubbles and crashes suitable for studying asset mispricing.

There are four sessions for every treatment, with three trading rounds in each session. Subjects trade with an invariable set of individuals throughout the session. One trading round consists of eight periods and each trading period lasts for 120 seconds.

The experimental asset yields a stream of dividends, with four possible dividend realizations: 0, 20, 40, or 60 Experimental Currency Units (ECUs). The dividend value is randomly and independently drawn, with an equal probability of $\frac{1}{4}$ at the end of each period, and is uniform for all asset holders. Thus, the expected periodic dividend value of one unit of asset is 30 ECUs. Since all assets expire at the end of the last period, the fundamental value declines from 240 ECUs at the start to 30 ECUs at the end. All subjects receive full information of the periodic fundamentals in a table format.

Participants engage in transactions by posting and accepting buying orders (*bid*) or selling orders (*ask*). They may buy any quantity as long as they have sufficient cash, and sell any quantity as long as they have sufficient securities. Borrowing of funds and short selling are prohibited. Also, cash holdings do not yield interest payment.

There are two types of traders in the market: *outsiders* and *insiders*.³ Information on the four possible dividend realizations is given to both outsiders and insiders prior to the trading stage. However, insiders also receive less than certain private information about the state of nature, at the start of each period. The *private information* reads ‘good dividend’ if the dividend drawn is either 40 or 60 ECUs, and ‘bad dividend’ if 0 or 20 ECUs.⁴ The system resembles the actual proprietary trading desk or mutual fund that receives a continuous flow of private signals through concerted research efforts. Outsiders are informed about the presence of insiders in the market.

Table 1.1. Experimental Design

Treatment	Session	Disclosure of transactions involving insiders	Holding rule	Insiders (subjects)	Normal Traders (subjects)	Trader's Initial Endowment	
						Cash	Assets
<i>NO DISC</i>	1	No	No	6	10	4800	6
	2	No	No	6	10	4800	6
	3	No	No	6	11	4800	6
	4	No	No	6	11	4800	6
<i>DISC</i>	5	Yes	No	6	11	4800	6
	6	Yes	No	6	10	4800	6
	7	Yes	No	6	11	4800	6
	8	Yes	No	6	10	4800	6
<i>HOLDING</i>	9	Yes	Yes	6	10	4800	6
	10	Yes	Yes	6	10	4800	6
	11	Yes	Yes	6	11	4800	6
	12	Yes	Yes	6	11	4800	6

Notes: Insiders receive additional information about the dividend state at the start of each period: ‘good dividend’ if the dividend drawn is either 40 or 60 ECUs, ‘bad dividend’ if 0 or 20 ECUs. Information revealed in the disclosure table includes transaction price, type of transaction and number of shares involving insider(s). Holding rule requires insiders to hold assets purchased, for a minimum of two periods, before being able to resell them again.

³ Previous studies demonstrate that the presence of multiple insiders heightens the likelihood of private information dissemination to the public (Plott and Sunder, 1982; Kyle, 1984; Laffont and Maskin, 1990). We therefore assign the insider roles to more than one subject in each market to set an environment with optimal private signal distribution as the baseline framework.

⁴ Engagement in trading comes naturally to insiders, as imperfect information on the liquidating dividends necessitates trading to hedge the endowment risk.

We implement three different treatments into an otherwise identical setting. In the baseline *NO DISC* treatment, insiders receive private information but do not disclose their transactions. Also, they may resell a purchased asset immediately. In the *DISC* treatment, insider transactions are visible to the market at the point of execution. *Live* information on the trading price and the type of transaction (purchases or sales by insider) are disclosed in a table and published according to the order of execution. We also re-display the complete disclosure table to all traders after the market concludes. Restriction on asset reselling is implemented in the *HOLDING* treatment. Not only do insiders have to observe the disclosure rule (identical to the *DISC* market), they are also required to *hold* a purchased asset for a minimum of two periods. That is, they may not resell assets bought in period t until period $t+2$ commences. Information about the total assets in the inventory and the *illiquid* assets are shown on the individual's screen. Outsiders, on the other hand, are not subject to this restriction.

We use Experimental Currency Units (ECUs) as a unit of account in the experiment. All traders receive the same initial endowment of 4,800 ECUs and six assets. They carry over their cash and asset holdings from one period to the next. However, the assets become worthless at the end of a round, and subjects' inventories will be reset at the start of a new replication. We can therefore view each replication as a distinct market, linked with the other replications only by the experience each trader accumulates from the preceding replication. Traders will be considered bankrupt when their working capital falls to zero. (We do not, however, record any case of bankruptcy in our experiment).

The evidence from previous research shows that individual innate psychological biases, such as overconfidence and risk aversion, exert non-negligible influences on price deviations (Biais et al., 2005; Hong et al., 2006; Crockett and Duffy, 2015). Overconfident traders accept prices that exceed their own valuation of future dividends, in anticipation of finding a new buyer who pays more. At the same time, subjects with a lower tolerance of

risk are found to demand higher expected returns which in turn accelerate the growth of asset bubbles (Blanchard and Watson, 1982; Daniel et al., 1998; Scheinkman and Wei, 2003). Thus, we create overconfidence and risk aversion profiles of the individuals by implementing the following two tests. In the first test, we ask subjects to input a series of confidence intervals (that contain the correct answer), to each of the twenty general knowledge questions with specific numerical answers. We then employ the methodology of Deaves et al. (2009), to measure the corresponding overconfidence level of the students by the submitted confidence intervals. In the second test, we present subjects with menu of 10 paired lottery choices and ask them to choose between “safe” and “risky” options in each of the 10 choices. This test is modeled closely after the standard practice introduced by Holt and Laury (2002).

There are a total of 198 undergraduates (without prior experience in experimental asset market) recruited from various faculties in Nanyang Technological University, Singapore. Upon arrival, participants enter a computer laboratory with high partitions installed between terminals. They are strictly prohibited to communicate with one another and identified through unique numeric identifications. Sixteen to 17 traders are grouped into one session, and six traders are randomly chosen (by *z-Tree*) as the insiders. All participants remain in the same role for the duration of the session.

The experiments are implemented with the *z-Tree* software (Fischbacher, 2007). We begin by administering the overconfidence test. After the test is completed, we distribute the instructions for the trading stage and read the instructions aloud. The sets of printed instructions given to all subjects are identical. A printout of the fundamental value table is provided to help subjects learn about the declining fundamentals. Traders are informed of the independent drawing of dividends by the server, and that the dividend value for both insiders and outsiders is uniform. Subjects are given enough time to study the materials independently and clarify any doubt they have about the experimental procedure. They

then proceed to trade in two un-incentivized practice periods designed to familiarize subjects with the arrangement in the actual paid session.

Quotes (or the price of trade proposals) are arranged according to the time of submission, and in a descending order of attractiveness. Subjects exchange assets by clicking the *buy (sell)* button to accept the most attractive bid (ask). We adopt a single unit transaction format, thus one click of the buy/sell button permits a single execution at a time. Information about outstanding cash, securities holdings, and the open order books of *bids* and *asks* are constantly updated while subjects trade. Subjects in the *DISC* and *HOLDING* treatments are granted access to the insider-trading disclosure table, which broadcast insider transactions *live* according to the time of execution. In addition, insiders in *DISC* and *HOLDING* can also find *private information* displayed on their trading screens.

At the completion of one period, subjects are given a summary of (i) individual's own final cash and securities, (ii) total dividends earned by the individual, (iii) market's closing price, and (iv) the average market prices of preceding periods. We conclude our experiment by administering the risk aversion test and a set of questionnaires to document subjects' demographic profiles. Subject's final wealth is then converted into Singapore Dollars for the actual incentive payments. One session typically lasts for two hours and most participants earn between S\$15 and S\$20, inclusive of the S\$4 "show-up" fee.

1.3. Price Predictability

To address the principal question of how the informational function of market price evolves under different treatments, we probe into the Dynamic Price Adjustment model introduced by Smith et al. (1988). Similar to our design, traders in the experiment face both the *exogenous* (i.e. the *dividend process*) and *endogenous* uncertainties (i.e. the *price*

process). As such, the intertemporal price behavior, measured by the change in mean price from period $t - 1$ to t , can be characterized by: (i) the expected periodic fall in the intrinsic value $E(d)$ and (ii) the lagged excess bid $(B_{t-1} - O_{t-1})$, according to the following equation:

$$(\bar{P}_t - \bar{P}_{t-1}) = \alpha + \beta_1(B_{t-1} - O_{t-1}) + \varepsilon_t \quad (1)$$

$$\alpha = -E(d) + K$$

where K is the adjustment term for the risk aversion level in market.

The literature produces robust evidences that refute the null hypothesis $\beta_1 = 0$ but not $\alpha = -E(d)$. This supports the Walrasian adjustment interpretation that asset price change tracks fundamental value, and that asset price adjustment is positively associated with the lagged excess demand as surrogated by the excess bid (Caginalp et al., 2001; Lei et al., 2001). Past work also shows weak evidence of $\alpha < -E(d)$, suggesting the influence of general risk aversion levels on intertemporal changes.

We modify the model by introducing the categorical variable pi_t , which is 1 when insiders are given optimistic information in period t (or when *private information* reads *good*) and 0 otherwise (*private information* reads *bad*):

$$(\bar{P}_t - \bar{P}_{t-1}) = \alpha + (\gamma + \delta pi_t) + \beta_1(B_{t-1} - O_{t-1}) + \varepsilon_t \quad (2)$$

Recall that there are four possible dividend realizations: 0, 20, 40, or 60 ECUs, with equal probability in the market. Traders should therefore expect to earn:

$$E(d) = \left[\frac{1}{4}(0) + \frac{1}{4}(20) + \frac{1}{4}(40) + \frac{1}{4}(60) \right] \text{ECUs} = 30 \text{ ECUs}$$

from each share held in period t . This constitutes a decline in the expected dividend value, as denoted by $\alpha = -30$ in Eq(1). The arrival of private information enables the recipients to revise the expected dividend value accordingly. Learning that the dividend in period t will be *bad* enables subjects to narrow the realizations down to either 0 or 20 ECUs. As such, traders should expect to earn:

$$E(d|pi_t = 0) = \left[\frac{1}{2}(0) + \frac{1}{2}(20) \right] \text{ECUs} = 10 \text{ ECUs} \quad (3)$$

from each share held in period t . In other words, there is a revision to α by⁵:

$$\gamma = E(d|pi_t = 0) - E(d) = 10 \text{ ECUs} - 30 \text{ ECUs} = -20 \text{ ECUs}. \quad (4)$$

On the other hand, learning that the dividend in that period will be *good* enables subjects to narrow down the realizations to either 40 or 60 ECUs. Traders should expect to earn:

$$E(d|pi_t = 1) = \left[\frac{1}{2}(40) + \frac{1}{2}(60) \right] \text{ECUs} = 50 \text{ ECUs}. \quad (5)$$

from each share held in period t . As the information changes from *bad* to *good*, there is therefore a revision to $(\alpha + \gamma)$ by⁶:

$$\delta = E(d|pi_t = 1) - E(d|pi_t = 0) = 50 - 10 = 40 \quad (6)$$

⁵ The following example is provided to illustrate the *revised* decline in the expected dividend value. Traders should expect to earn a total of $7 * 30 \text{ ECUs} = 210 \text{ ECUs}$ per share, when they hold one unit of asset from $t = 2$ to $t = 8$. In other words, there is a decline in the expected dividend value by 30 ECUs, from 240 ECUs in $t = 1$ to 210 ECUs in $t = 2$. However, if the dividend in $t = 2$ is *bad*, traders should expect to earn a total of $10 \text{ ECUs} + (6 * 30 \text{ ECUs}) = 190 \text{ ECUs}$. The *revised* decline in the expected dividend value is $(240 - 190) \text{ ECUs} = 50 \text{ ECUs}$, as denoted by $\alpha + \gamma = -50$.

⁶ The following example is provided to illustrate the *revised* decline in the expected dividend value. Traders should expect to earn a total of $7 * 30 \text{ ECUs} = 210 \text{ ECUs}$ per share, when they hold one unit of asset from $t = 2$ to $t = 8$. In other words, there is a decline in the expected dividend value by 30 ECUs, from 240 ECUs in $t = 1$ to 210 ECUs in $t = 2$. However, if the dividend in $t = 2$ is *good*, traders should expect to earn a total of $50 \text{ ECUs} + (6 * 30 \text{ ECUs}) = 230 \text{ ECUs}$. The *revised* decline in the expected dividend value is $(240 - 230) \text{ ECUs} = 10 \text{ ECUs}$, as denoted by $\alpha + \gamma + \delta = -10$.

It can be seen that our key parameters of interest are γ and δ . Rejection of the null hypotheses:

$$(i) \gamma = 0, (ii) \delta = 0$$

, underscores the non-negligible price reaction to information variability. Moreover, we also look for the evidence of:

$$(iii) \gamma = -20, \text{ and } (iv) \delta = 40 \quad (7)$$

, so as to study how accurately the price changes reflect the revision of expectations according to Equation (4) and (6). Inability to reject the null hypotheses of $\gamma = -20$ and $\delta = 40$ indicates high consistency between market price adjustment and the revision in the expected dividend values. Thus, it can be used as a measure of how predictable (and informative) the market price is.

1.4. Experimental Results

Table 1.2 summarizes the descriptive statistics of our experiment. Our samples comprise of undergraduate students from various faculties in Nanyang Technological University, Singapore. Eighty seven percent of the students have no prior experience in actual trading; fifty five percent of them are male. Subjects generally overestimate their abilities, with an average overconfidence bias score of 0.69⁷. In addition, the average crossover point in the risk preference test is located between the sixth and seventh choice. This implies that risk aversion characterizes the overall market attitude towards risk.

⁷ The extent of the bias is manifested in the distance of the test score from the maximum value of 1.

Table 1.2. Descriptive Statistics

Variables	Treatment						mean
	<i>NO DISC</i>		<i>DISC</i>		<i>HOLDING</i>		
	<i>mean</i>	<i>sd</i>	<i>mean</i>	<i>sd</i>	<i>mean</i>	<i>sd</i>	
Gender (1 if all males, 0 females)	0.53	0.5	0.51	0.5	0.59	0.5	0.55
Overconfidence Level	0.67	0.2	0.71	0.2	0.69	0.1	0.69
Risk Preference Turning Point	6.60	2	6.54	2.2	6.14	1.8	6.42
Years of Trading Experience	0.33	1	0.23	0.6	0.23	1	0.26

We present the most prominent empirical patterns observed in our experimental data in the following arrangement. In subsection 1.4.1, we start off by comparing asset mispricing across treatments. We then analyze how insiders' price signals evolve according to the treatments, and their impacts on market price adjustment in subsection 1.4.2 and subsection 1.4.3, respectively. Findings on how market responds to the systematic changes in price dynamics are documented in subsection 1.4.4. The final subsection provides observations with respect to the income distribution across different types of traders, in relation to the changing market efficiency.

1.4.1. Aggregate Asset Mispricing

Following Stöckl et al. (2010), we measure excess prices using *Relative Absolute Deviation (RAD)* and *Relative Deviation (RD)*⁸. Other common measurements such as

⁸ Our results open up a discussion on the fundamental value on which the measurement of the mispricing is based. At the center of the debate is the concept of revisions to the expected dividend value brought about by the arrival of new information. Unveiling positive (negative) information alters the recipients' expectations of the dividend value in the corresponding period, and entails upward (downward) adjustment to the remaining portion of the declining FV line of these subjects. This implies that price deviation should be measured from the adjusted fundamentals (which vary depending on the sequences of the private information) rather than the standard declining line.

The question of whether there are two different paths is certainly not an easy one to answer. Following our conversation with Vernon L. Smith at the Experimental Finance 2015 conference, we utilize the standard line on the grounds that private information given in our experiment belongs to the "available information" already incorporated into the market prices in an efficient market sense (Fama, 1970). The good and bad readings are

Total Dispersion (TD) and *Total Bias (TB)* (Haruvy and Noussair, 2006; Haruvy et al., 2007) are also employed in our analysis.

Table 1.3. Market Efficiency Measurements

Measure	Calculation
Relative Absolute Deviation (<i>RAD</i>)	$RAD_{r,t} = \frac{\frac{1}{8} \sum_{t=1}^8 \overline{P}_{r,t} - FV_{r,t} }{\overline{FV}_{r,t}}$
Relative Deviation (<i>RD</i>)	$RD_{r,t} = \frac{\frac{1}{8} \sum_{t=1}^8 (\overline{P}_{r,t} - FV_{r,t})}{\overline{FV}_{r,t}}$
Total Dispersion (<i>TD</i>)	$TD_{r,t} = \sum_{t=1}^8 \widetilde{P}_{r,t} - FV_{r,t} $
Total Bias (<i>TB</i>)	$TB_{r,t} = \sum_{t=1}^8 (\widetilde{P}_{r,t} - FV_{r,t})$

Notes: t denotes the t -th period in round r ; $\overline{P}_{r,t}$, $\widetilde{P}_{r,t}$ and $FV_{r,t}$ are the average trading price, median price and the asset fundamental value in period t , respectively. As the fundamental value declines from 240 ECUs to 30 ECUs, $FV_{r,1} = 240$ and the standard $\overline{FV}_{r,t}$ for our calculation is 135 ECUs.

The detailed entries of the bubble magnitudes are reported in Table 1.4, with the average count in one replication taken as a unit of observation. Across the three panels, we are able to reject the null hypotheses that *RAD* and *TD* are equal to zero. In particular, we record inefficiencies tantamount to 32%, 33% and 57% of the fundamental values in *NO DISC*, *DISC* and *HOLDING* markets respectively. We also look into the direction of price deviation, and find that *RD* and *TB* in *DISC* and *HOLDING* are statistically positive. Thus, assets appear to be overvalued when insider trading is disclosed.

internalized in the formation of traders' common expectations of the dividend value (30 ECUs). In addition, the small revision in the valuation is not expected to make much difference to our bubble findings, even in the case of traders utilizing two different paths instead of the standard declining fundamentals.

Table 1.4. Bubble Measurements

Bubble Measures	<i>NO DISC</i>		<i>DISC</i>		<i>HOLDING</i>	
	<i>mean</i>	Signed Rank <i>p</i> -value ($H_0:0$)	<i>mean</i>	Signed Rank <i>p</i> -value ($H_0:0$)	<i>mean</i>	Signed Rank <i>p</i> -value ($H_0:0$)
<i>RAD</i>	0.32	0.002	0.33	0.002	0.57	0.002
<i>RD</i>	0.19	0.117	0.25	0.004	0.49	0.012
<i>TD</i>	348	0.002	353	0.002	637	0.002
<i>TB</i>	211	0.136	266	0.004	531	0.012

Comparison of the bubble metrics in market with and without holding rule indicates a systematic change on asset mispricing. As shown in the first row of Table 1.4, the average *RAD* in *HOLDING* is 24% and 25% above those in *DISC* and *NO DISC* respectively. Reselling restriction also introduces visible increase in the extent of price overvaluation, as implied by the higher values of *RD* and *TB* in *HOLDING* markets.

Table 1.5. Regressions of Bubble Measurements

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	RAD			RD		TD		TB
Disclosure	0.0496	0.0440	0.0548	0.0378	58.21	53.96	56.63	41.07
(1 if <i>DISC</i> , 0 otherwise)	(0.0819)	(0.0835)	(0.0957)	(0.0936)	(93.11)	(94.82)	(108.4)	(106.5)
Holding	0.302**	0.299**	0.270*	0.261	351.0**	348.7**	300.0	291.4
(1 if <i>HOLDING</i> , 0 otherwise)	(0.136)	(0.139)	(0.155)	(0.159)	(154.5)	(157.7)	(178.6)	(182.4)
Overconfidence Level	0.808	0.799	1.375	1.347	717.1	709.8	1,533	1,507
	(1.041)	(1.055)	(1.371)	(1.391)	(1,175)	(1,188)	(1,546)	(1,567)
Risk Preference	0.133	0.127	0.229**	0.211**	161.6	157.2	281.9**	265.7**
	(0.0887)	(0.0839)	(0.108)	(0.0986)	(102.9)	(98.83)	(121.0)	(113.1)
Gender	3.102***	3.067***	3.444***	3.339***	3,511***	3,485***	3,859***	3,763***
	(0.568)	(0.600)	(0.646)	(0.690)	(638.0)	(679.0)	(740.7)	(787.0)
Age	-0.347**	-0.345*	-0.119	-0.111	-399.6**	-397.7*	-140.0	-133.2
	(0.165)	(0.172)	(0.193)	(0.202)	(187.2)	(194.5)	(221.3)	(230.6)
Ratio of Traders with Trading Exp.	1.318*	1.314*	1.539*	1.528*	1,413	1,410	1,588	1,578
	(0.745)	(0.753)	(0.895)	(0.887)	(840.0)	(853.6)	(1,007)	(1,007)
Round	-0.126***	-0.123***	-0.166***	-0.160***	-136.3***	-134.7***	-185.0***	-179.0***
	(0.0417)	(0.0420)	(0.0480)	(0.0488)	(47.70)	(47.67)	(55.32)	(56.62)
Number of Good States		0.00653		0.0197		4.938		18.08
		(0.0242)		(0.0280)		(27.18)		(31.43)
Constant	4.705	4.686	-1.416	-1.474	5,518	5,504	-1,584	-1,636
	(4.054)	(4.172)	(4.775)	(4.909)	(4,589)	(4,718)	(5,462)	(5,621)
Observations	36	36	36	36	36	36	36	36
R ²	0.742	0.743	0.725	0.731	0.740	0.740	0.717	0.721
Robust standard errors in parentheses								
*** p < 0.01, ** p < 0.05, * p < 0.1								

The statistical significance of the findings can be obtained from the following estimation:

$$y_{i,r} = \alpha + \beta_1 dd_i + \beta_2 hod_i + \gamma_3 r + X'_t \theta + \varepsilon_{i,r} \quad (8)$$

, where $y_{i,r}$ represents the average bubble measures in round r of session i ; dd takes 1 for *DISC* markets and 0 otherwise; and hod takes 1 for *HOLDING* markets and 0 otherwise. The control variables X' consist of the average market overconfidence (higher value indicates greater overconfidence), the risk preference level (higher value indicates greater risk aversion), the composition of gender (value closer to 1 means more male traders in the market), the average age, and the ratio of traders with prior trading experiences in the session. Variable r is included in the estimation, to control for the learning effects (Boening et al., 1993), while the number of good states in r is included to control for the impact of high income (high dividend earnings) on the asset bubble.

As shown in Table 1.5, the estimated coefficients β_1 of the disclosure dummy are statistically insignificant, suggesting negligible differences in the magnitude of the bubble metrics found between *NO DISC* and *DISC* markets. We also complement the statistical evidences with the visual analysis. Figure 1.1 displays the time series of the absolute price deviation from the fundamental of each of the three treatments; with the vertical axis denoting the average absolute median price deviation across all sessions in the same treatment, while the horizontal axis indicating the market period. As shown in the fourth panel of Figure 1.1, the solid line (*NO DISC*) continues to overlap the dashed line (*DISC*) throughout the replication. The two evidences reiterate the notion that disclosure rule imposes negligible improvement on pricing efficiency.

Figure 1.1. Time Series of Absolute Median Price Deviation from Fundamental Value

In contrast, asset mispricing in *HOLDING* are exacerbated, as apparent in the statistically positive β_2 coefficients in the second and sixth column of Table 1.5. From Figure 1.1, the dotted line (*HOLDING*) is persistently higher than the dashed line (*DISC*), with the last period showing the only exception. We can therefore clearly see that the aggravation to asset mispricing is consistently sustained throughout the replication of market with illiquidity constraint.

The main conclusion with respect to transaction prices is as follow:

Result 1: (i) *We find significant price departures from than the fundamentals in all treatments.* (ii) *While disclosure rule produces negligible impact on pricing efficiency, the addition of holding rule exacerbates the extent of asset mispricing.*

1.4.2. Insider Informativeness and Intertemporal Price Signal Adjustment

The systematic changes in asset mispricing prompt us to inquire into the corresponding insider behaviors. In particular, we seek to identify insiders' failure to disseminate *private information*, and its association with the observed decline in pricing efficiency.

We measure the extent of informed distortion by modifying the *Informativeness* index of Bossaerts (2014). We regard the discrepancy in the signal sent by the experimenter to the insiders (hereby labeled as *private signals*) and the signal sent by insiders to the market (hereby labeled as *price signals*) as *Insider Informativeness (INSI)* in our subsequent analysis. *INSI* is constructed according to the following equation:

$$INSI_{i,t} = (\overline{ITP}_{i,t} - \theta_t)$$

, where $\overline{ITP}_{i,t}$ represents the average prices of transactions involving insider i in period t (or *price signals*). *Private signal* θ_t is a function of the revised expected dividend value

$E(d|pi_t)$ according to Equation (3) and (5), following the arrival of *private information* pi_t :

$$\theta_t = E(d|pi_t) + (8 - t) * 30 \quad (9)$$

, where $(8 - t) * 30$ is the sum of the expected dividend (without any revision prior to the private information arrival) for period $t + 1$ to period 8⁹. It can be seen that the higher the value of *INSI*, the greater is the discrepancy between the *price signals* and the actual *private signals* received; and thus the more severe is the extent of informed distortion in the market.

Table 1.6. Average Individual Insider's *INSI*

Treatment	mean	sd	min	max	Signed Rank <i>p</i> -value ($H_0: INSI = 0$)	n
<i>NO DISC</i>	22.46	27.88	-22.25	63.38	0.001	24
<i>DISC</i>	26.10	33.55	-22.63	87.78	0.0007	24
<i>HOLDING</i>	58.29	56.95	-6.81	168.55	0.0001	24
					Mann-Whitney <i>p</i> -value	n
$H_0: NO DISC = DISC$					0.84	48
$H_0: DISC = HOLDING$					0.053	48
$H_0: NO DISC = HOLDING$					0.055	48
Kruskal-Wallis χ^2					5.01	
<i>p</i> -value					0.082	

Table 1.6 presents the average *INSI*, by each of the 72 insiders in one session. On average, *NO DISC* insiders price their transactions 22.5 ECUs above the *private signals*. Overvaluation in *price signal* is statistically significant, as we are able to reject the null hypothesis that *INSI* in *NO DISC* are equal to zero at conventional levels. Insiders play a role in sustaining price detachment from the fundamentals even in the baseline market.

⁹ There is no revision to the expected value in these periods, as insiders have yet to receive private information for period $t-1$ to period 8, and the expected value remains at 30 ECUs.

Table 1.7. *INSI* and Illiquidity Constraint.

VARIABLES	(1)	(2)
	Average <i>INSI</i>	
Ratio of Illiquid Assets	78.69*** (25.30)	82.83*** (20.60)
Number of Good Dividends Experienced		5.813*** (1.658)
Overconfidence Level		-1.456 (26.60)
Risk Preference		1.301 (2.659)
Gender		18.57** (8.584)
Age		-4.653 (2.994)
Trading Experience		-2.896 (5.699)
Constant	24.85*** (4.417)	30.52 (76.90)
Observations	72	72
R ²	0.153	0.353
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

We do not find statistically significant difference between *INSI* in *NO DISC* and *DISC*. Informed agents disseminate undesirable *price signals* to the public as much as their counterparts in opaque market do. Transparency regime therefore produces indistinguishable improvement in *insider informativeness*.

INSI in *HOLDING* is remarkably higher than *NO DISC* and *DISC*. *HOLDING* insiders price their transactions 59 ECUs above the *private signals*, close to two times the level of distortions in *NO DISC*. We are able to reject the null hypothesis that the difference between market with and without illiquidity constraint is equal to zero. Market with

holding rule is thus characterized by escalated and more severe distortions than the other two markets.

Strategic distortion evolves positively with the degree of reselling constraint experienced by the corresponding insider. We establish the correlation through the following estimation:

$$\overline{INSI}_i = \alpha + \beta_1 \overline{il}_i + X_i' \theta + \varepsilon_{i,r} \quad (10)$$

, where $\overline{il}_i$ denotes the average fraction of illiquid assets held by insider i in one session. The control variables X' consist of the number of *good* dividend distributions attained in the session, individual overconfidence, the risk preference level, age, gender and years of trading experience.

Table 1.7 shows that the estimate for $\overline{il}_i$ is statistically positive. There is a unidirectional association between *INSI* and the ratio of illiquid assets, suggesting that insiders incorporate price markup above the *private signals* that grows with the proportion of their *frozen* assets. We suspect that holding rule deprives insiders of the liberty to liquidate the restricted assets, even as the insiders discover favorable opportunities for transactions within the duration of the restriction. This induces them to seek higher price premium to mitigate the hedging inflexibility risk involuntary born by them. Therefore, the more effective the reselling constraint, the greater is the decline in *insider informativeness*.

In summary,

Result 2: *Exacerbation of asset mispricing is stimulated by a dramatic rise in the discrepancies between the prices of insider transactions and the private signal. Insider pricing increasingly deviates from the private signal as their fraction of illiquid assets grows, suggesting that insiders incorporate a price premium into their transactions to compensate for the hedging inflexibility risk under holding rule.*

Price quality is determined not only by how small its discrepancy is from the fundamental, but also by how well it co-moves with the dividend outcomes. In the subsection, we complement the earlier findings on insider *informativeness* (i.e. involving the overall distance) by evaluating the co-movement of *price signals* with the changes in the world outcomes (i.e. involving the intertemporal adjustment).

In the absence of *private information*, price co-movement with the fundamental materializes in the form of a periodic price fall by 30 ECUs. The infusion of *private information*, however, enables the recipients to revise their expectations and produce more accurate price adjustment. As shown in Eq.(3) and (5), a decline by 10 and 50 ECUs (instead of 30 ECUs) should ideally characterize the good and the bad states accordingly.

We define the intertemporal *price signal* adjustment (*IPSA*) by:

$$IPSA_{i,t} = \overline{ITP}_{i,t} - \overline{ITP}_{i,t-1}$$

, where $\overline{ITP}_t$ represents the average prices of transactions involving insider i in period t . When insiders receive good (bad) information, they are expected to cut their pricing by 10 units (50 units). The differences between $(IPSA_t|\theta_t = 1) = -10$ and $(IPSA_t|\theta_t = 0) = -50$ or denoted as $\Delta IPSA$, is expected to resemble $\delta = 40$ from Eq. (7).

Table 1.8 presents the average *IPSA* of individual insider in one session, segregated by the corresponding dividend outcomes¹⁰. We find $(IPSA_t|\theta_t = 0)$ to be statistically higher than -50 for all insiders, suggesting the attempts to downplay the negative news by undercutting the *IPSA* in all three treatment. *DISC* and *HOLDING* insiders, however, also deemphasize positive news by inflating the magnitude of his *IPSA* upon receiving good news, $(IPSA_t|\theta_t = 1)$. The overcutting of *price signals*, however, is not found among *NO DISC* insiders when they are given positive news: we are not able to reject the null hypothesis that $(IPSA_t|\theta_t = 1) = -10$ in *NO DISC*. Indeed, when we look at the

¹⁰ One insider in *HOLDING* do not trade at all when he receives bad news. Thus, we only have 23 observations, instead of 24 observations for the second and the third panels.

differences between *IPSA* in good and bad states, *NO DISC* is the only market where $\Delta IPSA$ is not statistically distinct from 40. Thus, *NO DISC* insiders create more accurately characterized and distinguishable *dual* responses towards the two states than *DISC* and *HOLDING* insiders. We believe this feature sets informed agents in the *NO DISC* and *DISC* markets apart, despite of their statistically insignificant differences in *INSI* indexes (as shown earlier). *NO DISC* insiders facilitate better market learning by producing more accurate and distinguishable *IPSA* than *DISC* insiders. We can infer that transparency protocol actually triggers higher rate of informed distortion.

HOLDING insiders show the least desirable responses among the rest. On top of the inaccurate *IPSA*s, *HOLDING* insiders do not demonstrate distinctive portfolio adjustment signal towards different news, unlike *NO DISC* and *DISC* insiders. This can be seen in Table 1.9, which details the average percentage change of asset holding of individual insider in one session, segregated by the corresponding dividend outcomes. *NO DISC* and *DISC* insiders show a clearly defined strategy of accumulating (releasing) assets in good (bad states), as evidenced by their statistically positive (negative) corresponding change in asset holdings. Such strategy is not detected among *HOLDING* insiders: we do not find statistically negative change in their assets when they receive bad news. Indeed, *HOLDING* insiders adopt an overall asset purchasing strategy in both good and bad states. Such unclear demarkation of portfolio management strategies between positive and negative news is expected to mislead the market even more. We will delve into its impact of the income distribution in the subsequent subsection.

Table 1.8. Individual $IPSA$ in Good and Bad States

Treatment	$\overline{IPSA}_t$ when $p_{i_t} = \text{Good}$		$\overline{IPSA}_t$ when $p_{i_t} = \text{Bad}$		$\Delta \overline{IPSA}_t$	
	mean	Signed Rank p -value ($H0: \overline{IPSA}_t = -10$)	n	mean	Signed Rank p -value ($H0: \overline{IPSA}_t = -50$)	n
<i>NO DISC</i>	-8.63	0.95	24	-44.01	0.001	24
<i>DISC</i>	-18.82	0.04	24	-36.21	0.007	24
<i>HOLDING</i>	-19.46	0.03	24	-43.17	0.02	23
					mean	Signed Rank p -value ($H0: \Delta \overline{IPSA}_t = 40$)
					35.39	0.2
					17.39	0.0002
					22.52	0.0005

Table 1.9. Individual Asset Adjustment in Good and Bad States

Treatment	% Change in Insiders' Assets when $p_{i_t} = \text{Good}$		% Change in Insiders' Assets when $p_{i_t} = \text{Bad}$		Signed Rank p -value ($H0: \Delta \text{Good} = \Delta \text{Bad}$)	
	mean	Signed Rank p -value ($H0: \Delta = 0$)	n	mean	Signed Rank p -value ($H0: \Delta = 0$)	n
<i>NO DISC</i>	70.04	0.0002	24	-11.7	0.002	24
<i>DISC</i>	45.44	0.001	24	-10.3	0.07	24
<i>HOLDING</i>	31.21	0.008	24	4.6	0.8	24

In essence,

Result 3: (i) *Insiders in market with disclosure undermine market learning by producing weakly characterized and less distinguishable dual price signal responses towards the two states.* (ii) *Insiders in market with holding rule produce the least desirable response towards dividend news in market with illiquidity constraint, as they do not demonstrate a clearly defined strategy of accumulating (releasing) assets in good (bad) states, on top of the inaccurately characterized price signals.*

1.4.3. Price Predictability

The impact of *IPSA* abnormality on the actual market price adjustment is reflected in the estimation results of equations in section 1.3.

Table 1.10 (Model 1 to 3) presents the estimations based on Equation (1). Following the dynamic price adjustment model of Smith et al. (1988), we use a total of 252 observations of price adjustment, where the difference between mean price in period t and $t-1$ is defined as a unit of observation. The estimated coefficients α and β_1 are statistically distinct from zero across all treatments, suggesting that price adjustment is influenced by the (*unrevised*) expected periodic fall in the intrinsic value and the correlation between lagged excess bids and price variation, respectively.

Table 1.10. Market Price Predictability

Variables	(1) <i>NO DISC</i>	(2) <i>DISC</i>	(3) <i>HOLDING</i>	(4) <i>NO DISC</i>	(5) <i>DISC</i>	(6) <i>HOLDING</i>
Lagged Excess Demand (β_1)	0.243** (0.101)	0.0826** (0.0406)	0.305** (0.140)	0.332*** (0.0870)	0.0760* (0.0386)	0.296** (0.148)
Private Information (δ)				36.56*** (6.691)	15.63** (5.952)	12.52 (10.88)
α	-25.23*** (4.125)	-25.33*** (2.866)	-33.83*** (4.727)	-42.95*** (4.891)	-34.74*** (4.448)	-40.31*** (4.766)
$\alpha + \gamma$				84	84	84
Observations	84	84	84	84	84	84
R^2	0.067	0.045	0.082	0.303	0.120	0.098
Robust standard errors in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1						
H0:				Wald Test, p-value		
(i) $\gamma = 0$				<i>NO DISC</i>	<i>DISC</i>	<i>HOLDING</i>
(ii) $\delta = 0$				0.0005	0.036	0.18
(iii) $\gamma = -20$				< 0.0001	0.01	0.25
(iv) $\delta = 40$				0.64	0.02	0.0058
				0.61	0.0001	0.014

Studying the magnitude of each of the coefficient, we are not able to reject the null hypothesis of $a = -30$ in these models. Price adjustment is also closely associated with traders' pursuits of capital gain, as evident in the statistically positive β_1 coefficient. The experimental result thus supports the Walrasian adjustment interpretation that asset price change tracks the fundamental value in all markets. This constitutes comforting evidence that our experimental design replicates the canonical findings of Smith et al. (1988).

We subsequently compare the success of intertemporal adjustment following the distribution of *private information* across the three treatments. Models 4 to 6 in Table 1.10 present the estimations based on Equation (2). The key parameters of interest γ and δ measure how accurate the price changes are at reflecting the revision of expectations, according to Equation (4) and (6). As shown in models 4 and 5, the null hypotheses $\gamma = 0$ and $\delta = 0$ are rejected at conventional levels. This underscores the presence of non-negligible mean price responses to information variations, in *NO DISC* and *DISC*.

A stark contrast between *NO DISC* and *DISC*, however, can be seen when we evaluate the magnitude of the adjustment. We are not able to reject the null hypotheses $\gamma = -20$ and $\delta = 40$ in *NO DISC* (with p -value of 0.64 and 0.61, respectively). This implies that the intertemporal adjustment is *exactly* proportionate to the change in the expected dividend value, in the baseline market. On the other hand, the estimated coefficients γ and δ in *DISC* are significantly lower than the accuracy thresholds in Equation (4) and Equation (6); with p -value of 0.02 and 0.0001, respectively. In other words, market price adjustment is *less* than proportional to the change in the world outcomes, when disclosure rule is implemented.

We attribute this phenomenon to the earlier decline in *IPSA*. Weakly characterized *price signals* in turn undermine the predictability of market prices. Our finding reinforces the notion that transparency regime impairs price co-movement with the fundamentals.

While assets in *NO DISC* are overvalued as much *DISC*, its intertemporal movement reflects the changes in information better than assets in *DISC* do. Transparency protocol allows outsiders to observe insider activities, but it does not enable the outsiders to learn about the dividend outcomes better. Indeed, our evidences show that disclosure rule actually jeopardizes market price predictability.

Evidence from the *HOLDING* market is also in line with the earlier findings. Price adjustment in *HOLDING* is still characterized by the periodic decline in the (*unrevised*) expected dividend value (30 ECUs). The γ and δ coefficients, however, are not statistically distinct from 0 upon the inclusion of the categorical variable pi_t into the estimation (Model 6 of Table 1.10). Furthermore, we are able to reject the null hypotheses $\gamma = -20$ and $\delta = 40$. The evidence therefore suggests that market price fails to capture any revision in the asset intrinsic value.

We attribute the complete price predictability breakdown to a combination of inaccurate *IPSA* and the indistinguishable buy and sell strategies exhibited by *HOLDING* insiders. (Recall that *HOLDING* insiders adopt an asset accumulating strategies in both good and bad states, unlike *NO DISC* and *DISC* insiders). Convolved outsiders' confusion over the *price signals* and portfolio adjustment signals subsequently translates into market prices ceasing to respond to the variation in information.

We summarize our findings on the impact of disclosure and reselling constraint on price predictability as follows:

Result 4: *Transparency protocol impairs market price predictability. The intertemporal price adjustment is less than proportional to the actual change in the expected asset value, potentially due to the decline in insider's contribution to market learning.*

Result 5: *Market prices cease to respond to the variation in private signals when holding rule is introduced. We attribute the complete breakdown in price predictability to the confusing price and asset adjustment signals sent by the informed agents.*

1.4.4. Market Responses to the Changes in Price Predictability

We expect tremendous decline in price predictability to stimulate the rise of speculative activities in *HOLDING*. To see this, we employ the model of Haruvy and Noussair (2014) and classify traders as:

- (i) Fundamental Value traders (*FVT*) if they increase their asset holdings when the mean price is below *FV*, or decrease their asset holdings when the mean price is above *FV*,
- (ii) Momentum traders (*MM*) if they increase asset holdings following an upward price trend, or decrease asset holdings following a downward price trend in the past, and
- (iii) Rational Speculator traders (*RA*) if they increase asset holdings when price increases in the next period, or decrease asset holdings when price decreases in the next period¹¹.

Market Influence of trader i in period t is measured by:

$$Market\ Influence_{i,t} = (s_{i,t} * \widetilde{P}_{r,t}) + c_{i,t} \quad (11)$$

where s_t , c_t , and $\widetilde{P}_t$ denote the total assets, total cash and median market price in period t , respectively.

Table 1.11 reports the average market influence of different types of traders, with the average count of an individual taken as a unit of observation. Employing a one-sided t-test on *NO DISC* and *DISC* data, we are not able to reject the null hypothesis that *Market Influence* of *RA* traders equals or is below, in favor of the alternative hypothesis that it is above *Market Influence* of *FV* and *MM* traders. There is no evidence that *RA* traders in markets without reselling restrictions are more dominant than the rest. In contrast, result from the *HOLDING* market indicates that *RA* traders acquire statistically higher *Market*

¹¹ Traders that do not satisfy any of the three criteria are classified as “other” and are not included in Table 1.11.

Influence than their *FV* and *MM* counterparts when insiders observe the reselling constraint. Thus, there is a significant growth of influences possessed by traders who choose expected future prices over current fundamentals in their trading strategies.

Table 1.11. Market Influence of Traders

Type	Average Market Influence of Individual Trader								
	<i>NO DISC</i>			<i>DISC</i>			<i>HOLDING</i>		
	mean	sd	n	mean	sd	n	mean	sd	n
<i>FV</i>	6655	484	17	6775	267	19	6853	702	19
<i>MM</i>	6662	377	20	6748	860	15	6806	740	14
<i>RA</i>	6688	371	14	6867	377	8	7178	385	14
<i>One-sided t-test</i>	<i>p-value</i>		<i>n</i>	<i>p-value</i>		<i>n</i>	<i>p-value</i>		<i>n</i>
<i>H1: FV < MM</i>	0.481		37	0.552		34	0.572		33
<i>H1: FV < RA</i>	0.420		31	0.239		27	0.064		33
<i>H01: MM < RA</i>	0.424		34	0.357		23	0.054		28

Accompanying this is the general lack of conservative trading strategies adopted by the mass. To see this, we measure individual *i*'s contribution to price deviation by the Potential Loss (*PL*) metric developed by Akiyama et al. (2014):

$$PL_i = \frac{1}{E} \sum_{t=1}^{24} (bv_t^i \max(bq_t^i - FV_t, 0) + av_t^i \max(FV_t - aq_t^i, 0)) \quad (12)$$

where bq_t^i and aq_t^i represent the maximum bid and ask quote of individual *i* in period *t*, respectively; $bv_t^i(av_t^i)$ represents the maximum number of assets demanded (supplied) that are associated with $bq_t^i(aq_t^i)$; and *E* represents the total value of the initial endowment given to subjects in the session (set at 18,720 ECUs each). Higher count of *PL* is thus indicative of greater portion of financial losses committed by the individuals through their trade proposals.

Table 1.12 reports the average *PL* of all 198 traders, with the average count in one session taken as a unit of observation. The *PL* of *HOLDING* traders is strikingly higher

than from *NO DISC* and *DISC* traders (p -value = 0.03 and 0.001, respectively), with an average “damage” of more than 11% of their initial wealth encapsulated in the submitted trade orders. Contrary to the intended goal of the *short swing* or *restricted asset* rule, our experimental shows that traders trade less conservatively in market with such restriction. We attribute this to the pervasive diffusion of informed distortions. Perplexing asset adjustment and *price signals* give rise to the growing presence of rational speculators, which in turn heighten the presence of price-destabilizing forces in market with holding rule. Price convergence process is hindered by trade proposals further from the fundamentals, and this eventually exacerbates the extent of mispricing.

Table 1.12. Potential Loss (*PL*) of Traders

Treatment	Aggregate <i>PL</i> (%)			
	mean	sd	min	max
<i>NO DISC</i>	3.48	4.85	0	35.11
<i>DISC</i>	6.42	11.77	0	75.20
<i>HOLDING</i>	11.33	17.65	0	95.40
Mann-Whitney	<i>p</i> -value	n		
<i>H0: NO DISC = DISC</i>	0.16	132		
<i>H0: DISC = HOLDING</i>	0.032	132		
<i>H0: NO DISC = HOLDING</i>	0.001	132		
Kruskal-Wallis χ^2	12.547			
<i>p</i> -value	0.0019			

Result 6 summarizes how the market responds to the changes in the price predictability, and affects the aggregate mispricing:

Result 6: *Holding rule scales up the influence of the traders who speculate, and spurs the growth of loss-generating trade proposals generated in the market. This sustains the price-destabilizing forces and aggravates asset mispricing in market with reselling constraint.*

1.4.5. Income Distribution between Informed and Uninformed Agents

Figure 1.2. Within-Group Average of Insider's Earnings Relative to Outsider's Earnings

In the last section, we assess the income distribution among traders with disparate information. Figure 1.2 presents the time series of the average earning of insiders (solid line) and outsiders (dashed line). The vertical axis measures the within-group average of the traders' wealth across all sessions in the same treatment, while the horizontal axis measures the market period. As shown in the leftmost panel of the table, the dashed grey line (*NO DISC* outsider) is higher than solid black line (insider), with the first and last period showing the only exception. The numerical result corroborates the visual impression Table 1.13 presents the ratio of within-group average of insider earnings to outsiders, with the average count in one replication taken as a unit of observation. As shown in Panel A,

informed agents accumulate 2% wealth *below* the uninformed agents, and the difference is statistically significant¹².

The finding is intriguing because we would expect informed traders to amass superior income over the outsiders (as shown in the many empirical studies). Empirical regularities from the data of insiders' asset inventories, however, provide a plausible explanation. Recall that both insiders and outsiders receive identical set of wealth at the start of the replication. The best strategy to accumulate earnings is to acquire assets when the prices are below the fundamental value, and/or liquidate the assets when they are priced above the fundamental values. Extensive asset overvaluation, however, means that traders are likely to exchange assets at price above the total sum of the expected dividend earnings (they can possibly accumulate). As such, asset hoarding strategies will render financial losses to the asset owners. Given that all three markets are characterized by asset bubbles, traders who rely on capital appreciation (and depend less on dividend earnings) may actually perform better than traders depend on dividend payout.

Outsiders in *NO DISC* market are better off than the insiders because the former maintain smaller asset inventories. Indeed, as shown in Panel B of Table 1.13, insiders generally accumulate 46% more asset holdings than outsiders do. As informed agents keep larger portfolios (and enjoy higher share of the dividend earnings), they suffer opportunity costs in the form of the forgone capital appreciation realization.

The exact opposite is observed among *DISC* insiders. From the second panel of Figure 3, we can see that solid black line (*DISC* insider) is consistently higher than the dashed grey line (outsider). As insiders accumulate 16% less securities than outsiders, they also attain 4% more income than the outsiders. Such negative correlation between relative income and asset ratio is demonstrated in the correlation tests presented in Panel C of

¹² As our market only consists of two types of agents, it is not possible for the within-group average income of insiders to increase without a corresponding fall in the within-group average income of outsiders.

Table 1.13. We find statistically negative Spearman's ρ and pairwise correlation coefficients between the two variables. Accumulating relatively smaller asset inventories presents a scope for the insiders to accumulate larger share of capital appreciations, later of which certainly outweigh the dividend earnings. This in turn capacitates them to attain more superior income positions over the uninformed agents. Moreover, we also find *DISC* insiders' venture into capital gain accumulation to be a possible explanation of their suboptimal *price signals* (and asset adjustment signals). As *DISC* insiders adopt more asset liquidating strategies, they downplay the negative news and conceal the positive news more than *NO DISC* insiders.

Interestingly, an introduction of the holding rule induces the reversal of income redistribution observed in *DISC*. As shown in Figure 1.2, the solid black line (*HOLDING* insider) overlaps the dashed grey line (outsider), suggesting that *HOLDING* insiders earn almost as much as the outsiders do. The relative income standings of *HOLDING* insiders are also statistically lower than the relative income standing of *DISC* insiders (Panel A of Table 1.13). Accompanying the fall in the relative income standing is a reversal in the asset holding ratio, as *HOLDING* insiders withhold 16% more assets than the outsiders now. We infer that the erosion of capital gain comes about because of insiders' decision to return to dividend earnings strategies. Insiders can no longer take advantage of capital appreciation as much as their counterparts in *DISC* market do. Another plausible explanation is that insiders would like to realize the potential capital appreciation he has "created", but do not successfully do likewise because of the effective restriction.

Table 1.13. Relative Income Ratio and Asset Holding Pattern

(A) Ratio of Average Insiders' ECUs against Outsiders' (%)					(B) Ratio of Insiders' Assets against Outsiders' (%)				
Treatment	mean	sd	min	max	mean	sd	min	max	
<i>NO DISC</i>	98	6	85	107	146	75	77	329	
<i>DISC</i>	104	5	98	113	84	34	31	144	
<i>HOLDING</i>	100	6	89	109	116	53	63	244	
Kruskal-Wallis χ^2					6.265				
<i>p</i> -value					0.0436				

Variable 1	Variable 2	Spearman's ρ	<i>p</i> -value	Pairwise Correlation	<i>p</i> -value	n
(C) Ratio of Insiders' ECUs over Outsiders' (%)	Ratio of Insiders' Assets over Outsiders' (%)	-0.7987	< 0.0001	-0.7671	< 0.0001	36

We can see how such shift in earning preferences undermines the overall market quality. Misleading portfolio adjustment signals come about because of *HOLDING* insiders' insufficient response towards the *bad* states. Disinclination to release assets is also embodied in the price premium attached to insiders' sales, later of which plays a role in sustaining the price divergence process. Contrary to the intended goal of the *short swing* and *restricted asset* rule, introducing illiquidity constraint is actually found to jeopardize pricing efficiency in a transparent market.

From the above findings on the distribution of income between insiders and outsiders, we conclude that:

Result 7: *Insiders attain bigger share of the overall wealth, as they depart from dividend earning accumulation strategy and capitalize on capital appreciation realization in market with disclosure. Asset liquidating strategies solidify their superior income standing, as assets are valued above the total sum of the expected dividend earnings. Holding rule induces insiders to revert back to asset accumulation strategies, eroding the capital appreciation gain of insiders.*

1.5. Conclusion

The goal of our experiment is to better understand market performance under a compulsory post-trade insider trade disclosure protocol, and the interaction of the protocol with a restrictive holding rule. Information on purchases and sales by subjects who possess additional information concerning the likelihood of high dividend payment in the period are unveiled publicly in the *DISC* treatment. In the *HOLDING* treatment we also require insiders to hold recently purchased assets for two periods before being able to resell them, a novel addition to the characterization of insiders in the experiment by Sutter et al. (2012). The laboratory experiment methodology—modeled after the continuous double-auction

market of Smith et al. (1988)—allows us to overcome common identification problems, such as those concerning structural information, e.g. aggregate supply and beliefs about dividend processes, the behavioral traits of the agents, and, more importantly, the private information possessed by informed traders and the intrinsic value of assets.

The two principal results of our paper are: (i) price adjustments adhere suboptimally to the information variability in *DISC* and (ii) market prices cease to respond the adjustment in the expected asset value, aggravating the asset bubble in *HOLDING*.

We do not find evidence of a significant improvement in asset pricing efficiency with trade observability (*DISC*). Insiders' *price signals*, however, co-moves suboptimally with the actual changes in dividend outcomes, when their transactions are revealed to the uninformed agents. This undermines price predictability, and market price adjustments are less than proportional to the revisions in expected dividend values. While transparency protocol may allow outsiders to learn more about insider activities, it does not enable the outsiders to know better about the dividend outcomes. Indeed, our evidence shows that disclosure rule actually triggers the surge of informed distortion.

The decline in *insider informativess* is perhaps catalyzed by insiders' growing inclinations towards capital appreciation realization strategies. Insiders secure superior income positions over the uninformed agents as they capitalize on sales of assets priced above the total sum of the expected dividend earnings.

Asset mispricing is exacerbated and market prices cease to respond to information variation, when the holding rule is introduced (*HOLDING*). We attribute the breakdown in price predictability to a combination of inaccurate *price signals* and misleading portfolio adjustment signals sent by the insiders. Uninformed traders respond by initiating more price-destabilizing transactions, which sustain the price-destabilizing forces in the market. Insiders revert back to dividend earning accumulation strategies when they are bound by the illiquidity constraint. Ballooning proclivity to withhold assets among the informed

agents proves to be detrimental to market quality, as it induces insiders to attach price premium in their transactions in order to compensate the hedging inflexibility risk involuntary born by them.

Our findings have important implications not only for the design of informed traders and transparency protocols in the SSW model but also, more importantly, for how we might think about the role of a restrictive rule in the dissemination of insider trade information. A conflict of interest between insiders and the general public remains one of the recurring ideas in this paper. Insiders are agents with fiduciary duties to disseminate non-public information to the uninformed. Reselling constraint, however, induces informed agents to impose price concession which distorts market learning. This provides a compelling reason to address the hedging flexibility issues entailed in the rule. One way is to complement the regime with an appropriate form of executive compensation plan, in an effort to better align insiders' interests with that of the market.

Our analysis also outlines the challenge of interacting transparency protocols with illiquidity constraints. Revealing more information may actually work to the disadvantage of the market, when the uninformed mass follow the insiders too closely. This highlights the need to safeguard the transparent institutional setting from the unintended replication and amplification of price-destabilizing forces.

Lastly, augmenting the market design with a single informed agent instead of multiple insiders would be an interesting extension of our work. Another topic for future research is the introduction of multiple-period private information structure, where additional information remains useful for more than one period, in order to investigate the evolution of traders' price forecasts and information aggregation process.

1.6. Appendix

Trading Instructions

Our experiments have three different instructions sets, depending on the treatment. Below is instruction for our most comprehensive treatment that includes both element of disclosure requirement (*DISC*) and holding restriction (*HOLDING*):

General Information

You are now taking part in an interactive study on decision-making. **Please pay attention to the information provided here and make your decisions carefully. If at any time you have questions to ask, please raise your hand and we will attend to you in private.**

Please note that unauthorized communication is prohibited. Failure to adhere to this rule would force us to stop the simulation and you may be held liable for the cost incurred in this simulation. You have the right to withdraw from the simulation at any point in, and if you decide to do so your payments earned during this study will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money. The amount depends on the decisions you make.

At the end of this session, this money will be paid to you privately and in cash. It would be contained in an envelope (indicated with your unique user ID) together with a claim card acknowledging that you have been given the correct payment amount.

General Instructions

Each of you will be given a unique user ID and your **anonymity will be preserved** for the study. You will only be identified by your user ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

STAGE 1 – General knowledge questionnaire

We would like to assess your general knowledge with a series of questions, which has specific numerical answers. The following is an example of the question:

Q1) The height of Singapore Flyer (in meters)	Lower bound	<input type="text"/>
	Upper bound	<input type="text"/>

You are required to provide two numerical figures as the lower and the upper bound of an interval such that you are 90% sure that the correct answer lies within your interval.

Reward Scheme (Stage 1)

One question will be randomly selected to generate your payment. To qualify for the reward, the correct answer has to lie within your proposed interval. Intervals given by the participants will be ranked from the smallest to the largest, and six participants with the smallest intervals will be rewarded 3.00 SGD.

STAGE 2 – Decision problem

In this part of the experiment you will be asked to make a series of choices. How much you receive will depend partly on chance and partly on the choices you make. The decision problems are not designed to test you. What we want to know is what choices you would make in them. The only right answer is what you really would choose.

For each line in the table in the next page, please state whether you prefer option A or option B. Notice that there are a total of **10 lines** in the table but just **one line** will be randomly selected for payment. You do not know which line will be paid when you make your choices. Hence you should pay attention to the choice you make in every line.

Reward Scheme (Stage 2)

After you have completed all your choices, the computer will randomly generate a number, which determines which line is going to be paid.

Your earnings for the selected line depend on which option you chose: If you chose option A in that line, you will receive \$1. If you chose option B in that line, you will receive either \$3 or \$0. To determine your earnings in the case you chose option B, there will be second random draw. The computer will randomly determine if your payoff is 0 or \$3, with the chances stated in Option B.

If you have any questions, please raise your hand and we will attend to you in private.

STAGE 3 – Trading

In this experiment, we are going to create a market in which you will trade units of a fictitious asset (i.e. “shares” of a “stock”) that earn dividend every trading period.

The currency used in this market is called ECU (Experimental Currency Unit). At the end of this stage, the ECU that you have accumulated will be converted to Singapore dollars for your payment with the following exchange rate:

Your final capital	Reward
First 4800 ECU and below	2400 ECU = 1.00 SGD
Above 4800 ECU	250 ECU = 1.00 SGD

To better understand the instruction below, please refer to schematic diagram and summary page given.

Duration of the experiment

The trading will take place over 3 rounds, and each round consists of 8 trading periods. Each trading period lasts for 120 seconds.

The market will terminate at the end of each 8th trading period and a new round will begin. The remaining time left in each period will be shown on your computer screen (Box G).

Endowment of Participants

In period 1, you will start with a starting capital of 6 asset units and 4800 ECU of cash.

All your asset units and cash will expire after the 8th period and are not carried over to the next trading round.

At the start of the next trading round, your endowments will be replenished with new asset units and ECU.

The Rules of the Experimental Market

During the trading period, you may **buy** or **sell** asset unit or you may do nothing.

Two ways to buy:

1. Input a price that you are willing to pay for one asset unit as a bid (Box M) and click “Submit a Bid to Buy”. An asset unit will be bought when another participant accepts your bid, OR
2. See the List of Offers (Box D) from other participants. If you are interested to buy at the given “Lowest Offer” (Box C), click “Buy at this Price”.

Two ways to sell:

1. Input a price that you are willing to receive in return for one asset unit as an offer (Box E) and click “Submit an Offer to Sell”. Your asset unit will be sold when another participant accepts your offer, OR
2. See the List of Bids (Box L) from other participants. If you are interested to sell at the given “Highest Bid” (Box K), click “Sell at this Price”.

In order for your bid (offer) to be accepted as the Highest Bid/Lowest Offer, it must be above (below) the standing/ current Highest Bid (Lowest Offer). In addition, you must have adequate cash on hand (asset units in inventory) to submit your bid (offer).

After submitting a bid/offer, you have the option to withdraw your bid/offer by clicking on the “Withdraw Bid” (Box N) or “Withdraw Offer” (Box F) button.

Dividend Process

At the end of each period, each unit of asset in your inventory will be awarded dividend according to the dividend drawn for that period. Each dividend is drawn independently and the value of dividend drawn will only be announced at the end of each trading period. Dividends will be given out 8 times for each round.

There are 4 possible dividend values per asset unit: 0, 20, 40 and 60 ECU with equal probability of being drawn. Dividend 0 or 20 ECU equates to a ‘Bad’ state of dividend outcome while dividend of 40 or 60 ECU equates to a ‘Good’ state of dividend outcome.

Thus, the expected value of dividend drawn per period is
 $= (0 \times \frac{1}{4}) + (20 \times \frac{1}{4}) + (40 \times \frac{1}{4}) + (60 \times \frac{1}{4}) = 30 \text{ ECU}.$

It is very important to note that since asset units are not carried over to the next round, the value of the asset unit decreases over time until it reaches zero at the end of eighth period.

At the end of eighth period, only your final cash on hand are considered your final wealth!

Hence, the fundamental value of each asset unit is calculated by $k \times 30$ ECU, where **k is the number of periods remaining**. The fundamental value therefore declines from 240 ECU at the first period to 30 ECU at the beginning of eighth period to 0 ECU at the end of eighth period. Please refer to Diagram A for fundamental value table.

Trading Profit

For every period, you can gain profit from:

1. Trading asset units
2. Earning dividend from your asset inventory at the end of period.

Trading Identity

At the beginning of each experiment, you will be randomly assigned a Trading Identity. You will either be assigned as a **Normal Trader** or an **Insider Trader**, and your identity will remain the same throughout the experiment (Box H).

Insider Traders are directors who buy and sell stock of their own companies. Insiders have additional knowledge about dividend state that is not accessible to Normal Traders (Box I). This knowledge may be useful in decision making. The identity assigned to traders will remain private to other participants.

Additional Rules for Insider Traders

1. Holding

After Insider Traders buy an asset unit, they are imposed a holding restriction of 2 periods before they can sell that particular asset unit.

For example: If an Insider trader buys an asset unit in Period 1, he/she can only sell that particular asset unit in Period 3.

2. Disclosure

Insider Traders' trading activities will be disclosed to the public during the trading period and at the end of each trading period.

Information disclosed is the number of asset units bought/sold by insider traders and the corresponding trade price (Box A). Latest trade is at the bottom of the list.

Normal Traders are not subjected to Holding restrictions and Disclosure requirement.

Reward scheme (Stage 3)

At the end of the experiment, you will be rewarded based on your final capital (final cash including final dividend earnings) from one randomly drawn trading round. The amount will be converted accordingly to Singapore dollars.

Your final capital	Exchange Rate
First 4800 ECU and below	2400 ECU = 1.00 SGD
Above 4800 ECU	250 ECU = 1.00 SGD

If you have a question that was not fully answered by the instruction please raise your hand and ask the experiment monitor before proceeding.

BEWARE! YOUR EARNINGS MAY SUFFER IF YOU PROCEED INTO THE MARKETPLACE WITHOUT UNDERSTANDING THE INSTRUCTIONS!

Instruction : Fundamental Value Table

Current Period	No of periods remaining	x	Expected value of dividend per period	=	Fundamental value per asset unit
1	8		30		240
2	7		30		210
3	6		30		180
4	5		30		150
5	4		30		120
6	3		30		90
7	2		30		60
8	1		30		30
End	0		-		0

Instruction : Trading Screen

Section 3 - Trading Game

Period 1

Remaining dividend payments: **8**

Remaining cash: **ECU7410.00**

Number of tradeable shares: **9**

Number of Total shares: **9**

Number of shares on-hold: **0**

66 seconds left!

You are a **Normal Trader**

Time remaining

Your Identity

Additional info for Insiders

Message for successful trade

Insiders' trading activity:
(Latest at the top)

bought a share at ECU 210

Best Offer for you to BUY

Lowest Offer
ECU220.00

Open Offers to Sell
ECU220.00
ECU230.00

Best Bid for you to SELL

Highest Bid
ECU200.00

Open Bids to Buy
ECU200.00
ECU180.00

Submit Offer to Sell

Make an offer to **sell**

Your current offer: No offer yet

Withdraw Offer

Submit Bid to Buy

Make a bid to **buy**

Your current bid: No bid yet

Withdraw Bid

Input price to SELL

Input price to BUY

Withdraw/Cancel your existing Offer

Input price to SELL

Input price to BUY

Withdraw/Cancel your existing Bid

Submit Offer to Sell

Make an offer to **sell**

Your current offer: No offer yet

Withdraw Offer

Submit Bid to Buy

Make a bid to **buy**

Your current bid: No bid yet

Withdraw Bid

Instruction : Summary Page Screen

Section 3 - Trading Game

This screen appears for at most 20 seconds!

Period 1 has ended

Dividend payment : ECU 0.00 per share

Total Shares : 8

Total dividend earned : ECU 0.00

Current cash position : ECU5191.00

Average Price:
(Latest at the top)

Period 1- ECU 208.20

Closing price this period : ECU 205.00

Done

Insiders' trading activity:
(Latest at the top)

bought a share at ECU 205
sold a share at ECU 220
bought a share at ECU 201
bought a share at ECU 205
bought a share at ECU 210
sold a share at ECU 210

Total Shares sold by insiders: 2 Shares

Total Shares bought by insiders: 4 Shares

Chapter 2. Consumption Smoothing and Price Predictability with Heterogeneous Traders in Experimental Asset Markets

2.1. Introduction

Asset markets are an integral part of modern economies. The reason for engaging in trade might differ across individual investors. Some of them might exchange assets in the pursuit of pure capital gains: buying at low prices and selling at higher prices. Others might use asset markets to generate a smooth stream of intertemporal consumption that would help cushion income fluctuations over time. That is, they buy assets when income is high, and sell them (to generate cash) when income is low.

The idea of consumption smoothing features prominently in the Permanent Income Hypothesis (Friedman, 1957). In the presence of transitory changes in income, people would want to attain more stable path of consumption by consuming only a fraction of their current income and allocating their remaining income on precautionary activities. There are many ways in which people do precautionary activities. They may, for example, place their remaining income on saving and deposit. Alternatively, they may also invest their remaining income in security market and utilize the security returns to boost their consumption when experiencing a negative income shock.

This paper focuses on the role of stock trading as a consumption smoothing instrument. Specifically, we are interested in answering the following set of questions. First, do asset prices deviate from the intrinsic value of the underlying asset? If so, would the deviation be the same across markets populated with varying proportion of agents with differing trading motives, where some of them primarily want to smooth consumption, and others want to

engage in speculation? Second, would consumption smoothing ability of agents with the income fluctuations be affected by the composition of agents with differing trading motives in the market? Third, to the extent that the aggregate output is predictable, do asset prices have a predictable component as well? Lastly, is it possible to link the extent of price predictability to the number of agents with the income fluctuations?

In order to answer these questions, we design an experimental asset market that is close to the setting used in the consumption-based general-equilibrium asset-pricing literature (Stiglitz, 1970; Lucas, 1978; Breeden, 1979). Knowing the answers to these questions would provide insights into which naturally occurring markets are more prone to mispricing, and might provide rationale for what contributes to price predictability.

We consider an environment with an indefinite horizon economy, a single perishable consumption good, and a long-lived asset. While laboratory markets are much simpler in structure than the actual markets (and thus studying them may not address some of the questions that are important to the applied researchers), they provide an invaluable controlled setting where certain hypotheses can be empirically tested and confounding factors can be isolated. The endowments, income processes, as well as the dividends paid by the asset are perfectly observed in the experiments. Deviations in prices due to the variation in the underlying dividend process can be computed with precision, and we can compare this measure across different markets. Uncertainty with regards to the dividend paid by the asset or the actual valuations can be introduced into and removed from an environment in which other factors are held constant.

There is a vast experimental literature that significantly enhances our understanding of price formation in markets. Early studies, including Plott et al. (1982), Forsythe et al. (1982), Friedman et al. (1984) motivate agents to trade by providing heterogeneous dividend values. They find that market prices effectively aggregate private information about dividends, and tend to converge toward rational expectations values. Smith et al.

(1988) introduce a particular class of asset market that tends to generate price bubbles¹³. Researchers had shown that the phenomenon of asset price bubble is robust to a variety of changes in the market structure (see King et al., 1993; Van Boening et al., 1993; Porter and Smith, 1995; Caginalp et al., 1998; Lei et al., 2001; Dufwenberg et al., 2005; Haruvy and Noussair, 2006; Haruvy et al., 2007; Hussam et al., 2008; Kirchler et al., 2012)¹⁴. In all of these studies, a market is created for a dividend-paying asset with a lifetime of finite periods, and the asset structure is common knowledge. The volume of trade is substantial, and a sustained duration of prices that greatly exceed the fundamentals (before finally crashing near the end of the experiment) is the typical empirical pattern observed. Another strand of experiments studies the static capital asset pricing model with only asset-derived income and no labor/endowment income (Bossaerts and Plott, 2002; Asparouhova et al., 2003; Bossaerts et al., 2007).

In our experiments, several participants are motivated to engage in trade, to offset income fluctuations they face over time. Thus, the primary reason for exchange in our setting is mainly for consumption smoothing - a feature we find largely unexplored in the experimental asset pricing literature, except in two recent papers by Asparouhova et al. (2016) and Crockett and Duffy (2015). Both studies implement multiple periods and indefinite horizon setting. Asparouhova et al. (2016) induce preference for consumption smoothing by paying only for the last period, forfeiting payments in all periods that end not being terminal. The perishable nature of payments (cash) is meant to capture the notion that the remaining cash (not used as medium of exchange) must be spent solely on consumption in that period - an important feature of the consumption-based general-equilibrium dynamic asset-pricing framework. In an alternative way of inducing

¹³ A bubble is typically defined as "trade in high volumes at prices that are considerably at variance from intrinsic values". This definition is given by King et al. (1993).

¹⁴ For a review of the literature, see Sunder (1995) or Duxbury (1995) as well as chapters 29 and 30 in Plott and Smith (2008).

consumption smoothing, Crockett and Duffy (2015) impose a schedule of final payments to participants that is non-linear in the period earnings.

To keep the analysis and the design simple, traders are told about the exogenous uncertainty (the dividend process). They know about the income shock in each period and must learn to take into consideration the endogenous uncertainty (the price process) while trading. We further simplify the setting by having only one security market open in any session. Cash plays a dual role within a period: as medium of exchange and as consumption good. While cash is perishable at the end of an interim period, the assets are long-lived and are the only intertemporal store of value. Similar to Asparouhova et al. (2016), we pay participants only for the cash in the last period, to mimic the perishability of money. Motivation for trade is provided to certain participants by making their income process variable over time. Other traders are insulated from income shocks, through constant flow of exogenous income at the start of each period.

This paper contributes to the literature in several ways. Unlike Asparouhova et al. (2016) and Crockett and Duffy (2015), we depart from the focus on testing the predictions of the Lucas model (1978). Instead, we introduce another type of traders with constant income vis-à-vis those with income fluctuations. This enables us to observe the behaviors of traders without the induced motive, later of which are more representative of the market outside the laboratory. To the best of our knowledge, this paper is the first to study the impact of the different proportion of traders with the induced motive, more specifically with regards to the role of traders insulated from income shocks. Secondly, we add another dimension by varying the initial asset endowments of the traders, to obtain insights on how portfolio adjustment decisions affect the consumption smoothing activities of the individuals. Thirdly, we also investigate the implications of dividend uncertainty and price uncertainty. The result is expected to complement the analysis of asset pricing from the usual settings with stochastic dividend and market-determined prices.

Another major departure (from the previous two studies) is the fact that we now investigate asset markets that are incomplete (in addition to our complete markets). Previous papers only deal with complete market setting: Crockett and Duffy (2015) consider markets with only one asset and no fundamental risk, while Asparouhova et al. (2016) have two assets and two states of nature.

We present several results. First, we find that the asset is overpriced compared to the risk-neutral fundamental value, in all our sessions. In the presence of constant income traders, the extent of overpricing is higher and the variability of prices is larger. Second, prices co-move with the underlying dividend state of the asset. We find strong evidence that prices have a significant predictable component, in all our treatments. Close to 50% of the variation in prices can be explained by the changes in the dividend state, in the presence of agents with income fluctuations. Third, traders with the induced motive are naturally aware of the need to mitigate income variation across periods, through trading. We observe gentler consumption undulations among these types of agent. Traders with constant stream of earnings do not show signs of such behavior. One certain subset of traders without income variability is able to exploit the predictability of prices, by acquiring (releasing) when everyone else release (acquire) the shares. In sessions where we fix the price and let agents exchange assets with the experimenter (instead of engaging in an actual transactions with other traders), individuals show preference for more equitable consumption not only over time but also across dividend states.

The remainder of the paper is organized as follows. Section 2.2 reviews the related background research and discusses questions that we ask in our study. In section 2.3, we describe the design and procedures of the experiment. Section 2.4 and 2.5 presents the data and summarizes our findings, respectively.

2.2. Background

The experiment is designed specifically to answer four questions related to price dynamics, price predictability, and consumption smoothing behavior in asset markets. Asparouhova et al. (2016) and Crockett and Duffy (2015) have already provided us with the framework to induce consumption smoothing activities in the laboratory. Both document considerable support for the predictions of the consumption-based general-equilibrium models of dynamic asset pricing. Specifically, Asparouhova et al. (2016) find results that are consistent with the most important predictions of the Lucas intertemporal pricing model (Lucas, 1978). Agents trade to level consumption and insure against risk, and there exists a counter-cyclical equity premium. They also report that prices are excessively volatile¹⁵. As opposed to the model, which predicts that changes in the dividend state should explain 100% of price changes, they find the corresponding value to be merely 18%. In markets with a single non-stochastic dividend-paying security, Crockett and Duffy (2015) report evidences supporting the claim that the frequency, magnitude, and duration of asset bubbles can be abated by the presence of an incentive to intertemporally equalize consumption in an otherwise identical economy.

Real market is likely to be populated with individuals where some of them trade in the pursuit of capital gains, while others use the institution primarily to offset income fluctuations. With the hope of mimicking such environment, we design treatments where the number of traders with income undulations is systematically varied. Our first question looks into the impact on the asset price dynamics, including the magnitude of price changes and the determinants of this variation. We also investigate whether prices deviate from intrinsic values.

¹⁵ The term *excessive volatility* is used to denote the fact that a large fraction of price movements is unrelated to the changes in the underlying dividend state (LeRoy and Porter, 1981; Shiller, 1981).

RESEARCH QUESTION 1: Do differences in the price dynamics across markets depend on the proportion of agents with the induced motive (to offset the income fluctuations)?

The sufficient amount of control in our experiments allows us to contribute to the debate on whether market efficiency and price predictability can co-exist in asset markets. The original account of the Efficient Market Hypothesis states that prices must not be predictable (Samuelson, 1973; Malkiel, 1999); investors would trade to exploit the predictability and in the process eliminate it. Using historical data from the field, several studies have documented that prices have a significant predictable component (Campbell and Shiller, 1988; Fama and French, 1988; Lo and MacKinlay, 1988; Bernard and Thomas, 1989; Fama, 1990).

The phenomenon of price predictability has been explained primarily in terms of cognitive biases in investor decision making (De Bondt and Thaler, 1985; Daniel et al., 1998; De Long et al., 1990). Another potential explanation is that the correct general equilibrium model of asset returns is consistent with the variation of returns over time. Extending the Lucas (1978) framework, Balvers et al. (1990) and Cecchetti et al. (1990) build models that demonstrate that predictability is not inconsistent with the concept of efficient markets. They argue that the interplay between consumption smoothing and risk correction can generate mean-reverting behavior of stock returns. In an effort to maximize expected utility, investors attempt to smooth consumption by adjusting their required rate of return for financial assets. The main message from these intertemporal models is that stock returns can be anticipated, to the extent that there is predictability in the endowment process. Because we can perfectly control and observe the endowment process in laboratory markets, we can compute measures of predictability with greater precision. More importantly, we can compare this measure across different composition of consumption smoothers. This constitutes our next research query.

RESEARCH QUESTION 2: Are prices predictable, in the sense that changes in the dividend state explain the variations in price? Is price predictability higher in markets where traders participate in asset trading primarily to smooth consumption?

The next question is concerned with the behavior of traders in heterogeneous markets (with both representatives of subjects with and without constant income). We expect that traders who face income variability would attempt to smooth their consumption stream, by taking part in the market activity. Lower trading volume is expected out of agents with constant income, and they are more likely to engage in speculative trades than the ones with income variations. It is also possible that certain traders are able to make use of this predictability for their own benefit. We seek to identify the characteristics of these traders as part of the third question.

RESEARCH QUESTION 3: In markets where different types of traders co-exist, do we see a clear difference in consumption smoothing and trading behavior of agents with different income patterns? Are there traders who are able to exploit the feature of price predictability in markets for their own benefit?

There are several sources of uncertainty in our setup. Our last question is aimed at understanding the effect of price uncertainty. To achieve this, we design a treatment where participants only engage in exchange of securities at fixed prices with the experimenter who acts as an intermediary. Thus, there is no asset market in the strict sense. The setting collapses to that of individual-choice, and presents subjects with the simplest of environments. The economy is still indefinite-horizon, and cash remains perishable at the end of a period to provide sufficient incentive for agents to smooth consumption.

RESEARCH QUESTION 4: Does a simpler environment where asset price uncertainty is absent, results in a different strategy being used by agents with respect to their consumption smoothing behaviors?

2.3. Experimental Design and Procedure

2.3.1. General Structure

The data for this study are gathered from 15 experimental sessions conducted at the Nanyang Technological University (NTU), Singapore. There are 16 participants in each session, except one session with only 14 participants. Thus, we have a total of 238 participants in this experiment. Subjects are undergraduate students recruited from various schools such as Humanities and Social Sciences, Business, Engineering, and Sciences; and they participate in at most one session. The sessions last approximately two hours and participants earn on average S\$24.20 in addition to a show-up fee of S\$2¹⁶.

We implement an indefinite horizon economy with a single perishable consumption good in each period. The standard procedure (Camerer and Weigelt, 1996) is used to randomly determine whether a period is terminal. At the end of each period, a six-sided die is rolled in public view of all participants. If the die roll is 6, we terminate the economy; otherwise, we continue to the next period. Thus, we have an indefinite horizon economy with a constant termination probability of $\frac{1}{6}$ per period. This ending procedure induces discounting with a discount factor equal to the probability of continuation. Assuming that subjects are expected utility maximizers with time-separable preferences, a stochastic ending time is (theoretically) equivalent to discounting over an infinite time horizon.

In the experiment, the consumption good is represented by cash which is "made" perishable in each period. That is, at the end of every non-terminal period, any remaining cash holdings disappear. Only cash held at the end of the randomly determined terminal period is credited to participant's final payout account (and hence "consumed"). Thus, we

¹⁶ Payoffs, inclusive of the show-up fee, range from S\$2 to S\$70.80 with a standard deviation of S\$11.64.

do not literally have consumption every period; participants in our experiments face the same optimization problem as if they actually have to consume every period.

We also implement the following termination protocol introduced in Asparouhova et al. (2016). It is announced that the experimental session would last until a pre-specified time and there would be as many replications of the economy as could be fit within the time limit. If a replication ends at least ten minutes before the announced ending time of the session, a new replication will begin; otherwise, the experimental session will end. If a replication still runs ten minutes prior to the indicated ending time of the session, we announce before the market opens that the current period would be either the last one (if the die turns up 6) or the next-to-last one (if the die turns up 1-5). This termination rule ensures that the laboratory economy is stationary¹⁷.

Table 2.1. Types of Traders, Exogenous Income, and Initial Assets

Agent Type	Exogenous Income (ECUs)	Initial Asset (units)
I	0 in odd periods, 15 in even periods	20
II	15 in odd periods, 0 in even periods	5
III	7.5 in odd and even periods	20
IV	7.5 in odd and even periods	5

The asset is long-lived and carried forward to the next period if the current period is non-terminal. In the event that the current period turns out to be terminal, all securities expire (or become worthless). Participants in our experiment belong to one of the four types of traders as mentioned in Table 2.1. The table summarizes the types of traders,

¹⁷For a detailed discussion on the termination protocol, see Asparouhova et al. (2016). They show that the termination rule produces pricing as if the economy is to continue infinitely.

traders' exogenous income at the beginning of a period, and traders' initial endowment of assets at the beginning of a replication.

Table 2.2. Summary of the Experimental Sessions

Session	Treatment	Number of Replications	Number of Periods (Total within Session, Minimum, Maximum)	Subject Count by Type of Trader (Type I, II, III, IV)
1	Baseline (<i>BL</i>)	3	(22,2,12)	(8,8,0,0)
2	Baseline (<i>BL</i>)	3	(17,1,13)	(8,8,0,0)
3	Baseline (<i>BL</i>)	3	(17,1,9)	(8,8,0,0)
4	Constant Income (<i>CI</i>)	6	(20,1,7)	(0,0,8,8)
5	Constant Income (<i>CI</i>)	2	(19,7,12)	(0,0,8,8)
6	Constant Income (<i>CI</i>)	1	(16,16,16)	(0,0,8,8)
7	Mixed Market (<i>MM</i>)	3	(23,3,11)	(4,4,4,4)
8	Mixed Market (<i>MM</i>)	1	(10,10,10)	(4,3,3,4)
9	Mixed Market (<i>MM</i>)	4	(18,1,13)	(4,4,4,4)
10	Constant Dividend (<i>CM</i>)	4	(20,3,7)	(8,8,0,0)
11	Constant Dividend (<i>CD</i>)	4	(19,3,7)	(8,8,0,0)
12	Constant Dividend (<i>CD</i>)	4	(19,2,8)	(8,8,0,0)
13	Fixed Price (<i>FP</i>)	5	(20,1,9)	(8,8,0,0)
14	Fixed Price (<i>FP</i>)	2	(14,4,10)	(8,8,0,0)
15	Fixed Price (<i>FP</i>)	2	(18,2,16)	(8,8,0,0)
Total		47	(272,1,16)	238

We can see that the characteristic of a trader differs across two dimensions. The first dimension is whether he starts out with a relatively larger endowment of assets (asset-rich) or smaller endowment (asset-poor). Type-I and Type-III are *asset-rich* while Type-II and Type-IV are *asset-poor*. The second dimension is the nature of the income shock received in each period. Type-I and Type-II traders receive positive income every alternate period. On the other hand, Type-III and Type-IV traders do not experience any income fluctuations across periods. Participants only know their own endowment of assets and the process of income shocks; they are not informed about the others' characteristics.

We vary the number of the different types of traders in each session¹⁸. Summary information about each session is given in Table 2.2. For each session indexed by identification number in the first column, the table indicates the treatment in effect and the number of replications (along with the number of periods). The parameters (initial endowment of assets, income shock each period, etc.) and the numbers of different types of traders per session are chosen to ensure that the aggregate amount of cash from income shocks and the total number of assets in the economy remain constant across periods and sessions^{19 20}.

All accounting is done in Singapore Dollars. The market is computerized and uses continuous double auction trading rules (Smith, 1962) implemented with the *z-Tree* computer program (Fischbacher, 2007)²¹.

2.3.2. Experimental Procedure

Upon arrival, subjects are seated at visually isolated computer stations. Instructions are read aloud and subjects receive a copy of the printouts²². Participants familiarize themselves with the key aspects of the open-book double auction mechanism (placing bids and asks, order cancellations, the transaction determination protocol, etc.) through one mock replication during the instructional phase of the experiment. Activity during the mock replication does not count toward final earnings.

After the instructional phase is completed, the paid phase of the experiment begins with the first replication of the economy. Agents receive their initial endowments of the

¹⁸ We elaborate on this issue later (subsection 2.3.3) when we discuss the various treatments implemented by us.

¹⁹ The exact amount of cash in the economy consists of cash from income shocks plus cash from dividends obtained from the securities. Thus, depending on the realization of the dividend, the exact cash varies across periods.

²⁰ Except in sessions 8 and 13-15. This is because we only had 14 traders in session 8. The number of assets per-trader is a constant in sessions 1-12. On the other hand, the number of assets in the economy (as well as per-trader) is not fixed for sessions 13-15, as they belong to a treatment that is fundamentally different from the rest. Please refer to subsection 2.3.3 for details.

²¹ Trading takes place through anonymous, electronic continuous open book system.

²² A sample copy of the instruction is provided in the Appendix.

asset and cash. The market unfolds period by period and each such period has $\frac{1}{6}$ probability being terminal. Subject then enters a new period with: (i) asset holding from the preceding period, (ii) cash (in the form of income) which magnitude vary according to the prevailing pattern of income shock, and (iii) the dividend earnings. One period lasts for three minutes, within which all subjects are free to purchase and sell units of the asset at any time provided that they do not violate the short-selling (negative holdings) constraint. If engaging in a trade violate either the short sale or cash balance constraint, the computer program will prohibit individuals from doing so²³. Termination uncertainty is resolved at the conclusion of each period, after subjects establish their assets and cash holdings for that period.

We can see that subject is essentially faced with a problem of how to re-distribute his wealth across cash and assets in each period - knowing that there is a $\frac{1}{6}$ chance that the replication would end that period, at which point he would earn the cash held but the assets in the portfolio will become worthless. At the same time, there is a $\frac{5}{6}$ probability that the economy moves to a subsequent period. The subject forfeits his cash as it is perishable (it will not be carried forward to the new period), but are allowed to carry the assets which will generate new cash (in the form of dividend earnings) in the new period.

We run as many replications as possible within the time allotted²⁴. Whenever a replication is terminated and there is still time left in the session, we initiate a new replication. Thus, the termination protocol is only applied to at most one of the replications in a session. If a replication ends naturally (i.e. through the roll of the die) close to the ten minute mark before the end of a session, we do not start a new replication. We pay subjects for two of the replications, randomly chosen after the conclusion of the experiment. If a

²³ No borrowing and/or short sales are standard restrictions in asset market experiments.

²⁴ Following completion of the last replication, subjects also participate in the standard risk-elicitation task (Holt and Laury, 2002).

session ends with exactly two replications, then we pay for both. If a session only has one replication, we pay two times the earnings from this sole replication.

2.3.3. Treatments

We implement five (5) treatments and conduct three (3) sessions for each of them. Table 3 summarizes all five treatments. We refer to sessions 1-3 as the *Baseline (BL)* treatment. In each session, half of the individuals are assigned the role of Type-I trader and the other half are assigned the role of Type-II trader. Thus, each subject has an induced motive to trade in order to offset the income fluctuations. A single long-lived asset is available for trading in the marketplace that pays, in each period, a stochastic dividend of 1 ECU when the state of nature is good, and 0 ECU when the state of nature is bad. The states are equally likely and the dividends are common for all units and subjects.

The composition of the experimental sessions is shown in Table 2.2. Sessions 4-6 constitute the *Constant Income (CI)* treatment and sessions 7-9 constitute the *Mixed Market (MM)* treatment. In the *CI* sessions, half of the traders are assigned the role of Type-III trader and the other half are assigned the role of Type-IV trader. The *MM* sessions have four traders of each type²⁵. Thus, in the *BL* sessions, 100% traders have an induced motive to smooth consumption. In contrast, this percentage is only 50% for *MM* sessions and 0% under *CI* treatment. A comparison of these three treatments allows us to investigate the effect of market heterogeneity on asset mispricing, price movements across periods, and consumption smoothing behavior.

²⁵ The sole exception is session 8, where we recruit only 14 subjects. There are seven traders having income fluctuations across periods while seven had constant income each period. So, the proportion of traders in the market with induced motive to smooth consumption across periods is still 0.5.

Table 2.3. Summary of the Treatments

Treatment	Composition of Agent Types	Dividend per share (ECUs)	Asset Price (ECUs)
Baseline (<i>BL</i>)	I, II	0 or 1 (equal probability)	Market Determined
Constant Income (<i>CI</i>)	III, IV	0 or 1 (equal probability)	Market Determined
Mixed Market (<i>MM</i>)	I, II, III, IV	0 or 1 (equal probability)	Market Determined
Constant Dividend (<i>CD</i>)	I, II	0.5	Market Determined
Fixed Price (<i>FP</i>)	I, II	0 or 1 (equal probability)	2.5

Constant Dividend (CD) treatment comprises of the sessions 10-12. These sessions are similar to the *BL* sessions except that the long-lived asset available for trading pays a constant dividend of \$0.50 per period (instead of a stochastic dividend). Given that the expected dividend is the same in *BL* and *CD* sessions, a direct comparison between these two treatments enables us to study how dividend uncertainty affects asset price dynamics and consumption smoothing behavior. The number of world outcomes and security units available for trading in *CD* market are equal. Unlike the other treatments, *CD* is therefore the only complete market in our setting.

Sessions 13-15 constitute the *Fixed Price (FP)* treatment. These sessions are similar to the *BL* sessions except that we eliminate the price and liquidity uncertainty of the asset. Participants are able to buy or sell the asset to the experimenter at a fixed market price of 2.5 ECUs²⁶. This price corresponds to the risk-neutral fundamental value at any instant. This is because the asset is long-lived in an infinite horizon economy with a discount factor

²⁶ Provided that they do not violate the short sale or positive cash balance constraints.

of $\frac{5}{6}$. Thus, if a trader holds a unit of the asset today, it is worth $(0.5)\left(\frac{5}{6}\right) + (0.5)\left(\frac{5}{6}\right)^2 + \dots = (0.5)\left(\frac{5}{6}\right)\left(\frac{1}{1-\frac{5}{6}}\right) = 2.5$ ECUs in terms of the expected payoff.

We do note that constant prices are not realistic. Nevertheless, by running *FP* treatment, we are able to isolate the influence of price uncertainty on trading activities. This allows us to study whether: (a) subjects show preferences for consumption smoothing in the simplest trading environment and (b) they engage in consumption smoothing more vigorously. Thus, this treatment essentially serves as our litmus test to ensure that our subjects fully grasp the need to smooth consumption, when experiencing income shocks. Note that in *FP* treatment, the uncertainty with respect to the dividend in each period remains as the asset pays a stochastic dividend. The uncertainty with respect to the planning horizon due to the indefinite horizon economy is still present as well. We keep these two features of uncertainty intact to facilitate comparison with our baseline treatment.

To summarize, every replication has the setting of an indefinite horizon economy with a single perishable consumption good in each period. Thus, there is uncertainty regarding the planning horizon in all treatments. *BL*, *CI*, *MM* and *FP* sessions are characterized by dividend uncertainty due to the presence of the risky asset. In contrast, *CD* sessions have a risk-free security which pays a constant dividend each period. Uncertainty about future prices is present in all treatments except *FP* sessions. Finally, all traders in treatments *BL*, *CD* and *FP* have income fluctuations across periods, while only half of the (zero) participants experience income fluctuations in *MM* (*CI*) treatment.

Treatment *BL*, *CI* and *MM* are designed to address our first three research questions, whereas treatment *FP* is needed to answer the fourth question. For analysis on the impact of dividend uncertainty on prices and consumption smoothing behavior, we implement the *CD* treatment. This also allows us to understand the differences in the characteristics of

price and consumption smoothing between a complete market (*CD*) and an incomplete market (*BL*).

2.4. Experimental Results

In this section, we present the most prominent empirical patterns observed in our experimental data. We start off by reporting the evidences of consumption smoothing behaviors exhibited by our subjects in subsection 2.4.1. While subsection 2.4.2 compares asset price dynamics across treatments, subsection 2.4.3 analyzes the factors affecting the price swings between trading periods in each treatment. Findings on trading volume and activity across treatments are documented in subsection 2.4.4. The final subsection provides observations with respect to consumption smoothing and trading strategies across different types of traders.

2.4.1. Consumption Smoothing across Periods

Figure 2.1 plots the evolution of the average consumption for each type of trader. In the figure, the vertical axis measures the average cash (ECUs) withheld at the end of each period, with concatenated replications within a session. On the other hand, the horizontal axis is the market period. As shown across all panels, the wavelike patterns of the solid lines for Type-I and II traders (actual consumption captured in our data) are visibly gentler than the dotted lines (the estimated consumption under autarky (assuming that they do not engage in asset exchanges at all))²⁷. This implies the successful attempt of both Type-I and II traders in offsetting the income fluctuations. In contrast, the solid lines for Type-III and

²⁷ The autarky values for consumption of different types of agents depends on the states, except in *CD* sessions. We use the sequence of realized states across all the sessions to compute their autarky consumption.

IV traders track the dotted lines closely, suggesting that traders with constant income do not appear to engage in consumption smoothing.

Figure 2.1. Average Consumption (against Autarky) for each Type of Trader

The visual observation is corroborated by the Wilcoxon signed-rank test outcome of the difference in the actual and the autarky consumption in Table 2.4. Here, we take average count per individual trader taken as a unit of observation²⁸. Regardless of the characteristic of the market, the (absolute) intertemporal differences in the actual final ECUs of Type-I and Type-II, are statistically smaller than that under autarky (p -values < 0.05 in *BL* and *MM*, and > 0.01 in *CD* sessions). In contrast, the difference in consumption of traders with constant income is not statistically significant. It can be seen that the numerical entries are supportive of the idea that Type-I and Type-II traders experience less

²⁸ To compute these differences, we ignore replications which last only for one period.

variation in their actual consumptions when they trade, even as they receive fluctuating initial incomes across periods.

Table 2.4. Difference in the Average Consumption (ECUs) across Odd and Even Periods

Treatment	Type of Trader	Trade	Autarky	Signed Rank p -value (H_0 : Trade=Autarky)	n
<i>BL</i>	Type I	-2.98	-10.84	< 0.0001	24
	Type II	8.18	16.04	< 0.0001	24
<i>CI</i>	Type III	4.68	5.46	0.250	24
	Type IV	2.15	1.37	0.350	24
<i>MM</i>	Type I	-4.00	-11.74	0.002	12
	Type II	6.13	15.98	0.003	11
	Type III	2.58	3.92	0.210	11
	Type IV	3.32	0.81	0.020	12
<i>CD</i>	Type I	-5.36	-15.00	< 0.0001	24
	Type II	5.36	15.00	< 0.0001	24
<i>FP</i>	Type I	-2.58	-10.00	< 0.0001	24
	Type II	0.95	16.25	< 0.0001	24

Recall that subjects in our setting can only perform precautionary activities through the exchanges of securities. Table 2.5 presents the net changes in assets across even and odd periods, with the average count per individual taken as a unit of observation. Consistent with the evidence from the average consumption, Type-I traders are net buyers in even and net sellers in odd periods. They accumulate assets when the income shock is positive and releases assets when there is no income. A completely opposite but mirroring arrangement pattern (net buying in odd and net selling in even periods) is exhibited by the Type-II agents. It is interesting to note that a more clearly defined portfolio adjustment strategy is shown by both Type-I and Type-II traders in *CD* and *FP* sessions (than *BL* or *MM* sessions), suggesting that subjects with income fluctuations are better able to attain stable consumption in the absence of dividend or price uncertainty.

Table 2.5. Net Change in Asset Holdings (Units) across Periods

Treatment	Trader Type	Period		Signed Rank p -value	n
		Even	Odd		
<i>BL</i>	Type I	0.87	-0.79	< 0.0001	24
	Type II	-0.87	0.79	< 0.0001	24
<i>CI</i>	Type III	-0.20	-0.05	0.49	24
	Type IV	0.20	0.05	0.48	24
<i>MM</i>	Type I	0.49	-0.89	0.0031	12
	Type II	-0.82	0.88	0.0033	11
	Type III	-0.15	0.07	0.40	11
	Type IV	0.40	0.02	0.012	12
<i>CD</i>	Type I	1.03	-1.30	< 0.0001	24
	Type II	-1.03	1.30	< 0.0001	24
<i>FP</i>	Type I	1.09	-1.68	0.0001	24
	Type II	-2.48	3.33	< 0.0001	24

Looking into agents with constant income, we do not find evidences of portfolio adjustments serving consumption smoothing purposes. Indeed, Type-III agents (who are *asset-rich*) are net sellers of assets in *both* even and odd periods. Interestingly, Type-IV agents (who are *asset-poor*) accumulate securities over time. This suggests that Type-IV traders are predominantly net purchasers of assets. The difference in the actual consumption of Type-IV traders in *MM* treatment under trading is statistically *higher* than under autarky (p -value <0.05, Table 2.4). In other words, the gap between the actual consumption in odd and even periods for Type-IV traders in *MM* is larger under trading than under autarky. We infer that this points to what could plausibly be anti-consumption smoothing behaviors among the Type-IV agents. As understanding the phenomenon requires insights of the market price dynamics, we will revisit the anti-consumption smoothing behaviors after the following analysis on asset mispricing and price predictability.

The main finding with respect to consumption smoothing conduct is summarized in the following result:

Result 1: *We find evidences that traders with income fluctuations in alternating periods smooth consumption over time.*

2.4.2. Transaction Prices across Treatments

Figure 2.2 displays the evolution of the mean prices by the experimental sessions in each treatment. In the figure, the vertical axis measures the average transaction price, concatenated over replications within a session. The horizontal axis demonstrates the number of periods recorded in the corresponding session. It can be seen that the time series graphs of the mean price in all four panels thread above the 2.5 ECUs threshold, indicating that traders generally value assets above the risk-neutral fundamental values in all treatments. The visual impression is also confirmed by the numbers reported in Table 2.6, where the average magnitude in one replication is taken as a unit of observation. Traders exchange assets at average price of 4.8, 3.6, 5.3, and 4 ECUs in the *BL*, *CI*, *MM* and *CD* markets respectively. All prices are statistically distinct from 2.5 ECUs, suggesting the presence of asset overvaluation in all treatments.

Figure 2.2. Time Series of the Average Transaction Prices per Period

Table 2.6. Average Transaction Prices across Treatments (ECUs)

Treatment	Average Price				Signed Rank p -value (H_0 : Price = 2.5)	n
	mean	sd	min	max		
<i>BL</i>	4.83	2.12	2.84	8.28	0.008	9
<i>CI</i>	3.55	1.17	2.92	5.64	0.008	9
<i>MM</i>	5.32	0.83	4.35	6.85	0.012	8
<i>CD</i>	3.96	0.95	2.73	5.25	0.002	12
Kruskal-Wallis χ^2	9.592					
p -value	0.0224					

To facilitate comparison of asset bubble across treatments, we measure the relative deviation of the mean and the median prices from the risk-neutral fundamental value:

$(\bar{P}_t - FV_t)/FV_t$ and $\tilde{P}_t - FV_t$, where $\bar{P}_t$ is the mean price in period t , FV_t is equal to the risk-neutral fundamental value of 2.5 ECUs and $\tilde{P}_t$ is the median price in period t . We

perform panel regressions of these bubble measures on treatment dummies and the average aggregate risk aversion, with replications as cross sections and periods as observations over time. Following Sutter (2012), the robust standard errors of Beck and Katz (1995) are employed to account for potential correlations within each replication and potential heteroskedasticity across replications. *BL* treatment serves as the baseline category in Table 2.7.

Table 2.7. Panel Regression of Mispricing Measurements

Explanatory Variables	$(\bar{P}_t - FV_t)/FV_t$	$\tilde{P}_t - FV_t$
<i>Constant Income</i> Treatment Dummy	0.0726** (0.0299)	0.178** (0.0711)
<i>Mixed Market</i> Treatment Dummy	0.0760*** (0.0154)	0.193*** (0.0277)
<i>Constant Dividend</i> Treatment Dummy	0.00974 (0.0420)	0.0221 (0.0931)
Market's Avg. Risk Aversion	-0.00758 (0.0269)	-0.0306 (0.0300)
Period	0.00292 (0.00522)	0.00939 (0.0122)
$(\bar{P}_t - FV_t)/FV_t$ (-1)	0.921*** (0.0243)	
$\tilde{P}_t - FV_t$ (-1)		0.924*** (0.0216)
Constant	0.0548 (0.108)	0.193 (0.158)
Number of Observations	182	182
R ²	0.874	0.872
Number of Markets	33	33

Panel regressions with replications as cross sections and periods as observations over time. $(\bar{P}_t - FV_t)/FV_t$ (-1) and $\tilde{P}_t - FV_t$ (-1) are dependent variables lagged by one period, where $\bar{P}_t$ and $\tilde{P}_t$ are the average and median market price at period t, respectively. To account for potential correlations within each replication and potential heteroskedasticity across replications, the robust standard errors of Beck and Katz (1995) are employed throughout this analysis. The z-values are included in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The coefficients of *CI* and *MM* dummies are significant and positive, suggesting that asset mispricing is exacerbated when Type-III and Type-IV traders are present (after controlling for the risk aversion level in the market). On the other hand, the coefficient of *CD* dummy is not statistically significant. The negligible difference in the bubbles measures between *BL* and *CD* treatment indicates that removing dividend uncertainty does not produce significant improvement on price deviation.

Table 2.8. Trend in Bubble Measures

Treatment	$(\bar{P}_t - FV_t)/FV_t$				$\tilde{P}_t - FV_t$				n
	First pd.	Final pd.	τ	p -value	First pd.	Final pd.	τ	p -value	
<i>BL</i>	1.11	0.78	-0.08	0.4299	2.78	1.96	-0.08	0.4294	56
<i>CI</i>	0.33	0.52	0.41	< 0.0001	0.85	1.33	0.40	< 0.0001	55
<i>MM</i>	1.08	1.12	0.005	0.9674	2.76	2.88	-0.002	0.9935	51
<i>CD</i>	0.62	0.57	-0.12	0.2188	1.57	1.41	-0.12	0.2347	58
τ from test for monotonic trend.									

The difference in the pricing efficiency is also reflected in the growth pattern of the market prices. Table 2.8 presents the summary of the relative deviation of prices in the first and the final period, with the average price of each period taken as a unit of observation. We find negative Kendall τ values in treatment *BL* and *CD*, with price trending downward towards the risk-neutral fundamental value of 2.5 ECUs over time. On the other hand, the Kendall τ values are positive in treatment *CI* and *MM*, with a statistically significant evidence of positive growth in markets when all traders receive constant income. What we learn from the analysis is that the presences of traders who trade to offset their income variations are critical in facilitating the price convergence process and improving market

efficiency. Removal of the induced motive to smooth consumption stimulates transaction prices to deviate away from the fundamentals, resulting in an exacerbation of asset bubble.

The main conclusion we draw from the data with respect to transaction prices and mispricing is stated below as Result 2:

Result 2: (i) *Transaction prices are higher than the risk-neutral fundamental value in all treatments.* (ii) *The extent of the mispricing is larger in the presence of traders without induced motive to smooth consumption.*

2.4.3. Determinants of Price Movement and Price Predictability

Table 2.9. Price Adjustment across Changes in the Dividend States (ECUs)

Treatment	Change in Dividend State	mean	sd	Signed Rank p -value (H_0 : Change = 0)	n
<i>BL</i>	(1) Good-to-Bad	-0.89	0.70	0.002	12
	(2) Bad-to-Bad	-0.23	0.45	0.116	13
	(3) Good-to-Good	0.06	0.52	0.552	13
	(4) Bad-to-Good	0.61	0.26	0.008	9
<i>CI</i>	(5) Good-to-Bad	-0.41	0.75	0.084	12
	(6) Bad-to-Bad	-0.11	0.36	0.465	4
	(7) Good-to-Good	0.16	0.29	0.008	20
	(8) Bad-to-Good	0.64	0.52	0.007	10
<i>MM</i>	(9) Good-to-Bad	-0.49	0.35	0.001	14
	(10) Bad-to-Bad	-0.39	0.33	0.043	7
	(11) Good-to-Good	0.26	0.51	0.046	13
	(12) Bad-to-Good	0.77	0.48	0.008	9

We examine how mean prices evolve according to the dividend states, to gain insight on the predictable component of the market prices. More specifically, we look at the average changes in prices according the following categories: (1) *Good-to-Bad*, (2) *Bad-to-Good*, (3) *Good-to-Good*, and (4) *Bad-to-Bad*. Table 2.9 reports the detailed entries of the price adjustment, stratified by the difference in the dividend states in period t relative to

period $t-1$. As seen in row (1), (5), and (9), prices decline when the state changes from *Good-to-Bad*, with p -values of 0.002, 0.084 and 0.001 for the *BL*, *CI* and *MM* treatments, respectively. Likewise, state changes from *Bad-to-Good* are accompanied by significant price increases, with p -values < 0.01 in *all* three treatments.

Another evidence in favor of the idea that prices are predictable in all markets can be seen in Table 2.10, where we estimate the intertemporal price adjustment ($P_t - P_{t-1}$) against the change in the dividend state dummy (with no change = 0, *Good-to-Bad* = -1, *Bad-to-Good* = +1). Estimation (1), (3), and (5) show that the effect of a change in the dividend state is substantial and statistically significant in each treatment (p -value < 0.001). Price increases when dividend state improves and vice versa, reiterating the presence of price co-movement with the dividend outcomes in all treatments.

Table 2.10. Price Adjustment Estimation

Explanatory Variables	<i>BL</i>		<i>CI</i>		<i>MM</i>	
	(1)	(2)	(3)	(4)	(5)	(6)
Change in State Dummy [#]	0.784*** (0.113)	0.784*** (0.142)	0.605*** (0.134)	0.605*** (0.135)	0.724*** (0.088)	0.724*** (0.0835)
Lagged Excess Demand		0.00188 (0.00388)		0.00979*** (0.00314)		0.0145*** (0.00365)
Period		-0.00666 (0.0272)		0.00240 (0.0225)		-0.0125 (0.0177)
Constant	-0.108 (0.0721)	-0.0577 (0.196)	0.118 (0.0711)	0.0721 (0.124)	0.089 (0.0757)	0.283** (0.130)
Observations	47	47	46	46	43	43
R ²	0.496	0.498	0.359	0.431	0.48	0.612

#None=0; *Good-to-Bad*=-1;*Bad-to-Good*=+1;
*significant at 10%, **significant at 5%, ***significant at 1%

Some more subtle patterns in the data, however, indicate that this is not the whole story. Estimation (1), (3), and (5) in Table 2.10 show that market prices adjust to changes in world outcomes better in sessions with Type-I and Type-II traders than in sessions

where these traders are absent (the coefficients of the state dummy are 0.784 and 0.724 in *BL* and *MM* respectively, higher than 0.624 in *CI*). Indeed, changes in the dividend state explain approximately 50% of the asset price variability in markets where traders of Type-I and Type-II are present ($R^2 = 0.496$ in *BL* and $R^2 = 0.48$ in *MM*). On the other hand, only roughly 36% of the variability of asset prices is explained by changes in the dividend state, when the market is populated by traders of Type-III and Type-IV only. Thus, markets populated with traders with fluctuating income have higher predictability. While it is possible for traders in all treatments to learn about the world outcome by examining the intertemporal price, they seem to learn better when they possess the induced motive to smooth consumption.

More importantly, the upward movement in prices is statistically significant in row (7) and (11) of Table 2.9, when both *CI* and *MM* treatments experience successive periods with good dividends. Furthermore, *MM* market also experiences a statistically significant downward price trend upon consecutive bad dividends, as shown in row(10). In contrast, we are not able to reject the null hypothesis that such drifts are statistically distinct from zero in the *BL* sessions. We infer that prices experience negative drift when there are consecutive periods with bad dividends, and positive drift under successive good dividends, when traders with constant income are present. The observed price momentums (without any accompanying change in the dividend states) imply that, in addition to the change in the intrinsic values of the assets, there are other forces at play that drives the intertemporal price adjustment in *CI* and *MM* markets.

To probe deeper into the origin of these forces, we extend the estimations in Table 2.10 to include additional regressors such as: (i) the lagged excess demand (denoted by $B_{t-1} - O_{t-1}$, where B_{t-1} is the total number of offers to buy (bids) and O_{t-1} is the total number of offers to sell (asks) in period $t-1$); and (ii) the period in which the data is extracted from. Model (4) and (6) in Table 2.10 show the coefficients of the lagged excess demand variable

of *CI* and *MM* sessions are statistically positive, albeit rather small in magnitude. Replicating the canonical pattern documented in the earlier studies (Smith et al., 1988; Lei et al., 2001), asset price is positively associated with the lagged excess demand as surrogated by the excess bid. What makes our finding interesting is that we only observe this pattern in *CI* and *MM* treatments, where traders without induced consumption smoothing motive (Type-III and Type-IV) are present. The inclusion of lagged excess bid variable also considerably increases the R^2 in *CI* and *MM* treatments (0.359 to 0.431 and 0.48 to 0.612, respectively), while R^2 remains unchanged in *BL* treatment. We deduce that the excess demand in period $t-1$ happens to be a significant predictor of the price changes in period t , *only* when the market is populated with (at least some) traders with constant income. When all traders experience induced motive to smooth consumption (as in treatments *BL* and *CD*), the lagged excess demand *ceases* to affect price changes significantly. Implicit in this outcome is the idea that consumption smoothing plays a critical role in guarding capital gain pursuits from creating undesirable price drift.

The following results summarize the impact of consumption smoothing activities on the price adjustment process:

Result 3: *(i) Transaction prices co-move with the dividend state. That is, they are generally higher in good states and lower in bad states. (ii) A larger proportion of the variability of asset prices could be explained by the changes in the dividend state, in the presence of traders with the induced consumption smoothing motive.*

Result 4: *Intertemporal price adjustment is influenced by the lagged excess demand only in the presence of traders without the induced motive for consumption smoothing, suggesting the role consumption smoothers play in guarding the impact of capital gain pursuits.*

2.4.4. Trading Activity

We would expect trading volumes to be relatively high in treatments *BL*, *MM*, *CD* and *FP*, where traders with income fluctuations are present. This is because in these treatments, decision to abstain from participating in the market will render more extreme income pattern (and lower overall welfare) to the individual. As shown in previous subsection, consumption smoothing is not the only factor that motivates trading. The pursuit of capital gains through speculative trading is also another equally important motive. This implies that even in the absence of income fluctuations (e.g. in our *CI* sessions), trading volumes can still be potentially high. Indeed, this is something that is found in the standard setting of Smith et al. (1988), where the income-shock induced motive to smooth consumption is absent.

Table 2.11. Trading Volume across Treatments (Units)

Periods	<i>BL</i>	<i>CI</i>	<i>MM</i>	<i>CD</i>	<i>FP</i>
1 and 2					
mean	26.39	37.56	30.13	35.71	99.89
sd	5.94	8.63	10.69	4.93	16.27
min	16.50	20.50	14.00	27.50	79.00
max	35.50	51.50	44.50	44.00	134.00
> 3					
mean	21.96	28.57	18.72	33.95	90.61
sd	6.02	6.61	6.41	5.70	13.26
min	14.80	15.36	13.00	29.00	74.25
max	29.27	34.60	26.45	45.00	104.50

Table 2.11 lists the average number of securities bought and sold in one period, with the average count in each replication taken as a unit of observation. There are substantially large transactions, with visibly higher volume in the first and the second periods (initial periods) in all treatments. Since the average supply is 200 assets, this means 10%-15% of

available securities are traded in each period. Trading volume in the *CD* treatment, where dividend always stays constant, is higher than in the other treatments *BL*, *CI* and *MM* with dividend uncertainty. We also find evidence that complete market (*CD*) is characterized by a lower variance in the trading activity.

Table 2.11, however, does not present the accurate numbers for the comparison across treatments for two reasons. First, the absolute levels of prices and the total number of traders are different and hence, these might influence the total number of transactions each period. Second, in the *FP* treatment, participants are able to buy from or sell to the experimenter at a fixed price. Thus, the total counts in *FP* sessions (Table 2.11) have to be divided by half, to make it comparable with the other treatments. We subsequently compute the dollar value of transactions per trader to address the two issues²⁹.

Table 2.12 Value of Transactions Per Trader

Treatment	All Periods	Periods following a Bad State	Periods following a Good state	<i>H0</i> : Good = Bad States	
				Signed Rank <i>p</i> -value (<i>H0</i> : Bad = Good)	n
<i>BL</i>	7.01 (1.98)	4.81 (1.40)	8.16 (2.05)	0.0277	6
<i>CI</i>	6.91 (1.20)	5.81 (1.35)	7.28 (1.40)	0.0679	4
<i>MM</i>	8.93 (3.39)	5.05 (2.15)	10.52 (3.52)	0.0277	6
<i>CD</i>	8.53 (2.23)	-	-	-	-
<i>FP</i>	7.76 (1.37)	7.90 (2.15)	7.91 (1.26)	0.7794	8

The standard deviations are presented in the parentheses.

Table 2.12 presents the summary of the measure which can be interpreted as the amount of cash exchanged per trader in one period, with the average count in one replication taken as a unit of observation. Data for all periods, as well as for periods

²⁹ In order to facilitate comparison with other treatments, we assign $\frac{1}{2}$ weight to the purchase/sale of an unit of the asset in *FP* sessions.

following the dividend state (bad or good) is presented with the standard deviation in the parentheses. Trading activity is higher in periods when the asset pays 1 ECU dividend than in periods when the asset pays no dividend. This is expected because in *good times*, traders have more cash that enable them to engage in dealings with larger nominal. While the difference is statistically significant in *BL*, *CI* and *MM* sessions, we find statistically indistinguishable gap between the good and the bad states when we remove price uncertainty in the *FP* session.

Result 5 summarizes our observations of the trading activities and how they differ across the treatments:

Result 5: *We find substantial trades in each period and across treatments. Trading activity is higher when the dividend state is good than when it is bad.*

2.4.5. Consumption Smoothing, Speculative Transactions and Trader Strategies

We have discussed consumption smoothing in the context of offsetting income variation between periods. However, there could be another dimension along which agents might attempt to equalize consumption. Individuals might want to balance consumption in *good* and *bad* dividend states. While this would require quite a sophisticated strategy, the next result argues that this was indeed the case in the *FP* sessions.

Table 2.13 presents the difference in the actual and the autarky consumption across dividend states, with the average consumption of each individual trader taken as a unit of observation. As seen in the last two rows of Table 2.13, the gap in the average consumption of Type-I traders across dividend states is only 3.11 ECUs, as opposed to 15.51 ECUs under autarky. The consumption gap for Type-II traders is only 1.65 ECUs, in contrast to 9.49 ECUs under autarky. We are able to reject the null hypotheses that the

actual consumption equals autarky, for both Type-I and Type-II traders in *FP* session (Signed Rank p -value < 0.0001 for both tests). This provides evidence that individuals show preference for a smooth stream of consumption, *not only* to offset the income variability between periods, but also to offset the wealth swings due to (exogenous) realization of the dividend state.

Table 2.13. Difference in the Average Consumption (ECUs) across Dividend States

Treatment	Type of Trader	Trade	Autarky	Signed Rank p -value (H_0 : Trade = Autarky)	n
<i>BL</i>	Type I	15.10	16.86	0.0425	24
	Type II	9.90	8.14	0.0919	24
<i>CI</i>	Type III	16.99	20.00	0.1096	24
	Type IV	8.01	5.00	0.0002	24
<i>MM</i>	Type I	16.98	19.35	0.4802	12
	Type II	7.95	6.47	0.4236	11
	Type III	16.95	20.00	0.0912	11
	Type IV	8.80	5.00	0.0186	12
<i>FP</i>	Type I	3.11	15.51	< 0.0001	24
	Type II	1.65	9.49	< 0.0001	24

Traders in treatment *BL*, *CI*, *MM* are not able to smooth consumption as well as traders in *FP*, plausibly due to the limitation imposed by the asset market. This includes the fact that prices are not fixed and hence must be forecasted by agents. In the *FP* sessions, individuals do not face any uncertainty with respect to prices or trading, which makes it easier for them to smooth consumption. It should be noted, however, that the total number of assets in the *FP* treatment is not constant, unlike the other treatments. Hence there might be several contributing factors to the additional dimension of consumption smoothing behavior observed in *FP* against all other treatments.

Looking into the average net asset change corroborates the above result. Table 2.14 presents the net changes in asset holding stratified by the changes in the dividend outcome, with the average count of each individual trader taken as a unit of observation. On average, traders buy assets when they experience positive income shock (even periods for Type-I, and odd periods for Type-II), *as well as* when the state changes from *Bad-to-Good*. Similarly, agents sell assets when they experience negative income shock (zero exogenous income), and when the state changes from *Good-to-Bad*. We are able to reject the null hypotheses that the actual consumption equals the autarky consumption in all these scenarios, at conventional levels.

Table 2.14. Net Change in Asset Holdings (Units) across Dividend States

Treatment	Trader Type	Change in State		Signed Rank p -value (H_0 : Good-Bad = Bad-Good)	n
		Good-to-Bad	Bad-to-Good		
<i>BL</i>	Type I	0.06	0.04	0.87	24
	Type II	-0.06	-0.04	0.54	24
<i>CI</i>	Type III	-0.56	0.10	0.18	24
	Type IV	0.56	-0.10	0.013	24
<i>MM</i>	Type I	-0.26	-0.17	0.66	12
	Type II	-0.03	0.73	0.29	11
	Type III	-0.36	-0.28	0.79	11
	Type IV	0.62	-0.31	0.0084	12
<i>FP</i>	Type I	-0.96	1.17	0.0026	24
	Type II	-2.80	1.91	0.0002	24

Our result therefore shows that traders perform another dimension of consumption smoothing behaviors, by successfully balancing consumption in good and bad dividend states in *FP* treatment. Taking away the price and liquidity uncertainty, thereby making the environment merely dependent on that of an individual decision making task, facilitates the formation of an even smoother stream of consumption.

To summarize subjects' consumption smoothing across the change in dividend states:

Result 6: *In the absence of price uncertainty and liquidity uncertainty, traders' choices reveal preference for consumption smoothing over time and across dividend states.*

In the following segments, we will look at the interaction between the two elements in market with heterogeneous traders, later of which are more representative of markets outside the laboratory than any of the other treatments. Our analysis will be centered on *MM* sessions (where all four types of traders are present), where we will attempt to rank these different types of traders in terms of their activity in the marketplace.

We first revisit the detailed entries of *MM* market in Table 2.5. The intertemporal net change in assets is largest among Type-II traders, with an average turnover rate of 1.70 units. This is followed by Type-I traders, who register an exchange of 1.38 assets. We are able to reject the null hypothesis that the net change in assets is negligible for Type-I, Type-II (p -value are 0.0033 and 0.0031, respectively). Thus, Type-I and Type-II traders in *MM* markets demonstrate portfolio adjustment strategies that are consistent with consumption smoothing behaviors - similar to their counterparts in *BL*, *CD* and *FP* markets.

The same, however, cannot be said for traders with constant income. Indeed, we do not find statistically significant intertemporal asset adjustment activities among the Type-III traders. The result comes as no surprise, given that the latter receive stable income and relatively high number of assets endowment (*asset-rich*). As they are most comfortably placed compared to other agents, Type-III traders therefore have the least incentive to trade. The most striking observation is with respect to Type-IV traders. As is evident from Table 2.5, Type-IV traders in *MM* market accumulate assets in *both* odd and even periods. This translates into what could be perceived as anti-consumption smoothing behaviors, with Type-IV traders experiencing larger final cash turnover rate under trading, than under autarky.

Looking into how Type-IV traders manage their asset inventories across dividend states, provides a possible clue to the observed anti-consumption smoothing behaviors. As shown in Table 2.14, Type-IV traders are net buyer of assets when the state changes from *Good-to-Bad*, and net seller of assets under *Bad-to-Good*. This is in stark contrast with the rest of the market (Type-I, II, and III traders) who do not demonstrate such clearly defined strategy according to the world outcomes.

Recall that prices have a predictable component in all treatments, including the *MM* market. It seems that Type-IV agents are able to make use of this predictability, and systematically exploit it. Income fluctuations for Type-IV traders come mainly from the changes in the dividend distribution. Instead of buying (selling) assets in high (low) income when dividend changes from *Bad-to-Good* (*Good-to-Bad*), Type-IV agents actually sell (buy) their assets. The strategy subsequently exacerbates the income gap between high and low income periods.

It might be true that Types-I and II are aware of the price predictability, but are unable to capitalize on it. This is perhaps due to the fact that Type-I and Type-II traders are constrained to use the asset market for the sole purpose of consumption smoothing (the primary motivation for engaging in a trade for agents with income shocks). Being aware that there would be low income in the next period, they (Type-I and Type-II traders) would attempt to transfer wealth to the period of scarcity. As cash is perishable, the only way to transfer wealth to the next period is by increasing the inventory of the long-lived asset. Thus, Type-I and Type-II agents might be willing to accept a lower rate of return in order to smooth consumption.

A vast majority of the naturally occurring markets are likely to have both types of traders: those who use the asset market to offset their income variability, and those who are in the marketplace for capital gains by engaging in speculative trades. The above discussion implies that even though prices have a significant predictable component, and

that the predictability of price is vulnerable for exploitation by the speculative traders, the presence of agents who are in the marketplace only to smooth their intertemporal consumption ensures that the predictability does not wither away.

Table 2.15. Regression of δ^i

Explanatory Variables	Coefficient Estimate	Standard Error
Constant Income	-0.0822*	0.043
Low Initial Asset	0.125***	0.026
Constant Income * Low Initial Asset	-0.331***	0.054
Mixed Market	-0.0329	0.035
Constant Dividend	0.0459	0.035
Fixed Price	0.0657**	0.031
Risk Preference	-0.00132	0.006
Gender	0.00384	0.024
Constant	0.601***	0.044
Observations	238	
R ²	0.44	

*significant at 10%, **significant at 5%, ***significant at 1%

This brings us to enquire into the factor that motivates consumption smoothing the most. To assess how successful it is relative to the strategy of others, we first define a consumption smoothing strategy for participant. Trading of individual i in period t exhibits a consumption smoothing strategy (i.e. γ_t^i equal to 1) if:

$$c_t^i < (>) y_t^i + d_t a_{t-1}^i \text{ when } y_t^i + d_t a_{t-1}^i > (<) y_{t-1}^i + d_t a_{t-2}^i$$

, where c_t^i is the final cash (consumption) at the end of period t , y_t^i is the exogenous income given to individual i at the start of period t , d_t is the dividend paid per unit of the asset at the start of period t , and a_{t-1}^i denotes the number of assets held at the start of period t . That is, an agent reduces consumption fluctuations if he/she buys (sells) assets

when his/her wealth increases (decreases) in period t . We define $\delta_t^i = \frac{1}{T} \sum_{t=1}^T y_t^i$ as the proportion of individual per-period actions that are consistent with the consumption smoothing behavior. As such, δ^i gives the extent or the success rate of individual consumption smoothing.

Table 2.15 presents the coefficient estimates from the regression of δ^i against the following indicator variables: ‘constant income’ which takes a value of 1 if there is no induced income fluctuation between periods and 0 otherwise; ‘low initial asset’ that takes a value of 1 if *asset-poor* and 0 otherwise; an interaction between ‘constant income’ and ‘low initial asset’; ‘mixed market’ that takes a value of 1 for *MM* session and 0 otherwise; ‘constant dividend’ that takes a value of 1 for *CD* session and 0 otherwise; and ‘fixed price’ that takes a value of 1 for *FP* session and 0 otherwise³⁰.

As evident from Table 2.15, the coefficient on ‘constant income’ is negative and statistically significant. This implies that the absence of income fluctuations alone has a negative effect on δ^i . On the other hand, lower initial asset endowment induces higher fraction of consumption smoothing activities, as supported by the statistically positive coefficient (p -value < 0.01) of ‘low initial asset’. We evaluate the interaction terms to make sense of the magnitude of the coefficients. The coefficient of the interaction term between ‘constant income’ and ‘low initial asset’ is statistically negative (p -value < 0.01). The marginal effect of stable income is -0.41 for the *asset-poor* trader, much greater than the marginal effect of -0.08 recorded by the *asset-rich* agents. This indicates that the effect of income fluctuations between periods on consumption smoothing is enormous when the trader is *asset-poor* (Type-II against Type-IV). This effect, however, is mild when only *asset-rich* traders are considered (Type-I against Type-III).

³⁰ In addition, a constant and two other variables: ‘risk’ (values from the risk elicitation task are used on a scale of 1-11 with 1 as highly risk-loving and 11 if highly risk-averse) and ‘gender’ (1 if male and 0 otherwise) are included as well.

In addition, the marginal effect of lower initial asset endowment is +0.13 when traders have income fluctuations, and -0.20 when traders have constant income. Thus, being *asset-poor* affects consumption smoothing positively for traders with income fluctuations, as more transactions of Type-II agents are consistent with consumption smoothing behavior than Type-I individuals. In contrast, being endowed with lower initial assets has a negative effect on minimizing consumption variability for traders with constant income, as fewer transactions of Type-IV agents are consistent with consumption smoothing behavior than Type-III traders.

From the above discussion, we can rank the extent of consumption smoothing activities of various types of traders according to the following order (as measured by δ^i , with the most successful attempts at the leftmost): Type-II; Type-I; Type-III; Type-IV.

Finally, a positive and significant coefficient on ‘fixed price’ suggests that removing price uncertainty has a favorable effect on consumption smoothing³¹. We characterize the behavior of traders in the mixed markets and the factors that provide an impetus to the consumption smoothing activities in the following result:

Result 7: *In markets where all types of traders are present, the asset-poor traders with income fluctuations are the most active, followed by the asset-rich with income fluctuations. Asset-rich agents with constant income are the least active. Asset-poor agents with constant income capitalize on the predictability of prices, by buying when prices are lower (as state changes from Good-to-Bad) and selling when prices are higher (as state changes from Bad-to-Good).*

Result 8: *The percentage of transactions consistent with consumption smoothing behavior is higher when traders have fluctuating income and smaller initial assets. This percentage*

³¹ Further support is obtained from a separate regression with δ^i as the dependent variable, *BL* as the default treatment and indicator variables for other treatments.

is also higher when prices are fixed, as opposed to market with endogenously determined prices.

2.5. Conclusion

We implement an indefinite horizon economy with perishable consumption goods and durable assets in the laboratory. The incentive to smooth consumption over time is provided to some individuals, by subjecting them to income shocks. Agents could use asset trading to offset income fluctuations or accumulate capital gain appreciation. Thus, the setting is reminiscent of the consumption-based asset pricing models that are widely popular in macroeconomics or finance literature. Within this controlled environment, we study the effect of different composition of traders with induced motive to level consumption, on asset price dynamics and consumption smoothing behavior. We also investigate the implications of dividend uncertainty and price uncertainty in this setting. We believe that our research would complement the analysis of asset pricing that uses field data.

We find strong evidence for consumption smoothing behavior among traders with induced motive to do so. Agents with a constant stream of income in each period do not engage in consumption smoothing under trading, relative to autarky. Our experimental results show that the transaction prices are higher compared to the (constant) risk-neutral fundamental value in all our treatments. The extent of mispricing is severe and the magnitude of the price change between periods is greater, in the presence of traders without induced motive to smooth consumption. As the dividend process is perfectly observable in experiments, we are able to assess the exact proportion of the variability of asset prices explained by changes in the dividend state. Market prices co-move with the dividend states in all treatments, demonstrating a significant predictable component.

However, price predictability is higher in the presence of traders with induced motive to smooth consumption. In sessions where traders with constant income are present, prices are affected by the lagged excess demand: a market thick (thin) with bids relative to asks tends to display increasing (decreasing) prices.

We find that there is substantial trade in our experiment. This is true even for the sessions where only traders with constant income are present. Even without the presence of traders with income fluctuations, agents engage in asset exchanges. A higher amount of activity takes place in periods with good dividends than periods with bad dividends, driven partly by the fact that prices are higher in the good states.

It is observed that prices are comparatively "well-behaved" in the setting where the asset market is complete than under incomplete markets. A potential reason could be that under incomplete asset market settings, there are multiple rational expectation equilibria which create such pricing patterns. Another alternative explanation is that traders transact under "imperfect foresight". Evidence from the trading activity seems to indicate likewise. While trading should be the same, in principle, with dividend uncertainty and without, it is substantially higher in the latter case. Consumption smoothing "works" much better under constant dividend setting than with dividend uncertainty: with constant dividend, prices are less variable which aids individuals in planning ahead.

In heterogeneous market, individuals with income fluctuations are the most active. Unconstrained by the requirement to smooth consumption, traders with constant income and relatively small initial endowment of assets are able to exploit the predictability of prices, by buying low and selling high, where the high and low prices are governed by the change in underlying dividend process. Agents with constant income and relatively large initial units of the security are the least active participants.

In the absence of price and liquidity uncertainty, individuals show preference for equitable consumption not only over time but across dividend states as well. Eliminating

uncertainties with regards to trading thus has a positive effect on the overall consumption smoothing behavior of agents with income fluctuations.

There are several avenues to pursue in future research. First, developing a theoretical model that considers the co-existence of different types of traders (with and without the induced motive to smooth consumption) is a potentially fruitful endeavor. Within this setting, generating predictions on asset price dynamics as a function of the proportion of traders with induced motive would be insightful. Second, future experiments could inform us about the implications of introducing income growth in our setting, thereby creating the possibility of "rational" bubbles. Third, long-lived bonds are used as the trading instrument in all of the experimental studies (including ours) that investigate markets populated with traders with income fluctuations. With the exception of some perpetual bonds issued by the British treasury in the 19th century, these infinite-horizon bonds are no longer issued and do not exist anymore³². Thus, it would be interesting to implement infinite-horizon economies in the laboratory with finite-maturity bonds within the framework of a dynamic general equilibrium asset-pricing model³³.

³² See Calvo and Guidotti (1992) for a theory of government debt structure that explains why modern governments do not issue infinite-horizon bonds.

³³ Judd et al. (2011) provide a theoretical analysis of complex bond portfolios in such a setting.

2.6. Appendix

Experimental Instructions

Trading Stage

Dear Participant, welcome to our experiment. **Please pay attention to the information provided here and make your decisions carefully. If at any time you have questions, please raise your hand and we will attend to you in private.**

Please note that unauthorized communication is prohibited. Failure to adhere to this rule would force us to stop the simulation and you may be held liable for the cost incurred in this simulation. You have the right to withdraw from the study at any point in time, and if you decide to do so your payments earned will be forfeited.

By participating in this study, you will be able to earn a considerable amount of money. The amount depends on the decisions you make.

At the end of this session, this money will be paid to you privately and in cash. It would be contained in an envelope (indicated with your unique user ID) together with a payment receipt acknowledging that you have been given the correct payment amount.

Each of you will be given a unique user ID and your **anonymity will be preserved** for the study. You will only be identified by your user ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

Trading Stage

In this experiment, we are going to create an auction market in which you will trade units of a fictitious asset (hereinafter referred to as ‘securities’) that earn dividend for every period. **Please note that all securities are identical.**

The currency used in this market is called ECU (Experimental Currency Unit), which will be converted to Singapore dollars for your payment at the end of this stage with the following exchange rate:

You final capital	Reward
First 30 ECU and below	1 ECU=1.00 SGD
Above 30 ECU	1 ECU=0.30 SGD

To better understand the instruction below, please refer to Diagram A and B given.

1. Duration of the experiment

This experimental **session** consists of a number of replications of the same situation, referred to as trading **rounds**. One **round** consists of a number of **periods**. Each period lasts for 120 seconds.

The total number of rounds is **not known** beforehand. Instead, we determine whether the current round continues in the following manner. We will draw a **random number using a dice**. **If the number drawn is 1 – 5, we then proceed to the next period within the current round. If the number drawn is 6, the current round will terminate and the first period of a new round will start.**

Notice, the termination chance is time-invariant; it does not depend on how long the experiment has been going.

Prior to the real trading game, there will be a trial round consisting of 3 trading periods for you to practice.

Below is the illustration of the relationship between trading rounds and periods:

(only shown to traders in Treatment *BL*, *CI*, *MM*, *FP*)

2. Dividend and Fundamental Value of the Securities

At the beginning of a period, each security in your inventory will be awarded dividend. The dividend income is added to your cash inventories immediately before trading market starts. There are 2 possible dividend values per security: 0 or 1 ECU with equal probability of being drawn. Past dividends have no influence on this chance. In each period the value of dividend is drawn by the computer randomly and will only be announced at the beginning of that period. The dividend is the same for each security and for each participant.

The expected value of dividend drawn in every period is

$$E(\text{Dividend}) = (0 \times 0.5) + (1 \times 0.5) = 0.5 \text{ ECU}$$

Since there is a $1/6$ chance that the round ends in the period when a security is bought and the maturity of the security is indefinite, the fundamental value of the security can be calculated as follows:

Hence, the **fundamental value** of a security is 2.5 ECUs.

(only shown to traders in Treatment CD)

2. Dividend and Fundamental Value of the Securities

At the beginning of a period, each security in your inventory will be awarded dividend, and dividend income is added to your cash inventories immediately before trading starts. The dividends are always 0.5 ECUs. The dividend is the same for each security and for each participant. Since there is a 1/6 chance that the round ends in the period when a security is bought and the maturity of the security is indefinite, the fundamental value of the security can be calculated as follows:

Hence, the **fundamental value** of a security is 2.5 ECUs.

3. Market Description

There are 16 traders in the market. At the start of each **round**, you will be allocated **securities** which you can **trade** in the market.

You will start this round with **20**³⁴ securities. Other traders may start with different initial allocations.

There will be two sources of fresh cash injection in each period. **First**, the securities you hold at the end of the previous period may pay **dividends** at the beginning of the next period. These dividends will be your source of cash in the next period. An exception would be for the **first period of every round**, where the dividend will always be 1 ECU. In subsequent periods, dividend value will be randomly determined.

Second, at the beginning of a period, you may be given **income**.

³⁴Only applicable to instructions given to Trader Type I/III. For Type II/IV, it will be replaced with “5”.

(only shown to Trader Type I or Type II)

You will receive income in every alternate period. In **odd periods** (1st, 3rd,...) you will receive **nothing**³⁵. In **even periods** (2nd, 4th,...) you will receive **15 ECUs**³⁶. This income is added to your cash inventory at the beginning of **every new period**. It will be made known beforehand in which periods you will receive income. Others may have a different income flow.

(only shown to Trader Type III or Type IV)

You will receive **7.5 ECUs** as income in every period. This income is added to your cash inventory at the beginning of **every new period**. It will be made known beforehand in which periods you will receive income. Others may have a different income flow.

All in all, your total cash at the end of each period will be the sum of the dividend payment you receive from your securities, the income you receive for that period and the profit from trading. **It is important to note that your cash in one period will expire and will not be carried forward to the next period; while your securities will always be carried over to the next period. However, securities expire at the end of each round and will not be carried forward to the next round.**

Note that **within a round**, you will therefore only receive securities endowment **once** at the start of the round. However, you will likely receive income **more than once** depending on the number of the **periods** in that round.

³⁵ Only applicable to instructions given to Trader Type I. For Type II, it will be replaced with “15 ECUs”.

³⁶ Only applicable to instructions given to Trader Type I. For Type II, it will be replaced with “nothing”.

(only shown to traders in Treatment BL, CI, MM, CD)

4. The Rules of the Experimental Market (Please refer to Diagram B)

Trade is conducted in the form of a double auction market. During the trading period, you may **buy** or **sell** securities or you may do nothing. The trading is anonymous.

Basic concept of Bid and Ask:

The Bid price: represents the price that a buyer is willing to pay for a security.

The Ask price: represents the price that a seller is willing to receive for a security.

A trade or transaction occurs when the buyer and seller agree on (accept a Bid/ accept an Ask) a price for the security.

Example:

Submit a Bid at x1 ECU: means you are willing to buy a security at **x1** ECU.

Submit an Ask at y1 ECU: means you are willing to sell a security at **y1** ECU.

Accept a Bid at x4 ECU: means you agree to sell a security in exchange for **x4** ECU.

Accept an Ask at y5 ECU: means you agree to pay **y5** ECU for a security.

Two ways to Buy:

- 1) Submit a Bid: Input a price that you are willing to pay for one security as a bid (*Box E*) and click 'Submit Bid'. The bidding price has to **be higher than or equal to** the highest current bid. Your bids will only be successful (you successfully buy a security) when another participant accepts your bid. OR
- 2) Accept an existing Ask: Select offer with the lowest price from the Ask List (*Box A*) and click on the 'Buy' button at the bottom.

Two ways to Sell:

- 1) Submit an Ask: Input a price at which you are willing to sell one security as an Ask (*Box B*) and click "Submit Ask". The asking price has to **be lower than or equal to** the lowest current ask. Your security will be sold when another participant accepts your ask, OR
- 2) Accept an existing Bid: Select bid with the **highest price** from the Bid List (*Box D*) and click on the "Sell" button at the bottom.

Note:

- 1) You can submit multiple bids/asks. Each bid/ask is for one unit of security. You cannot accept your own bids/asks.
- 2) The List of Bids (Asks) will be arranged according to the price in descending (ascending) order and the order of submissions in ascending (ascending) order.
- 3) If your bids/ask are accepted by other traders, there will be a corresponding deduction/increase of cash from the cash account and increase/fall in the security holding in *Box H*. Note that you are only allowed to submit a bid/ask if you have sufficient cash/number of securities to trade. If you no longer have adequate cash on hand /security in the inventory to support your outstanding bid/ask, your bid/ask will be *invalidated*.
- 4) After submitting a bid/ask, you have the option to **withdraw** your bid/ask by **selecting your bid/ask (in blue color)** and clicking on the “Withdraw Bid (Ask)” button in *Box F (Box C)*.
- 5) You will receive messages (*Box G*) about your successful actions.
- 6) At the start of a Period, the screen will display the Dividend Drawing Page (*Diagram A-1*). At the end of a Period, the screen will display a summary page (*Diagram A-2*).

(only shown to traders in Treatment *FP*)

4. The Rules of the Experimental Market (Please refer to schematic diagram in Diagram B)

During the trading period, you may **buy** or **sell** securities or you may do nothing. The trading is anonymous.

Basic concept of Bid and Ask:

The Bid price: the price that the experimenter is willing to pay for a security, in this case fixed at 2.5 ECU.

The Ask price: the price that the experimenter is willing to receive for a security, fixed at 2.5 ECU.

Buy from Experimenter: means you indicate your willingness to buy a security from the experimenter.

Sell to the Experimenter: means you indicate your willing to sell a security to the experimenter.

To Buy:

The price per unit of security is fixed at 2.5 ECUs. You can buy a security by clicking the “*Buy from experimenter*” button. Your bid will only be successful (you successfully buy a security) when the experimenter accepts your bid.

To Sell:

The price per unit of security is fixed at 2.5 ECUs. You can sell a security by clicking the “*Sell to experimenter*” button. Your security will be sold when the experimenter accepts your ask.

Note:

- 1) The experimenter will execute submitted offers to buy and sell according to the order of submissions.
- 2) You can submit multiple bids/asks. Each bid/ask is for one unit of security.
- 3) The List of Bids (Asks) will be arranged according to the order of submissions in ascending (ascending) order.
- 4) After submitting a bid/ask, you have the option to **withdraw** your bid/offer by **selecting your bid/ask (in blue color)** and clicking on the “Withdraw Bid (Ask)” button in *Box F (Box C)*.
- 5) You will receive messages (*Box G*) about your successful actions.
- 6) If your bids/ask are accepted by the experimenter, there will be a corresponding deduction/increase of cash from the cash account and increase/fall in the security holding in *Box H*. Note that you are only allowed to submit a bid/ask if you have sufficient cash/number of securities to trade. If you no longer have adequate cash on hand /security inventory to support your outstanding bid/ask, your bid/ask will be *invalidated*.
- 7) At the start of a Period, the screen will display the Dividend Drawing Page (*Diagram A-1*). At the end of a Period, the screen will display a summary page (*Diagram A-2*).

5. Trading Profit

Your earnings for a round are determined by the cash you are holding at the last period of that round.

So, if you end a period without cash, and the round terminates at that period, you will earn zero ECU for that round. This does not mean, however, that you should always end one period with only cash and no securities. If you do so and that period is not the terminal period, you will not receive dividends in the next period. Consequently, you start the next period without cash (since cash cannot be carried over periods) unless you receive income in that next period.

We will run as many rounds as can be fit in the allotted time for the experiment. If the ongoing round has not been terminated within 10 minutes before the end of the session,

then we will throw the dice. If 1-5 is drawn then we move to the next period and that period will be the last period. If 6 is drawn, then the current period is the terminal period.

Two randomly chosen rounds will be selected to determine your final payment from this experiment. However, if we only have one round for the entire two (2) hours, then you will receive twice the amount of earnings from that round. If there are exactly two (2) rounds, then you will receive the sum of earnings from these two rounds.

Decision Problem Stage

In this part of the experiment you will be asked to make a series of choices. How much you receive will depend partly on chance and partly on the choices you make. The decision problems are not designed to test you. What we want to know is what choices you would make in them. The only right answer is what you really would choose.

For each line in the table in the next page, please state whether you prefer option A or option B. Notice that there are **10 lines** in the table but just **one line** will be randomly selected for payment. You do not know which line will be paid when you make your choices. Hence you should pay attention to the choice you make in every line.

Reward Scheme

After you have completed all your choices, the computer will randomly select a line in the table.

Your earnings for the selected line depend on which option you chose: If you chose option A in that line, you will receive 1 SGD. If you chose option B in that line, the computer will randomly determine if your payoff is 0 or 3 SGD with the probabilities stated in Option B in that line.

If you have any questions, please raise your hand and we will attend to you in private.

Chapter 3. Agency Problem, CEO Incentives and Stock Price Dynamics: Theory and Experiment

3.1. Introduction

Figure 3.1. Pay Ratio between CEO and Median Employee Compensation over Time

Source: Mishel and Sabadish, 2012. "Options granted" compensation series include salary, bonus, restricted stock grants, options granted, and long-term incentive payouts for CEOs at the top 350 firms ranked by sales. "Options exercised" compensation series include salary, bonus, restricted stock grants, options exercised, and long-term incentive payouts for CEOs at the top 350 firms ranked by sales.

The world witnesses a sharp increase in CEO pay after the Second World War. According to a research report by Economic Policy Institute (Mishel and Sabadish, 2012), the pay ratio between the CEO and a median employee compensation in the company increases from about 20 in the 1960s to about 200 times in the 2010s. The highest CEO

pay ratio against the other employees is 1795 times³⁷. This trend naturally stimulates discussion by researchers on whether it is efficient and worthwhile to pay the CEOs this much. The empirical evidences are mixed. While Jensen and Murphy (1990b) find positive relationship between wealth growth of CEO and firm performance, Core et al. (1999) find that CEO pay is related to bad corporate governance, and may be the result of revenue extraction by insiders.

Not only does the payment amount change, so does the payment structure. Many firms start to offer compensation in terms of stock shares and stock options to CEOs in late 1990s. Theoretically, this is a response to the “agency problem” between the CEO and the shareholders, as proposed by Jensen and Meckling (1976), and Jensen and Murphy (1990a). The main idea in the theory is that since there is a separation between the income and the control right of the CEO and shareholders, the CEO may deviate from maximizing the shareholders’ investment returns in his decision making. Granting stock shares can theoretically reconcile this problem because it increases the interest congruence between the two parties. This argument is supported by an empirical study by Mehran (1995), who find firm performance is positively correlated to the percentage of equity based compensation.

In this paper, we study how CEO incentive structure matters for the managerial effort and stock price experimentally. The research questions are two folded: (1) Do the CEOs invest higher effort when the same amount of payment is paid in terms of stock shares rather than cash bonus? Is the market able to price the CEO’s effort correctly by incorporating the information into share prices? (2) How does the restriction on the CEO’s ability to trade the shares of his own firm matter on his effort and price dynamics? Will he work harder when he is granted this opportunity? Will this lead to larger price volatility?

³⁷ Bloomberg (2013): Top CEO Pay Ratios, <http://go.bloomberg.com/multimedia/ceo-pay-ratio/>

The questions are studied in an experimental market where the stock shares do not pay a dividend, i.e. all profits are automatically reinvested and paid at the final period to the owners of the shares. Depending on the CEO's choice of his effort, the profit of the firm can be positive, negative or zero in each period. The stock traders of the firm trade the shares in a typical double auction market a la Smith et al. (1988). We implement a two by two design, where the treatments are differentiated based on: (1) if the CEOs receive 20% of the profit as cash bonus or 20% of the total stock shares as endowment and (2) whether or not the CEOs are allowed to trade stock shares in the open market. This design guarantees that both stock and cash payment generate the same monetary return to the CEOs, if they do not change their stock holdings. If the CEOs invest higher effort in the stock ownership treatments, it suggests that "ownership" indeed helps to foster higher working morale than cash bonus do. Furthermore, CEOs are usually forbidden to trade stocks of their own firms in real markets. A usual motivation of such regulation/restriction is that the CEO may behave opportunistically by using his insider information for trading, or selling all the shares if he expects himself to shirk. We add this dimension to the study to see if the CEO's effort and the market stability are indeed worse when the CEO can trade. The advantage of studying the questions via experiments is that some key variables of interest, for example, the effort by the CEO unobservable in the field data can be completely recorded in a laboratory experiment.

Our result shows that to the contrary of public beliefs, stock ownership does not significantly improve the managerial effort decisions. There is, however, a greater alignment between CEO's decisions and investors' valuation of the firm assets. Investors utilize the information provided to them, produce an *effective* estimator of the actual fundamental value, and follow them closely. This enhances the actual intrinsic value discovery process and improves market price quality. Meanwhile, we observe that granting CEO the opportunity to trade nullifies the positive growth CEOs brings about to the firm

values. Higher rate of change in the managerial efforts induces larger asset mispricing, greater costs of transactions and more volatile market prices. Investors anticipate the growth of the asset values, and utilize information of the CEO's portfolio adjustment to estimate the endogenously determined fundamental values. The generally small gap between market prices and the (estimated) fundamental values, coupled with the small price deviations, indicate that endogenously determined fundamental value system greatly alleviates asset bubbles in the experimental setting.

Our study is related to several recent studies in experimental corporate finance. Lefebvre and Vieider (2014) conduct an experiment to compare stock option with cash bonus compensation, to study risk taking by the CEOs when making investment decisions. They find that when the CEOs are paid by the stock options, they take more risk than when they are paid by cash bonus. Similar result is reported by Holmen et al. (2014) and Kleinlercher et al. (2014) where fund managers in experimental markets are found to buy more shares when they are paid by option like incentives, which leads to greater overvaluation or asset price bubbles. The main difference between their paper and ours is that we study effort taking instead of risk taking, and we have a group of outsiders to trade the stocks shares, which are not featured in their paper. Fullbrunn and Haruvy (2013) conduct an experiment on the dividend puzzle, where the initial endowment of stock shares for the management team is a key dimension for the treatment design. They study whether the management team will vote more in favor of the interest of the shareholders (e.g. vote for paying dividend instead of reinvesting the profit or conducting self-dealing) if they own more shares themselves, but find negative result to the proposition. The paper is related to ours as we also look at the impact of stock ownership on the CEO or management team behavior. However, while the managerial decision in Fullbrunn and Haruvy (2013) is centered upon the issue of how to split the "pie" (profit), the managerial decision in our paper is focused on whether or not to make the profit larger, and if so, by how much. Oprea

(2008) studies whether takeover threats can reduce self-dealing in firms with exogenously generated high and low cash flow, and finds the high cash flow firms suffer more from the management self-dealing – managers tend to pay excessive dividends to signal their “good will” in the short run. As such, takeover threats are found to be more effective in solving the problem in high cash flow firms. Kale and Noe (1997) and Cadsby and Maynes (1998) study how different voting rules and different levels of endowment of shares matter in determining the success of a takeover bid. Dittmann et al. (2014) study how individuals bid for stocks with and without the voting shares. Croson et al. (2006) use six experiments to test the predictions of cooperative game theory in a dynamic merger and acquisition game. Lastly, Dai et al. (2013) investigate similarity in the bidder’s value in a takeover experiment.

In our experiment, the fundamental price of the asset is determined endogenously by the CEO effort; it is not established exogenously as in the typical SSW markets³⁸. To the best of our knowledge, only Jaworski and Kimbrough (2016) have implemented an endogenous fundamental setting. In their study, the dividend of the firm is contingent upon the pricing decision by the CEO of the monopoly producer. They find that introducing endogenous fundamentals leads to slightly larger price bubbles and slower mitigation of bubbles when subjects become more experienced.

Our study is also related to the experiments on insider trading, such as the study by Plott and Sunder (1982) and Oechssler et al. (2011) that investigate the case where the insiders have information advantage (about the exogenous fundamental values) over other traders. In this paper, we study the situation where the CEO can also influence the fundamental price of the stock by exerting different levels of effort.

³⁸ E.g. Lei et al. (2001), Dufwenberg et al. (2005), Haruvy and Noussair (2006), Haruvy et al. (2007), Sutter et al. (2012), Akiyama et al. (2014) and Eckel and Füllbrunn (2015).

3.2. Experimental Setup

3.2.1. Parameterized Model of CEO Compensation without the Possibility of Trading

CEO has the following production function:

$$Y_t = f(e_t) = 1000e_t - 2000 \quad (1)$$

where Y_t is the value (profit) he creates for the firm in period t and e_t is the effort he puts in period t . As there are a total number $N = 200$ of shares issued by the firm, the additional value per share created by the CEO in one period is determined by $y_t = \frac{Y_t}{N}$. We require CEO to make the production decision in ten periods.

CEO faces a cost function, which increases at an increasing rate:

$$c_t(e_t) = 50e_t^2 \quad (2)$$

For simplicity, we assume that the stock does not pay dividends, and the value created by the CEO is added to the fundamental value FV_t of the stock. In this experiment, the fundamental value is a function of the effort. We assume the stock has an initial baseline value of 110 ECU:

$$FV_{t=0} = 110$$

The baseline terminal value evolves into the following in period t :

$$FV_t = FV_{t-1} + y_t = FV_{t-1} + \frac{(1000e_t - 2000)}{200} = FV_{t-1} + 5e_t - 10 \quad (3)$$

This means that the fundamental value FV_t will be unchanged if $e_t = 2$. FV_t will increase (decrease) if e_t is greater (smaller) than the *neutral effort* 2.

The CEO can be compensated either with the Linear Wage Compensation plan (L) or the Stock Ownership Plan (S). We add another dimension to the experimental design, by

allowing CEO to trade the stock of his firm in two other treatments. We call the linear wage compensation and the stock ownership program with the possibility to trade as the Linear Wage Compensation with Possibility to Trade (*LT*) and the Stock Ownership Plan with Possibility to Trade (*ST*) treatment, respectively. Thus, our experiment employs a two by two design.

CEO receives a fixed salary $a_t = 400$ in each period. Depending on the treatment design, he may receive a cash bonus b_t , and/or a capital gain (through changes in ownership value) $s_t y_t$ for holding stock shares. In both cases, the cash bonus and capital gain are proportional to the profit Y_t .

In the Linear Wage Compensation plan (*L*) treatment, we let

$$b_t = 0.2Y_t \quad (4)$$

This means, in monetary terms, the cash bonus to the CEO is equivalent to 20% of the profit of the firm. This bonus will be credited as CEO's salary in each period.

Table 3.1. Framework of CEO Compensation in Treatment *L* and *S*.

Effort (e_t)	Change in Fundamental Value (y_t)	Cost at t $c(e_t)$	Benefit at t ($a_t + 0.2Y_t$)	Utility at t ($a_t + 0.2Y_t - c(e_t)$)
0	-10	0	0	0
1	-5	50	200	150
2	0	200	400	200
3	5	450	600	150
4	10	800	800	0

Note: Despite the common notation of $0.2Y_t$ used in both treatment *L* and *S*, benefit for CEO under treatment *L* comprises of fixed salary a_t and *cash bonus* $0.2Y_t$. On the other hand, benefit for CEO under treatment *S* consists of fixed salary a_t and *ownership value* $0.2Y_t$.

In Stock Ownership Plan (*S*) treatment, we give the CEO an endowment of $s_0 = 40$ shares, and the CEO is not allowed to sell this endowment. The endowment of stock shares generates capital gain of

$$\frac{s_0}{N} Y_t = \frac{40}{200} Y_t = 0.2Y_t \quad (5)$$

in each period to the CEO. This means, without the possibility to trade, holding the CEO's effort e_t equal, the cash bonus in treatment *L* and capital gain in treatment *S* are *the same*. Nevertheless, unlike the cash bonus in treatment *L*, the ownership value is not credited as CEO's salary in each period. Instead, it will only be realized at the end of the round.

In both treatment *L* and *S*, the utility of the CEO can be written as the following function:

$$U_t = a_t + 0.2Y_t - c(e_t) = [400 + (200e_t - 400)] - 50e_t^2 \quad (6)$$

The *payoffs* for the CEO at different level of effort are shown in Table 1. If the CEO purely maximizes his individual payoff, he should always choose $e_t = 2$, in which case $Y_t=0$, and the terminal value FV_t of the stock shares will stay unchanged in the experiment.³⁹ In other words, the optimal effort e_t^* in treatment *L* and *S* always remain as the *neutral effort* 2.

3.2.2. Parameterized Model of CEO Compensation with the Possibility of Trading

We let s'_t be the number of stock shares held by the CEO in each period in addition to his initial endowment in treatment *LT* and *ST*. That is, if s_t is the stock position held by the CEO in treatment *LT* at period t , then $s'_t = s_t$. Similarly, if s_t is the stock position held in treatment *ST*, then $s'_t = s_t - 40$.

³⁹ We refrain from having a negative net wage, so as not to produce unintended aversion towards high effort.

The net utility gained from choosing effort e_t can be expressed as a function of the effort (e_t) and the number of assets before the stock trading begins (s'_t):

$$U_t = a_t + 0.2Y_t + s'_t * y_t - c_t(e_t) \quad (7)$$

$$U_t = [400 + (200e_t - 400)] + [5e_t * s'_t - 10s'_t] - 50e_t^2$$

$$U_t = -50e_t^2 + (200 + 5s'_t) * e_t - 10s'_t \quad (8)$$

The total utility U he received at the end of one trading round is therefore:

$$U = \sum_{t=1}^{10} [-50e_t^2 + (200 + 5s'_t) * e_t - 10s'_t] \quad (9)$$

Table 2 shows that the *neutral effort* is the optimal effort for CEO, when a CEO is not endowed with any additional assets (which is the initial condition at the start of period 1), and has yet to accumulate any assets through trading stocks. That is, $e_t^*(s'_{t=1} = 0) = 2$. The fundamental value of each stock share of the firm remains at 110 ECU if: 1) the CEO does not change his asset endowment (hence $s'_t = 0$), and 2) the CEO always chooses the optimal level of effort $e_t^*(s'_t = 0) = 2$.

Table 3.2. Framework of CEO Compensation in Treatment *LT* and *ST*.

Effort (e_t)	Change in FV (y_t)	Cost at t $c(e_t)$	Benefit at t $(a_t + 0.2Y_t + s'_t * y_t)$	Payoff at t $(a_t + 0.2Y_t + s'_t * y_t - c_t(e_t))$
0	-10	0	$-10s'_t$	$-10s'_t$
1	-5	50	$200 - 5s'_t$	$150 - 5s'_t$
2	0	200	400	200
3	5	450	$600 + 5s'_t$	$150 + 5s'_t$
4	10	800	$800 + 10s'_t$	$10s'_t$

Note: Despite the common notation of $0.2Y_t$ used in both treatment *LT* and *ST*, the benefit for CEO under treatment *LT* comprises of fixed salary a_t , cash bonus $0.2Y_t$ and change in ownership value $s'_t * y_t$. On the other hand, the benefit for CEO under treatment *ST* consists of fixed salary a_t and ownership value $0.2Y_t + s'_t * y_t$.

Table 3.3. Shift in Optimal Effort.

Additional Shares Owned	Notation	Optimal Effort $e_t^*(s'_t)$
$0 \leq s'_t < 10$	Low Possession (<i>LP</i>)	$e_t^*(s'_t) = 2$
$10 < s'_t < 30$	Medium Possession (<i>MP</i>)	$e_t^*(s'_t) = 3$
$30 < s'_t \leq 200$	High Possession (<i>HP</i>)	$e_t^*(s'_t) = 4$
The total shares outstanding N=200		

However, it can also be seen that the CEO would want to purchase and accumulate shares over time. When CEO owns more stock shares, it is optimal for him to invest higher effort (above $e = 2$). The number of shares in the possession varies from period to period depending on the CEO's trading activities. Taking into account the above compensation model, it is not difficult to see that the optimal effort in period t varies depending on s'_t .⁴⁰ Table 3.3 summarizes the shift in the optimal effort.

3.3. Experimental Design and Procedure

3.3.1. General Structure

Like the typical SSW market, each investor in our experiment is endowed with some cash and stock shares, and they trade in a double auction asset market. When the CEO is allowed to trade, he takes a dual role as the CEO and a trader.

An individual investor (or non-CEO trader) starts with uniform endowment of 40 shares at the start of the round⁴¹. Given the initial terminal value is 110 ECUs⁴², the total ownership value is 4400 ECUs per trader. In addition, each non-CEO trader receives a cash

⁴⁰ Investors are able to derive how the optimal effort of CEO changes with the his asset holding, as they are also given information on how s'_t affects the CEO's payoff (that is identical to the information given to the CEOs).

⁴¹ We give equal initial asset endowment to both CEO and investors, to create a setting where shareholders (of the company) split the securities equally. Thus, we have one less investor in Treatment *S* and *ST*, to ensure that the total number of shares in the market always stays at 200.

⁴² As the asset value falls by at most 10 ECUs in each period, we set 110 ECUs as the starting value of asset. This is to ensure that the asset terminal value will never be negative (to avoid the situation where the firm enters a bankruptcy).

endowment of 4000 ECUs. Thus, the total initial endowment of each investor is 8400 ECUs.⁴³

All CEOs also receive cash amounting to 4000 ECUs at the beginning of a replication. For CEO-LT and CEO-ST, this cash can be used for trading. For CEO-*L* and *S*, this cash will be stored in a saving account.

Table 3.4. Initial Endowment of CEO and Non-CEOs.

Treatment:	CEO							
	<i>L</i>		<i>LT</i>		<i>S</i>		<i>ST</i>	
Type of Account:	Saving	Liquid	Saving	Liquid	Saving	Liquid	Saving	Liquid
Initial Cash	4000	0	0	4000	4000	0	0	4000
Free Gift	4400	0	4400	0	0	0	0	0
Total Initial Cash	8400	0	4400	4000	4000	0	0	4000
Initial Share	0		0		40		40	
Initial Ownership Value	0		0		4400		4400	
Total Initial Endowment Value	8400		8400		8400		8400	
C/A for CEO	-		-		91%		91%	

Treatment:	Investors (Non-CEO Traders)			
	<i>L</i>	<i>LT</i>	<i>S</i>	<i>ST</i>
Type of Account:	Liquid	Liquid	Liquid	Liquid
Total Initial Cash	4000	4000	4000	4000
Initial Share	40	40	40	40
Initial Ownership Value	4400	4400	4400	4400
Total Initial Endowment Value	8400	8400	8400	8400
C/A for Trader	91%	91%	91%	91%

The total initial ownership value of CEO in treatments *S* (CEO-*S*) or *ST* (CEO-*ST*) is 4400 ECUs, given the initial endowment of 40 shares. In contrast, the initial ownership value of CEO in treatments *L* (CEO-*L*) or *LT* (CEO-*LT*) is 0 ECUs, as he does not receive any share ownership. To make the total initial wealth of CEO-*L* and CEO-*LT* comparable with that of CEO-*S* and CEO-*ST*, we allocate an additional “free gift” cash of 4400 ECUs to CEOs in *L* and *LT*. This adds up to a total of 8400 ECUs worth of beginning wealth for

⁴³ CEO and investors are equally wealthy at the beginning of the session.

all CEOs (equivalent to the total initial wealth of an investor). CEO-L and CEO-LT are not able to use the “free gift” for trading. It is stored in the saving account and is only realized at the very end. The saving account will also be used to store CEO’s salary in each period⁴⁴. Table 3.4 summarizes the initial endowment of CEO and investors.

We also standardize the market parameters as much as possible, to facilitate the comparison across treatments. To create identical number of ‘stakeholders’ in each market, we cut the number of investors in treatment *S* and *ST* to four (instead of five, like in *L* and *LT*), as CEO-S and CEO-ST also act as one of the company stakeholders. This feature subsequently entails a corresponding fall in total number of subjects in the session. Treatment *S* and *ST* have five subjects (which comprises of four investors and one CEO), while *L* and *LT* have six subjects in the laboratory.

Table 3.5. Variation in the Number of Active Traders across Treatments

	<i>L</i>	<i>LT</i>	<i>S</i>	<i>ST</i>
The number of active traders	5 (5 investors)	6 (5 investors and 1 CEO trader)	4 (4 investors)	5 (4 investors and 1 CEO trader)

Table 3.5 summarizes the number of active traders across treatments. Allowing CEO to participate in trading, however, means that we have to forgo identical setup of the total cash across the four treatments, if we want to keep the cash-to-asset ratio at 91% for all active traders.⁴⁵ Recall that while CEO-L and CEO-S are given 4400 ECUs at the start

⁴⁴ As discussed in the setup for Equation (4) and (5), the total gross salary of CEO-L or CEO-LT comprises both the fixed salary and the cash bonus. Change in the capital value brought about by asset ownership of CEO-S or CEO-ST is not credited into the salary. The net salary of CEO-S or CEO-ST therefore comprises of the difference between the fixed salary and the cost of effort.

⁴⁵ There is a trade-off between having identical number of active traders, and having identical marginal impact/market power of each trader the same. We choose to retain the latter, because we expect the difference of C/A ratio to more likely impose effect on the behaviors of the non-CEO investors than the difference in the monetary base (which results from the non-identical shares per trader). Furthermore, competition can be assumed to be sufficiently high as long as we have more than 3 traders (thus we do not necessarily need to have identical number of active traders).

(like their counterparts), these currencies will never enter and circulate in the market. On the other hand, the total cash endowments of CEO-LT and CEO-ST are inevitably part of the currencies that circulate in the market. As such, the total currencies in a market range from 16000 ECU to 24000 ECU.

3.3.2. Experimental Procedure

We divide subjects according to the arrangement shown in Table 3.6. We have three markets run in parallel, for each repetition of 10 periods. Unlike non-CEOs who participate in all three replications, CEO only participates in one round randomly assigned to him, and he has to observe the other two repetitions.

We re-match four investors (or five investors, depending on the treatment) with one new CEO at the start of a new round, to remove all market-specific characteristics. As such, there will be three unique and independent observations of managerial decisions in each round.⁴⁶ We divide 236 undergraduate students from various faculties in Nanyang Technological University, into 24 markets for Treatment *L* and *LT* each, and 22 markets for Treatment *S* and *ST* each. Unlike investors who gain exposure to the trading platform through three practice periods, CEO only practices in one randomly selected trial periods.⁴⁷ This feature simulates the arrangement in actual paid session.

⁴⁶ We allow the inactive CEOs to observe the market, to ensure that the replacement CEO is as experienced as the investors in the second or the third rounds.

⁴⁷ We adopt the design of Smith et al. (1988), where initial endowments are reset at the beginning of each trial period. This is done to ensure "subjects were trained in an asset trading market in which no capital gains (or losses) were possible across trading periods... to (allow) subject experience in trading mechanics to be acquired while controlling for bubbles and crashes."

Table 3.6. Regrouping of CEOs and investors in Each Replication

	Round 1	Round 2	Round 3	Remarks
CEO 1	Market 1	0	0	Randomly determined out of a pool of 9 CEOs in each session ⁴⁸
CEO 2	Market 2	0	0	
CEO 3	Market 3	0	0	
CEO 4	0	Market 4	0	
CEO 5	0	Market 5	0	
CEO 6	0	Market 6	0	
CEO 7	0	0	Market 7	
CEO 8	0	0	Market 8	
CEO 9	0	0	Market 9	
Investors	Randomly assigned into Market 1 - 3	Randomly Assigned to Market 4 - 6	Randomly Assigned to Market 7 - 9	Investors do not know which CEO is assigned to their market

The sequence of the session is as follows. Upon arrival, subjects are seated at visually isolated computer workstations and given a copy of the instructions⁴⁹. After the instructions are read aloud, subjects have to complete a quiz on the experiment procedure, before proceeding to the practice period. It is a common knowledge that the experiment will progress after subjects have answered all questions correctly. Subjects are given randomly assigned trading ids (and also assignment as CEO or investors) in the practice round, and they will assume the same roles in the actual market.

Traders familiarize themselves with the key aspects of the open-book double auction mechanism, such as the bid and ask submissions, order cancellations, the execution of transactions), as well as the re-matching process, during the trial periods. Activities during these mock replications do not count toward subjects' final earnings.

⁴⁸ Out of every three sessions in one treatment, there are two sessions with 9 CEOs each, and one session with 6 CEOs.

⁴⁹ We include phrases such as "As CEO does not possess any of the firm's stocks, his net salary will be the overall payoff received"; "On top of the net salary received, CEO can also enjoy greater payoff if there is an increase in the terminal value of the asset"; "Higher effort will increase the gross salary received"; and "As CEO exerts higher effort, his cost of effort will increase at an increasing rate" in the instruction, to help subject see the intuition behind/make sense of the mathematical formula presented for CEO's net payoff.

Information on the prevailing terminal value is always given to the CEO before he enters the market.⁵⁰ Unlike the CEO, the investors only learn about this at the conclusion of the period. Thus, investors trade only with the knowledge of the past terminal values and effort.

One period lasts for hundred seconds, within which all subjects are free to purchase and/or sell, provided that they do not violate the short-selling constraint. CEO-ST is also required to observe a minimum holding of 40 assets in his inventory. All traders have to maintain a positive cash balance to make any purchases. If the transaction violates the short sale or the cash balance constraint, then the computer program will prohibit the individuals from doing so. Subjects receive a summary of: (i) their wealth and (ii) the CEO's effort and assets held in period t , at the end of the trading in period t . On top of that, CEO will also be informed of: (iii) his salary in the saving account.⁵¹

The average duration of the experiment is 2.5 hours. At the end of the session, trader is rewarded based on his final wealth in a randomly selected trading round. Subjects also complete the Holt and Laury risk aversion test and questionnaires, after the trading sessions.

3.4. Testable Hypotheses

We formulate the following testable hypotheses for our experiment:

Hypothesis 1: *CEO always chooses $e = 2$, and the terminal value of the asset stays at 110 in treatment L and S.*

In the absence of asset holding adjustment (and external cash injection), effort that rewards the highest payoff to the CEO is always 2. When $e_t < 2$, we say that CEO exerts

⁵⁰ Even though the net salary equals the net payoff in treatment L, we include the details of both elements in the instruction for Treatment L, to standardize it with the instructions in the other treatments.

⁵¹ We reveal information about CEO holding at the end of each period, to control for such uncertainty.

low effort and causes FV_t to be less than FV_{t-1} . When $e_t > 2$, CEO exerts *high effort* and causes FV_t to be higher than FV_{t-1} .

As the total wealth of the investors varies linearly with the terminal value, we should therefore expect zero growth of their wealth, if CEO never deviates from the optimal choices. Investors are expected to retain an average of 8,400 ECUs (the initial endowment) at the end of the session.

Rejection of Hypothesis 1 suggests that CEO does not always choose the optimal effort, in the absence of trading capacity. If the hypothesis is rejected, we will examine: (i) whether CEO generally exerts superoptimal or suboptimal effort (higher or lower than the level determined by individual utility maximization, respectively), and (ii) its impact on the general welfare of the investors.

Hypothesis 2: *CEO does not accumulate stock shares in treatment LT or ST, namely, $s' = 0$ in all periods, and he always chooses the neutral effort.*

In treatment LT and ST, CEO's optimal effort $e^*(s'_t)$ (and thus CEO's highest payoff) is no longer a constant. Instead, it is contingent upon his portfolio s'_t . Deviation from the optimal effort means that $FV_t \neq FV^*(s'_t)$. When $e_t < e^*(s'_t)$, CEO exerts *low effort* and causes FV_t to be *less* than $FV^*(s'_t)$. When $e_t > e^*(s'_t)$, CEO exerts *high effort* and causes FV_t to be *greater* than $FV^*(s'_t)$. It is therefore interesting to investigate whether the CEO explores the opportunity to hold more securities and moves beyond the *neutral effort* 2.

Rejection of Hypothesis 2 suggests that the CEO has an incentive to trade the stock of his own firm. If the hypothesis is rejected, we will examine whether: (i) the CEO's optimal effort moves beyond the *neutral effort*, (ii) CEO's effort is equal to $e^*(s'_t)$, and (iii) if there is persistent over- or under-investment of effort (*high effort* or *low effort*).

Hypothesis 3: *Holding other things equal, CEOs do not exert more effort when they are paid by the stock ownership as compared to the cash bonus.*

The results from traditional finance literature suggest that granting CEOs stock ownership leads to more effort than cash bonus do, because CEOs probably derive greater sense of attachment to the company, for the same amount of monetary benefit.

Rejection of Hypothesis 3 suggests the CEOs are indeed more motivated by the stock ownership program.

Hypothesis 4: *Investors anticipate the CEO to retain the surrender value at 110, and price their transactions according to this neutral value.*

Fundamental values in Smith et al. (1988) are pre-determined *exogenously* and are informed to all traders prior to transactions. Despite the existence of such deterministic (be it a declining, constant, or increasing) intrinsic value system, traders deviate from the intrinsic value and create price-diverging forces that sustain asset bubble in most of their transactions. Only when the experimental sessions come near the end, do the realizations that all unsold assets will become worthless at the end of the game, come into fruition. The superseding frantic sales of assets induce a sudden (and usually steep) downward pressure on the market prices. Asset price crashes when it dramatically converges to the actual fundamental value, after reaching its peak. The bubble-and-crash phenomenon is widely replicated and found to be robust by many subsequent studies.

The fundamental values in our experiment are *endogenously* determined by CEO's decision. As a result, the intrinsic value no longer follows a deterministic pattern over time. It may increase, decrease, or stay constant *depending* on the CEO's effort decision over time. Furthermore, assets are repurchased by the experimenters at the end of the session. As such, they do not become worthless by the end of the experiment. We find these elements to be a significant departure from the usual setting of Smith et al. (1988). Investors in treatment *L* and *S* should expect the fundamental value to remain at 110 as long as CEO does not depart from the optimal choices. However, once CEO deviates from

the optimal choices in any of the trading period, the subsequent trajectory becomes unknown to the investors.

The situation becomes more complicated in treatment *LT* and *ST*. Investors can reasonably expect the fundamental value to remain at 110, *as long as* CEO does not enter the *MP* or *HP* regimes. When CEO accumulates enough assets to trigger an upgrade in the optimal effort, the subsequent FV trajectory becomes a stochastic process to the investors. We can see that the elements of uncertainty in treatment *LT* and *ST* come not only in the form of whether CEO will choose effort 2 or not (as long as he is in *LP*), but also whether or not CEO decide to accumulate enough assets and realize the shifting optimal effort (or entering the *MP* and *HP* phases).

Under such nature of the fundamental value system, variables e_t , s'_t , and FV_t are not observable to the investors when they trade in period t . Investors however can utilize the information of FV_{t-1} and s'_{t-1} given to them at the end of trading in period $t-1$, to compute the (estimated) fundamental value or $\widetilde{FV}_t$. As such, we find *two* potential candidates of $\widetilde{FV}_t$ that can be used by the investors in our experiment.

As the first candidate, we assume that investors use only FV_{t-1} to estimate the intrinsic value of asset exchanged in period t . That is,

$$\widetilde{FV}_t = FV_{t-1}$$

Such a *backward looking* way of estimating the fundamental value is especially applicable for investors who observe $s'_{t-1} = 0$ all the time. When investors trade by FV_{t-1} , we say that they follow the *backward looking (BL)* path.

The second candidate for $\widetilde{FV}_t$ is more applicable for investors who observes variation in s'_{t-1} over time. We assume that investors substitute s'_t (Table 3.3) with s'_{t-1} , to estimate the (expected) e^* . When investors believe that CEO will behave rationally, they

can derive the expected *optimal* change in the terminal value (hereby denoted as $dFV^*(s'_{t-1})$) according to the following rule:

- (i) $dFV^*(s'_{t-1}) = 0$ if $s'_{t-1} < 10$,
- (ii) $dFV^*(s'_{t-1}) = 5$ if $10 \leq s'_{t-1} < 30$, and
- (iii) $dFV^*(s'_{t-1}) = 10$ if $s'_{t-1} > 30$.

We can see that $dFV^*(s'_{t-1})$ serves as an estimator for y_t , and enables the investors to derive $\bar{FV}_t$ as:

$$\bar{FV}_t = FV_{t-1} + dFV^*(s'_{t-1}).$$

When investors trade by $FV_{t-1} + dFV^*(s'_{t-1})$, we say that they follow a *forward looking(FL)* path.

Rejection of Hypothesis 4 suggests that investors price their transactions away from the *neutral* path (estimated asset value of 110) because they anticipate CEO to depart from the optimal effort (and thus for the firm asset value to grow). It will be interesting to see whether or not investors follow the *backward looking* or *forward looking* path when they expect the firm values to grow. This analysis can also be used to derive insights about the extent of the bubble and crashes phenomenon in our *endogenous* system.

3.5. Experimental Results

3.5.1. Deviation from *Neutral* Effort

Table 3.7 reports the detailed entries of the CEO's effort, with the average count exerted by each individual in one market taken as a unit of observation. Across all treatments, CEO exerts effort statistically higher than the *neutral effort*. It is, however, important to note that the optimal efforts of CEOs in treatment *LT* and *ST* (hereby denoted as CEO-LT and CEO-ST) vary according to the assets held by the CEOs. We thus first

focus our discussion on treatment L and S , where the optimal effort of the CEOs (hereby denoted as CEO-L and CEO-S) always stay at 2.

Table 3.7. Average Effort of CEOs

Treatment	Average Effort				Signed Rank p -value (H_0 : Mean Effort = 2)	n
	mean	sd	min	max		
L	2.22	0.41	1.2	3.1	0.014	24
LT	2.53	0.54	1.5	3.7	0.0002	24
S	2.16	0.4	1.1	2.9	0.076	22
ST	2.39	0.77	0.9	3.8	0.003	22

Table 3.8. Welfare Gain of Individual CEO

Treatment	CEO's gain from suboptimal efforts (%)		Signed Rank p -value (H_0 : Gain = 0)	n
	mean	sd		
L	-15.10	12.10	< 0.0001	24
LT	-21.76	20.48	< 0.0001	24
S	-14.20	15.78	0.0001	22
ST	-20.77	21.41	< 0.0001	22

As shown in the first and the third row, CEO-L and CEO-S over-exert their efforts by 22% and 16%, respectively (p -value = 0.01 and 0.08). Contrary to the above prediction, CEOs under both linear and SOP compensation choose higher effort and bring about positive growth in the surrender value. The decisions, however, come at the expense of the CEOs' welfare. To see the loss of CEOs' wealth, we compute the differences between the actual payoff (defined as the total sum of net salary and the change in the ownership values) and the highest payoff CEOs can expect to earn if they always choose the optimal effort. Table 3.8 presents the average of the CEOs' payoff gain, with the average count in one market taken as a unit of observation. It can be seen that CEOs forgo 15.1 % and 14.2

% of their maximum earnings in treatment *L* and *S*, respectively. The incurred losses are statistically distinct from zero at conventional level, illustrating the significant losses (or negative gain) of CEO-L and CEO-S due to their effort choices.

It is not feasible to calculate the investors' optimal gain from exchanging securities (or optimal capital appreciation gain). To evaluate the impact of effort decisions on the general welfare, we therefore look at the average ownership values per individual investor in one session⁵². The first and the third row of Table 3.9 indicate that investors in treatment *L* and *S* enjoy 6.64% and 4.41% gain above the total ownership values they can attain when CEO always chooses the optimal effort (p -value < 0.0001 and 0.002 respectively). We interpret that the positive growth of the surrender value improves the general welfare of the investors.

Table 3.9. Welfare Gain of Individual Investor

Treatment	Investor's gain from suboptimal efforts (%)				Signed Rank p -value (H_0 : Gain = 0)	n
	mean	sd	min	max		
<i>L</i>	6.64	5.86	-7	18	< 0.0001	40
<i>LT</i>	1.90	10.62	-20	22	0.2368	40
<i>S</i>	4.41	7.00	-10	19	0.0018	32
<i>ST</i>	-2.79	11.18	-29	17	0.2035	32

Unlike CEO-LT and CEO-ST, CEO-L and CEO-S are not given the possibility of trading to compensate the loss in their payoffs. As such, there exists a perpetual conflict of interest between the CEO and the investors with regards to the choice of effort e . The manager wants to exert effort 2, but the desirable effort level from the investor's point of view is effort 4. Our result demonstrates that CEO-L and CEO-S forgo the optimization of their welfares, in order to advance the asset value (and thus benefiting the non-CEOs), by

⁵² Unlike subjects assigned as CEOs, investors trade in three replications (or three regrouped markets) within one session.

departing from the optimal effort 2. Plausible explanation for the effort deviation may include: (1) CEOs have altruistic preferences towards the non-CEO investors; (2) CEOs think it is a social norm for the CEOs to work hard or (3) they think the identity of CEOs requires them to serve the stock owners.

We reject Hypothesis 1 and summarize our findings as follow:

Result 1: *CEOs' efforts deviate positively from the optimal level, under both the linear compensation and stock ownership plan without the possibility of trading, boosting the fundamental value of the firm shares and improving the welfare of investors.*

3.5.2. Impact of Trading Opportunity on Effort Choices

In the following segment, we examine the experimental results from treatment *LT* and *ST* to study if CEO still exerts superoptimal efforts when he can participate in the market. Table 3.10 reports the average s'_t in the final period of treatments *LT* and *ST*. Our result shows that the CEO-LT and CEO-ST withhold an average of 18.5 and 18 units more (than their initial endowments) by the end of the experiment. While there is no significant difference between the final s' of CEO-LT and CEO-ST, both figures are statistically distinct from zero. Moreover, less than 10% of the CEOs possess zero s'_t at the end of the session. We infer that the majority of the managers choose to accumulate assets over time.

Table 3.10. CEOs' Asset Holdings

Treatment	CEO's Final s'_t		Signed Rank p -value (H_0 : Final $S'_t = 0$)	n
	mean	sd		
<i>LT</i>	18.46	17.52	< 0.0001	24
<i>ST</i>	18	12.53	< 0.0001	22
Mann-Whitney p -value				
$H_0: LT = ST$	0.7495			

General expansion in the CEO's portfolio means that the optimal efforts grow well beyond the *neutral* level (for more details on the shift in optimal effort, please refer to Table 3.3). As such, analysis in Table 3.7 provides little insight as to whether CEO-LT and CEO-ST over-exert or under-exert their efforts. We subsequently derive the average of $e_t - e^*(s'_t)$, with the average count per individual CEO within one session taken as a unit of observation. As shown in the second and the fourth row of Table 3.11, we are not able to reject the null hypothesis that the effort deviation is equal to zero in both treatment *LT* and *ST*. In other words, our data seem to suggest that CEO-LT and CEO-ST exert *optimal efforts*. This is in sharp contrast with their counterparts in treatment *L* and *S* who choose *higher efforts*. However, we interpret this result with caution, on the basis that there appears to be more variations in the effort deviation of treatment *LT* (*ST*) than *L* (*S*), as demonstrated by the larger standard deviation registered (0.74 and 0.61 in *LT* and *ST*, respectively).

Table 3.11. Average Effort Deviation

Treatment	Average of $e_t - e^*(s'_t)$				Signed Rank p -value (H_0 : Deviation = 0)	n
	mean	sd	min	max		
<i>L</i>	0.22	0.41	-0.8	1.1	0.01	24
<i>LT</i>	0.08	0.74	-1.5	1.7	0.49	24
<i>S</i>	0.17	0.41	-0.9	0.9	0.07	22
<i>ST</i>	-0.09	0.61	-1.3	1.4	0.44	22

The higher rate of change in efforts is also shown in the time series graph of the effort deviation. In Figure 3.2, the vertical axis measures the average effort deviations across all sessions in the same treatment, while the horizontal axis measures the market period. As shown in the leftmost panel of the table, the solid line (treatment *L* and *S*) hovers above the horizontal line (deviation equals zero), with the second last period of treatment *S* showing

the only exception. This suggests that CEO-L and CEO-S consistently exert *high efforts* throughout the session. On the other hand, the dashed line (treatment *LT* and *ST*) fluctuates above and below the zero deviation line. Unlike CEO-L and CEO-S, we find evidences that CEO-LT and CEO-ST venture into *low efforts*. Indeed, we observe what appears to be a sequence of *low efforts* in the first half, followed by *high efforts* in the second half of treatment *LT*.

Figure 3.2. Average Deviation from Optimal Effort

To produce the statistical document, we run OLS estimation of the frequency of each effort type (*low*, *optimal*, and *high*) against treatment dummies and CEO's demographic profiles, with the average count per individual CEO taken as a unit of observation⁵³. Model

⁵³ We compute the proportion of low (optimal) effort as the number of low efforts (optimal efforts) out of 10 choices made by each CEO in each replication. In order to take into account that CEO with high possession

(2) and (4) of Table 3.12 show that allowing CEO to trade increases (reduces) his proclivities to exert suboptimal (optimal) effort: the coefficient of CEO trading dummy for *low (optimal)* effort is statistically positive (negative) at the conventional levels. On the other hand, the trading dummy coefficient for *high effort* is statistically insignificant, indicating the negligible differences between CEO with and without the trading opportunity. The analysis reveals that while CEO-LT and CEO-ST work as hard as their counterparts in treatment *L* and *S*, they are *also* more likely to under-exert their efforts at the same time.

Table 3.12. Composition of Low and High Effort

VARIABLES	<i>Low Effort</i>		Proportion of: <i>Optimal Effort</i>		<i>High Effort</i>	
	(1)	(2)	(3)	(4)	(5)	(6)
SOP dummy	2.557 (4.645)	2.669 (4.604)	4.792 (6.087)	5.331 (6.188)	-6.477 (5.775)	-7.000 (5.864)
CEO Trading dummy	11.52** (4.614)	12.08*** (4.538)	-13.04** (6.080)	-12.35** (5.999)	2.777 (5.825)	1.699 (5.813)
CEO's Risk Preference		0.396 (1.160)		-0.867 (1.373)		0.274 (1.471)
CEO's Gender		4.163 (4.294)		3.447 (6.031)		-6.733 (5.866)
Constant	9.864*** (3.487)	4.729 (8.247)	59.23*** (4.939)	62.45*** (10.54)	30.49*** (4.714)	33.07*** (10.88)
Observations	92	92	92	92	92	92
R ²	0.068	0.077	0.055	0.063	0.016	0.031
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1						

This perhaps explains why the actual payoffs of CEO-LT and CEO-ST are statistically lower than the highest payoff CEOs can possibly attain from always choosing the optimal effort (second and fourth row of Table 3.8). Underlying the seemingly negligible optimal effort is a combination of *low* and *high* efforts that cancel each other. The actions prove to be detrimental to the overall welfare of the investors: the positive earnings of the investors

(*HP*) will not be able to exert high effort, we compute the proportion of high effort as the number of high efforts out of periods without high possession in each replication.

used to enjoy in the absence of CEO's trading (Table 3.9) are now eroded, because both the *low* and *high efforts* render the investors cumulative sub-par payoff in each period. We construe that the allowing CEO to trade nullifies the positive benefits the market used to enjoy in treatment *L* and *S*. We will look more into the possible reason for the effort variation in the later subsection.

From the above analysis, we are able to reject Hypothesis 2. In essence,

Result 2: *CEOs choose to accumulate assets over time when they are allowed to trade and deviate from the neutral effort. Allowing CEO to trade increase his propensity to under-exert his effort, eroding the superoptimal benefits initially enjoyed by the investors in the absence of trading opportunity for the CEO.*

3.5.3. Market Responses to Endogenously Determined Fundamental Values

Before examining the impact of SOP plan on CEO's effort, we will first investigate how the investors' $\widetilde{FV}_t$ (section 3.4) evolve over time and how well the actual market prices fit the two possible $\widetilde{FV}_t$. Figure 3.3 presents the time series graph of the average price and $\widetilde{FV}_t$. The vertical axis measures the average value (in ECUs) across all sessions in the same treatment, while the horizontal axis measures the market period. We include the baseline $\widetilde{FV}_t = \text{neutral}$ value 110 in our analysis, to provide insights on investors' anticipation of firm value growth. As seen across all panels of Figure 3.3, the gap between solid line (average price) and the dashed-square line ($\widetilde{FV}_t = 110$) increases, while the gap between the solid line (average price) and the dashed line ($\widetilde{FV}_t = BL$) and the dashed-dotted line ($\widetilde{FV}_t = FL$) closes as we move in the eastward direction. Market price seems to increasingly deviate away from the $\widetilde{FV}_t = \text{neutral value}$ path, and converge towards the *BL*

and *FL* path. Whether *BL* or *FL* path fits the market price better, however, is not visible from Figure 3.3.

Figure 3.3. Average Price and (estimated) Fundamental Values

We tabulate the average price dispersion (from the respective paths) to complement the visual analysis. Restriction on CEO's trading means that investors in *L* and *S* observe $s'_{t-1} = 0$ all the time. Thus, we only derive the mean price dispersion of $\widetilde{FV}_t=110$ and $\widetilde{FV}_t=BL$ for market *L* and *S*. Table 3.13 presents the average distance between mean prices and $\widetilde{FV}_t$, with the average count (in ECUs) in each market taken as a unit of observation. We are able to reject the null hypothesis that the mean prices equal to all candidates of $\widetilde{FV}_t$, with the first row of Panel B and last row of Panel C showing the only exceptions. Evaluating the extent of the price error, we find that the gap between market prices and *neutral* $\widetilde{FV}_t$ are larger than mean price dispersion from *BL*, in treatment *L* and *S*. In other

words, investors anticipate CEO not to exert *neutral* effort, but to grow the firm value instead.

Table 3.13. Mean Price Dispersion from (estimated) Fundamental Path

(A). $\bar{FV}_t=110$							
Treatment	Mean	Signed Rank p -value ($H0: Dispersion = 0$)		n			
L	5.14	0.05		24			
LT	13.33	0.002		24			
S	4.21	0.08		22			
ST	15.07	0.002		22			

(B). $\bar{FV}_t=BL$				(C). $\bar{FV}_t=FL$			Signed Rank p -value ($H0: BL = FL$)
	mean	Signed Rank p -value ($H0: Dispersion = 0$)	n	Mean	Signed Rank p -value ($H0: Dispersion = 0$)	n	
L	-0.90	0.29	24	-	-	-	-
LT	6.42	0.001	24	4.39	0.005	24	0.0002
S	0.22	0.08	22	-	-	-	-
ST	8.13	0.01	22	5.31	0.51	22	0.0001

Unlike investors in L and S , investors in LT and ST are likely to observe variation in s'_{t-1} over time. Comparing the entries in Panel B and Panel C, we find that investors price their transactions closer to $FV_{t-1} + dFV^*(s'_{t-1})$ than to FV_{t-1} . The difference between the mean price error of BL is statistically larger than that of FL in both treatments, suggesting that investors further utilize the information of s'_{t-1} (on top of the information of FV_{t-1}). That is, investors adopt *forward looking* strategies in estimating the value of their assets, when CEO is able to trade. It is interesting to note that the price divergence from the BL and FL path accounts for less than 5% of the actual value of FV_{t-1} and $FV_{t-1} + dFV^*(s'_{t-1})$, respectively. We view such investors' tendencies to follow both

$\bar{FV}_t$ closely as one of the contributors to the high pricing efficiency, explored in the last subsection later.

From the above analysis, we are able to reject Hypothesis 4. The following results summarize our findings in this subsection:

Result 3: *Investors anticipate the CEO to depart from the neutral effort and grow the firm value. In markets where restriction on CEO trading, investors utilize the information of lagged terminal value and adopt a backward looking strategy in estimating the actual intrinsic value. In market where CEO can participate in trading, investors further utilize the information of CEO's portfolio adjustment (on top of the lagged terminal value) and adopt a forward looking strategy in assigning predicted values to the firm assets.*

3.5.4. Impact of SOP Plan on Effort Choices

Table 3.14 presents the OLS estimation of the effort deviation against treatment dummies and CEO's profiles, with the average count per individual CEO within one session taken as a unit of observation. As shown in model (1) and (2), the coefficients of CEO Trading dummy are statistically negative, reiterating the earlier inference that allowing CEO to trade boosts CEO's inclination to exert *low effort*. More importantly, we are not able to reject the null hypothesis that the coefficients of the SOP dummy are statistically distinct from zero. Our evidence indicates no significant improvement on CEO's effort when cash bonus is replaced with SOP plan. As such, the finding casts doubt on the frequent and important theoretical assumption that stock ownership motivates managers to work harder.

CEO, however, behaves differently towards changing market demand under the two compensation schemes. Table 3.15 reports the pairwise correlation test between effort deviation and investors' lagged net buy volume, with the average count in one period taken as a unit of observation. Here, we consider investors' lagged net buy volume as a proxy for

market's anticipation of CEO's effort adjustment. Investors will purchase assets when they believe that CEO will increase the firm value, and sell the assets when they believe otherwise. This is especially true in a market where investors utilize the information of s'_{t-1} and follow $FV_{t-1} + dFV^*(s'_{t-1})$ closely. We argue that the lagged excess demands and purchases in such markets are *not* likely the outcome of blind capital gain pursuits or speculative activities. Instead, they are a probable result of a general anticipation of higher *actual* firm value (hereby denoted as rational demand or investor sentiment).

Table 3.14. OLS Estimation of (Absolute) Deviation from Optimal Effort

	(1)	(2)
Variables	Effort Deviation	
SOP Dummy	-0.111 (0.116)	-0.120 (0.117)
CEO Trading Dummy	-0.198* (0.117)	-0.221* (0.119)
CEO's Risk Preference		-0.00193 (0.0320)
CEO's Gender		-0.158 (0.118)
Constant	0.249*** (0.0821)	0.362 (0.227)
Observations	92	92
R ²	0.041	0.060
Robust standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

As shown in Table 3.15, the Spearman's ρ and the pairwise correlation coefficients are negative in both treatment L and LT (and they are statistically distinct from zero in treatment LT). CEO's effort adjustment in market with the linear compensation appears to move *against* the surge of demand from the investors. On the contrary, the Spearman's ρ and the pairwise correlation coefficients are positive in both treatment S and ST (and they are statistically distinct from zero in treatment ST), suggesting that CEO's effort

adjustment in market with SOP plan move *in tandem* with the general surge of rational demand or investor sentiment.

Table 3.15. Correlation between Effort Deviation and Lagged Net Buy Volume

Treatment	Variable1	Variable2	Spearman's ρ	p -value	n	Pairwise Corr.	p -value
L	Deviation from Optimal Effort	Market Net Buy Volume (-1)	-0.049	0.47	216	-0.11	0.1
LT			-0.17	0.015	216	-0.35	< 0.0001
S			0.023	0.74	198	0.079	0.27
ST			0.18	0.0097	198	0.22	0.0017

One caveat of the above analysis is that the stationarity of the number of available effort options heavily influences the decision outcomes. CEO with *LP* has more choices (deviation +1 and +2) to over-exert his effort than CEO with *MP*, where the deviation produced by *high effort* is +1. (see Table 3.3 for details on the grouping of CEO based on the size of their portfolios). In other words, the intensity of *high effort* is expected to be naturally lower as CEO increases his assets. Conversely, CEO with *HP* has more option to under-exert his effort (any choice of deviation between -4 and -1), as opposed to CEO with *MP* (any choices between -3 and -1) and CEO with *LP* (deviation -2 and -1). In other words, the intensity of *low effort* is expected to be higher as CEO increases his assets.

Table 3.16. Panel Regression of Effort Deviation

VARIABLES	Dependent Variable : Deviation from Optimal Effort							
	L		LT		S		ST	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Effort Deviation (-1)	0.345*** (0.114)	0.341*** (0.113)	0.455*** (0.122)	0.425*** (0.123)	0.264* (0.139)	0.264* (0.140)	0.281** (0.139)	0.283** (0.134)
(2) CEO's Net Buy			-0.0394** (0.0167)	-0.0418** (0.0165)			-0.0389* (0.0231)	-0.0304 (0.0218)
(3) Volume (+1)			-0.0151* (0.00826)		0.00621 (0.00893)		0.0228** (0.0104)	
(4) Market Net	0.00226 (0.00859)					0.0245 (0.0525)		0.136* (0.0711)
(5) Bid Vol (-1)		-0.0471 (0.0348)		-0.156** (0.0676)			-0.456*** (0.144)	-0.457*** (0.142)
(6) <i>MP</i> Dummy			-0.199 (0.162)	-0.129 (0.145)			-0.354* (0.205)	-0.277 (0.194)
(7) <i>HP</i> Dummy			-0.408 (0.332)	-0.247 (0.327)			0.0914 (0.0913)	-0.0385 (0.102)
Constant	0.122** (0.0542)	0.162** (0.0634)	0.167** (0.0674)	0.282*** (0.103)	0.143*** (0.0460)	0.117** (0.0564)		
Observations	216	216	192	192	198	198	176	176
R ²	0.125	0.133	0.372	0.401	0.082	0.080	0.186	0.195
Number of groupid	24	24	24	24	22	22	22	22

Panel regressions with market as cross sections and periods as observations over time. Effort Deviation (-1) are dependent variables lagged by one period. To account for potential correlations within each market and potential heteroskedasticity across markets, the robust standard errors of Beck and Katz (1995) are employed throughout this analysis. The z-values are included in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

To control for the impact of different asset endowment on the effort outcome, we perform panel regressions of the periodic effort deviations, with markets as cross sections and periods as observations over time (Table 3.16). Included in the set of regressors are the *future* CEO's net buy volume (defined as CEO's net buy volume in period $t+1$), market lagged excess demand ($B_{t-1} - O_{t-1}$), as well as market lagged excess purchases ($Buy_{t-1} - Sell_{t-1}$), where B_{t-1} , O_{t-1} , Buy_{t-1} , and $Sell_{t-1}$ are the total market bid, ask, buy and sell volume in period $t-1$. Following Sutter (2012), we also employ the lagged dependent variables and the robust standard errors of Beck and Katz (1995), to account for potential correlations within each market and potential heteroskedasticity across markets.

The estimation outcomes in Table 3.16 indicate two possible reasons for CEO to depart from the optimal effort. As shown in the third row of model (3), (4), (7) and (8), the coefficient of CEO's *future* net buy volume is statistically negative for both *LT* and *ST*, with the coefficient in model (8) as the only exception. We view this as the internal factor (from the CEO himself) that drives the variation in effort decisions, when CEO is given to opportunity to trade. *Low effort* is exerted when CEO intends to purchase assets in the succeeding period, suggesting the possible attempt to drive the market price down and create favourable buying prices. CEO then switches to *high effort* when he no longer intends to accumulate assets in the following period.

At the same time, CEO appears to be affected by the lagged market response (or the external factor) as well. The impact is seen especially in treatments *LT* and *ST*. The coefficients of the lagged market excess demand and excess purchases are statistically negative in model (3) and (4). We regard this as a possible indicator of misalignment between market interest and CEO's actions. A general increase in market demand and purchases of assets (which are manifested from anticipation of rising asset values) is likely to motivate CEO-LT to exert *lower* effort.

The misalignment between CEO-LT's decisions and the market demand is expected to undermine investors' confidence in the $FV_{t-1} + dFV^*(s'_{t-1})$ path. Indeed, as shown in Figure 3.3, market price starts to diverge from the *FL* path and converge towards the *BL* path instead, at the later periods: the solid line of treatment *LT* moves closer to the dashed line (and away from the dashed-dotted line) from the seventh period onwards. Investors abandon their *forward looking* strategy after a while, and we anticipate this to undermine the price efficiency (as *forward looking* strategy is expected to enhance market price efficiency better than the *backward looking* strategy). We posit that CEO-LT distorts market anticipations due to his greater eagerness to accumulate assets. Recall that unlike his counterparts in *ST*, CEO-LT does not have any initial asset endowment. Despite of identical starting $s'_{t=0}$, CEO-LT goes further than CEO-ST (in creating downward pressure on market prices) to secure more attractive buying prices.

On the contrary, the coefficients of the two variables are statistically positive in model (7) and (8). We reckon this as evidence of the greater alignment of CEO-ST's and market interests. Higher rational demands are likely met with a *corresponding higher* effort, giving affirmation that CEO will retain the growth of the asset value. We deduce that there is a greater alignment between the market interest and the *actual* effort in *ST*. Such enhanced co-movement between CEO's decision and market anticipation of the firm value (or investor sentiment) proves to be critical in preserving investors' *forward looking* attitude. Indeed, as shown in Figure 3.3, market price tracks the *FL* path closely *throughout* the session. We will test whether this subsequently improves market price quality in the last subsection.

From the above analysis, we are not able to reject Hypothesis 3. The following results summarize our findings in this subsection:

Result 4: *Holding other things equal, CEOs do not exert more effort when they are paid by the stock ownership as compared to the cash bonus. However, we find evidences of greater*

alignment between CEO's effort adjustment and the general market anticipation of the firm value, in markets with SOP, which proves to be critical in preserving investors' forward looking strategy. In market with cash bonus, investors abandon the forward looking strategy (and revert back to the backward looking strategy), plausibly because of the confusion created by CEO's decisions.

3.5.5. Market Efficiency and Price Quality

In our final analysis, we evaluate: (i) asset mispricing, (ii) bid-ask spread and (iii) price volatility to study how the two compensation schemes eventually affect the market price quality. We measure the extent of mispricing by the *RAD*, *Total Dispersion (TD)*, and *Price Amplitude (PA)* indexes (Stöckl et al., 2010; Haruvy and Noussair, 2006); the cost of transactions by the *Absolute Spread (AS)* and *Relative Spread (RS)*; and price volatility by the *VOLA* index (Stöckl et al., 2015).

Table 3.17 presents the average count of each index in one market. As shown in Panel A to C, all three bubble measures (*RAD*, *TD*, and *PA*) are statistically higher in *L (LT)* than *S (ST)*, indicating that the stock ownership program reduces the absolute price deviation from the *actual* fundamentals, and narrows the gap between the highest and the lowest price. The cost of transaction is also lower: *AS* and *RS* are statistically lower in *S (ST)* than in *L (LT)*. Moreover, *VOLA* is statistically higher in treatment *L (LT)* than in *S (ST)*, suggesting that prices are more volatile in markets where CEO receives the linear compensation.

Table 3.17. Market Efficiency and Price Quality

Treatment	(A) <i>RAD</i>			(B) <i>TD</i>			(C) <i>PA</i>		
	mean	sd	Signed Rank (<i>H0</i> : <i>RAD</i> =0)	mean	sd	Signed Rank (<i>H0</i> : <i>TD</i> =0)	mean	sd	Signed Rank (<i>H0</i> : <i>PA</i> =0)
<i>L</i>	0.09	0.11	< 0.0001	89	116	< 0.0001	0.26	0.29	< 0.0001
<i>LT</i>	0.12	0.09	< 0.0001	124	106	< 0.0001	0.37	0.23	< 0.0001
<i>S</i>	0.04	0.04	< 0.0001	48	49	< 0.0001	0.15	0.15	< 0.0001
<i>ST</i>	0.11	0.17	< 0.0001	110	164	< 0.0001	0.21	0.13	< 0.0001
Mann-Whitney	<i>p</i> -value	<i>n</i>		<i>p</i> -value	<i>n</i>		<i>p</i> -value	<i>n</i>	
<i>H0</i> : <i>L</i> = <i>LT</i>	0.016	48		0.002	48		0.004	48	
<i>H0</i> : <i>S</i> = <i>ST</i>	0.018	44		0.010	44		0.016	44	
<i>H0</i> : <i>L</i> = <i>S</i>	0.037	46		0.033	46		0.039	46	
<i>H0</i> : <i>LT</i> = <i>ST</i>	0.059	46		0.082	46		0.003	46	
Kruskal-Wallis χ^2	17.827			21.075			22.113		
<i>p</i> -value	0.0005			0.0001			0.0001		

Treatment	(D) Absolute Spread			(E) Relative Spread			(F) VOLA		
	mean	sd	Signed Rank ($H0: AS=0$)	mean	sd	Signed Rank ($H0: RS=0$)	mean	sd	Signed Rank ($H0: VOLA=0$)
<i>L</i>	14.72	13.97	< 0.0001	0.12	0.12	< 0.0001	0.052	0.11	< 0.0001
<i>LT</i>	17.75	9.66	< 0.0001	0.15	0.10	< 0.0001	0.070	0.08	< 0.0001
<i>S</i>	8.91	10.41	< 0.0001	0.08	0.10	< 0.0001	0.029	0.10	0.0001
<i>ST</i>	11.98	9.83	< 0.0001	0.10	0.08	< 0.0001	0.023	0.02	< 0.0001
Mann-Whitney	<i>p</i> -value	<i>n</i>		<i>p</i> -value	<i>n</i>		<i>p</i> -value	<i>n</i>	
<i>H0: L=LT</i>	0.0163	48		0.0392	48		0.017	46	
<i>H0: S=ST</i>	0.0689	44		0.1661	44		0.0013	44	
<i>H0: L=S</i>	0.0073	46		0.0147	46		0.0207	44	
<i>H0: LT=ST</i>	0.003	46		0.0046	46		0.0012	46	
Kruskal-Wallis χ^2	22.324			18.836			24.926		
<i>p</i> -value	0.0001			0.0003			0.0001		

Our experimental result shows that stock ownership plan improves the overall market quality. We attribute this to the co-movement between CEO's effort decisions and market demand for assets. Greater alignment between CEO's actions and the market interests preserves the *forward looking* transactions of the investors. As *FL* strategy follow the actual FV more closely than the *BL* strategy, SOP plan subsequently enables the price to track the *actual* fundamentals more closely. In contrast, misalignment between CEO's and market interests undermines market efficiency in treatment *LT*, plausibly due to the eventual abandonment of the *FL* strategy by the investors.

Comparing treatment *L (S)* and *LT (ST)*, we can also see that allowing CEO to trade induces changes that undermine market price quality, as evident in the statistically higher bubble measures, bid-ask spread, and the price volatility indexes. We attribute this to the higher rate of effort changes (discussed in subsection 3.5.2), which ascribes more uncertainty among the investors. Our experimental result resonates the findings in the literature, where frequent changes of fundamental (which is inevitable in *LT* and *ST*, given that the CEO's optimal effort shifts) hinder price discovery process, resulting in greater price deviation (Noussair and Tucker, 2016). To put it in another word, price becomes risky because the fundamental is risky.

Nevertheless, it is critical to note that all our markets (linear compensation and SOP plan) demonstrate greater price efficiency than observations in previous studies, especially considering the low percentage of price deviation and price volatility (as shown in Table 3.17, the average relative absolute price deviations are less than 13% of the actual fundamental values, while price volatilities are less than 8% in all four treatments). We conjecture that asset bubble could be alleviated to a great extent in markets where the fundamental values are endogenously determined (by CEO's decisions, in our case) *and* assets do not become worthless at the end of the session. Investors (voluntarily or involuntarily) follow the (estimated) fundamental values

closely, minimizing the possibility for speculative or other price-diverging forces to arise. We will leave this to the future studies.

In summary,

Result 5: *Compensating CEO with stock ownership program improves market efficiency and price quality, plausibly due to the greater alignment between market valuations of firm assets and CEO's effort decisions. On the other hand, granting CEO opportunity to trade leads to larger mispricing, higher cost of transactions and greater price volatility, possibly due to the higher rate of effort changes.*

3.6. Conclusion

Executive compensation has always been at the heart of the research in corporate finance and corporate governance. This paper tests two commonly held beliefs about CEO compensation and the regulation on it: (1) that stock ownership program provides stronger incentives for CEOs, and (2) that CEO should be forbidden to trade stocks of their own firms.

For the first point, our paper finds no significant improvement in CEO's effort when the cash bonus is replaced by the SOP plan. SOP plan, however, effectively reduces market confusion about the *actual* intrinsic values, thanks to the co-movement between the investors' signals (through *lagged* excess demand and purchases of firm assets) and CEO's effort adjustment. Investors utilize information of managerial portfolio adjustment to produce *effective* estimators of the asset surrender value, and follow these estimated values closely. Such *forward looking* attitudes of the investors greatly facilitate the actual price convergence process, producing higher market price quality. We argue that our result is relevant to the actual practice where companies are also more likely to construct *restrictive rule* that forbids the owners from reselling the assets, within certain duration of time after the conferment. Our result is supportive of

the role of *restricted shares* as a useful device to facilitate greater alignment between managerial decisions and the market interests.

For the second point, our result shows that providing CEOs with the opportunity to trade induces CEO to exert *lower* effort, especially when he is in the process of accumulating more shares. We suspect that this is associated with the CEO's attempt to drive down market prices and create favourable buying prices. Higher rate of effort changes hinders price discovery process and worsens the market price quality. One implication is that the regulators indeed need to weigh the advantages and disadvantages before deciding whether to permit or ban trading by the CEOs.

Another interesting result is that compared to former experimental finance literature that repeatedly reject market efficiency, market price in our experiment tracks the fundamental values well. This is plausibly due to the stochastic nature of the endogenously determined fundamental value system and the buy-out schemes at the end of the session, which induces investors (voluntarily or involuntarily) to either follow the lagged fundamentals or the revised lagged fundamentals closely, subsequently minimizing the gap between market prices and the actual fundamental value greatly.

3.7. Appendix

Experimental Instruction

STAGE 1 – Trading Stage

Dear Participant, welcome to our experiment! **Please pay attention to the information provided here and make your decisions carefully.** If you have questions, please raise your hand and we will attend to you in private.

Please note that unauthorized communication is prohibited. Failure to adhere to this rule would force us to stop the experiment and you may be held liable for the cost incurred in this experiment. You have the right to withdraw from the experiment before you give your consent to participate in this study. However, you have to complete this experiment once consent is given.

By participating in this study, you will be able to earn a considerable amount of money. The amount depends on the decisions you and others make.

At the end of this session, this money will be paid to you privately and in cash. It would be contained in an envelope (indicated with your unique user ID) together with a payment receipt acknowledging that you have been given the correct payment amount.

Each of you will be given a unique user ID and your **anonymity will be preserved** for the study. You will only be identified by your user ID in our data collection. All information collected will **strictly be kept confidential** for the sole purpose of this study.

General Information

This is an experiment about the stock market of a fictional firm, where the **terminal value** of the stock is determined by the **effort of the CEO**.

Duration of the experiment

The trading will take place over **3 rounds**, and each round consists of **10 trading periods**. Each trading period lasts for **100 seconds**. The remaining time left in each period will be shown on your computer screen.

The market will terminate at the end of each 10th trading period and a new round will begin. At the start of the next trading round, your endowments will be replenished with new set of stocks and ECUs.

Trading Role

You will be randomly assigned a Trading Identity, either as the CEO or a trader. Your identity will remain the same throughout the session.

If you are assigned as the *CEO*, you will be required to make effort decisions in 1 round and observe the market in the other 2 rounds. The computer will randomly choose the trading round the CEO will be playing in. If you are assigned as the *investors*, you will be participating in the trading market for all three rounds. Nevertheless, you will not trade with the same set of subjects at each round. At the end of round 1 and round 2, there will be a “regrouping”. We will reshuffle the market assignment and randomly assign you to a new market with different set of traders and new CEO.

Terminal Value of the Stocks

The terminal value of the stocks varies according to the effort exerted by the CEO. **The firm will purchase all stocks held by the CEO and traders at the end of each round, based on the stocks terminal value in the last period (or the surrender value).** The firm issues **200** stocks in total.

The terminal value at the start of the first period is **110 ECU** (the experimental currency).

In each period, the CEO chooses between **5 levels of effort; {0,1,2,3,4}**. *The higher the effort exerted by CEO, the higher the profit made by the firm, and the higher the terminal value of the stock will be.* The relationship between the effort level and the change in the terminal value *per stock in period t* is shown in the following table:

TABLE 1

Effort	Change in Terminal Value
0	-10
1	-5
2	0
3	5
4	10

For example, if the CEO always chooses effort=3 for the entire 10 periods of round 1, the terminal value of each stock at the end of round 1 is $110 + 5 \times 10 = 160$ ECUs. In other words, the terminal value increases by 5 ECUs in every period, resulting in a total increase of 50 ECUs from the initial starting value of 110 ECUs. If the CEO chooses effort 0 for the first 5 periods, and 1 for the remaining 5 periods, the terminal value of each stock at the end of the round will be $110 + (-10) \times 5 + (-5) \times 5 = 35$ ECU per stock. Note that the terminal value of the stock cannot be negative.

The CEO incurs **a personal cost which varies according to the effort exerted**. When the effort exerted is e , the associated cost is **$(50 * e^2)$** . *Exerting effort is costly.*

Trading Rules

Please refer to the schematic diagram in *Diagram A* to better understand the following explanation on the trading procedure.

Trade is conducted in the form of a double auction, i.e. each trader can either **sell** or **buy** the stock at any time during the trading period. They can submit any **bid/ask quote** as well as **the number of stocks** they want to trade.

The trading is anonymous, which means the identity of the trader/CEO who makes the offer is not revealed to other participants. Information about the trading period you are trading in and the remaining time to the end of current period can be found in *Box A* and *Box B* respectively. Information about your current cash and stocks is provided in *Box C*.

During the trading period, you may **buy** or **sell** stock(s) or you may do nothing.

Two ways to buy:

1. Input the price and quantity of stock(s) you are willing to pay for in *Box D* and click “Submit Bid”. The bidding price has to **be higher than or equal** to the highest current bid. Purchase does not take place until another participant accepts your bid completely or partially, OR
2. Select ask with the **lowest price** from all asks listed in the List of Asks (*Box F*) and input the quantity of stock(s) you would like to buy and click “Buy”.

Two ways to sell:

1. Input the price that you are willing to receive in return for the quantity of stock(s) you would like to sell for in *Box D* and click “Submit Ask”. The asking price has to be **lower than or equal** to the lowest current ask. Your stocks will be sold when another participant accepts your ask completely or partially, OR
2. Select bid with the **highest price** from all bids listed in the List of Bids (*Box E*) and enter the quantity of stock(s) you would like to sell and click “Sell”.

The List of Bids (Asks) table will be arranged according to the price in descending (ascending) order and the time of posting in ascending order (earliest at the top).

If your bids (asks) are accepted by other traders, there will be a corresponding deduction (increase) of cash from the cash account and increase (fall) in the stock holding in *Box C*. Note that you are only allowed to submit a bid (ask) if you have sufficient cash (number of stocks) to trade. If you no longer have adequate cash on hand (stocks in inventory) to support your outstanding bid (ask), your bid (ask) will be *invalidated*.

After submitting a bid (ask), you have the option to **withdraw** your bid/ask by **selecting your bid (in blue color), inputting the quantity of stock(s)** you would like to withdraw from your outstanding order and clicking on the “Withdraw Bid (Ask)” button in *Box F* (*Box E*). Current price in the market is shown in *Box H*.

You will be able to make profit from buying and selling stock(s). CEO can also earn profit from the net compensation received based on the effort exerted at the start of each trading period.

Market Description

There is 1 CEO and $\{L, LT: 5 \text{ investors}\}$ $\{S, ST: 4 \text{ investors}\}$ in the market. The CEO is $\{L, S: \text{not}\}$ allowed to participate in the stock trading (buy and sell stocks). $\{L, LT: \text{CEO (Investors)}\}$ will receive a set of cash endowment (cash and stock endowment) which will be shown at the screen at beginning of the round. $\{S, ST: \}$ Both CEO and investors will receive a set of cash AND stock endowment which will be shown at the screen at the beginning of the round. In every period investors $\{LT, ST: \text{and the CEO}\}$ can trade the stocks with cash, and the balance of cash and stocks will be carried over across the periods. Each trading period will be ended automatically after 100 seconds.

Note that CEO will be played by different subjects in different rounds. Investor will also be trading with different set of investors in each round.

The Compensation of CEO

Salary given to the CEO in period t consists of a **fixed salary component** of 400 ECU $\{L, LT: \}$ and a **variable salary component** which varies according to the following equation: $0.2 (1000 \text{ effort}_t - 2000)$. You can consider the variable component as a form of **profit sharing**. The CEO will have 20% out of every profit made by the company. The profit varies proportionately with the effort the CEO puts in.

The **gross salary** received by the CEO is therefore determined by:

$$\text{salary}_t = 400 + 0.2 \times (1000 \text{ effort}_t - 2000)$$

Higher effort will increase the gross salary received. Exerting effort, however, is costly. The cost of CEO effort varies according to the level of effort exerted : $50 * \text{effort}^2$. As CEO exerts higher effort, his cost of effort will increase at an increasing rate.

Thus, the net salary for the CEO in each period is

$$\text{net salary}_t = \text{salary}_t - \text{cost}_t$$

$\{L: \}$ The CEO is not allowed to own or trade the stocks of his/her firm. As CEO does not possess any of the firm's stocks, his net salary will be the overall payoff received.

For example, if the CEO chooses $\text{effort}_t=1$ (see **Table 2**), the change of terminal value is -5; his salary will be $400 + 0.2 * (1000 * 1 - 2000) = 200$; cost incurred upon exerting $\text{effort}_t=1$ is $50 * (1^2) = 50$. Therefore, his net salary (and his net payoff) is $200 - 50 = 150 \text{ ECU}$. }

$\{LT: \}$ CEO has to purchase stocks from the market using the cash in his possession in order to own stocks. In addition to the salary received, CEO may also gain from trading stocks in his portfolio. Gain from holding stocks will vary according to **the change in the terminal values of additional stocks s'_t the CEO owns**, which in turn varies

according to $effort_t$ exerted in that period. On top of the net salary received, CEO can also enjoy greater payoff if there is an increase in the terminal value of the asset.

Table 2

<i>Effort</i>	Change in Terminal Value	Salary	Cost of Effort	Net Salary (deposited into your saving account at t)	Change in Stock Value	Overall Payoff at t
0	-10	0	0	0	0	0
1	-5	200	50	150	0	150
2	0	400	200	200	0	200
3	5	600	450	150	0	150
4	10	800	800	0	0	0

Therefore, the **overall payoff** for the CEO in each period

$$net\ payoff_t = net\ salary_t + the\ change\ in\ the\ value\ of\ stocks\ held_t$$

Table 2 shows the benefit, cost and net payoff of CEO choosing $effort_t$ when holding stock s'_t :

Table 2

<i>Effort</i>	Change in Terminal Value	Salary	Cost of Effort	Net Salary (deposited into your saving account at t)	Change in Stock Value	Overall Payoff at t
0	-10	0	0	0	$-10s'_t$	$-10s'_t$
1	-5	200	50	150	$-5s'_t$	$150 - 5s'_t$
2	0	400	200	200	0	200
3	5	600	450	150	$5s'_t$	$150 + 5s'_t$
4	10	800	800	0	$10s'_t$	$10s'_t$

where s'_t is the number of stocks he has in period t.

When the CEO retains his stocks holding at $s'_t = 0$, the actual benefit, cost and overall payoff the CEO received is shown in Table 3:

Table 3

<i>Effort</i>	Change in Terminal Value	Salary	Cost of Effort	Net Salary (deposited into your saving account at t)	Change in Stock Value	Overall Payoff at t
0	-10	0	0	0	0	0
1	-5	200	50	150	0	150
2	0	400	200	200	0	200
3	5	600	450	150	0	150
4	10	800	800	0	0	0

For example, if the CEO chooses $effort_t = 1$ (see Table 3), he will receive salary of $400 + 0.2(1000 * 1 - 2000) = 200$. If he is not holding any stock upon choosing the effort 1, he receives 0 ECUs from the change in terminal value and incurs cost of $50*(1^2) = 50$. Therefore, his net salary (and his net payoff) is $200 - 50 = 150$ ECU.}

{S: On top of the salary, the CEO also receives stock compensation. Specifically, he receives **40 stocks** at the beginning of the trading round. **However, it should be noted that CEO can neither sell these stocks nor buy more stocks (not allowed to participate in the trading market)**. In addition to the salary received, CEO may also gain from **the change in the terminal values of stocks he owns**, which in turn **varies according to $effort_t$ exerted** in that period . On top of the net salary received, CEO can also enjoy greater payoff if there is an increase in the terminal value of the asset.

Thus, the **overall payoff** for the CEO in period t is

$$net\ payoff_t = net\ salary_t + change\ in\ the\ value\ of\ the\ stocks\ held_t$$

Table 2 shows the benefit, cost and net payoff of CEO choosing $effort_t$:

Table 2

<i>Effort</i>	Change in Terminal Value	Salary	Cost of Effort	Net Salary (deposited into your saving account at t)	Change in Stock Value	<i>Net Payoff at t</i>
0	-10	400	0	400	-400	0
1	-5	400	50	350	-200	150
2	0	400	200	200	0	200
3	5	400	450	-50	200	150
4	10	400	800	-400	400	0

For example, if the CEO chooses $effort_t = 1$ (see Table 2) when he holds 40 assets, the change of terminal value is -5; his salary will be **400**; the cost incurred upon exerting $effort_t = 1$ is $50*(1^2) = 50$. Therefore, net salary deposited into saving account is $400 - 50 = 350$ ECU. Since the change in the stock value is $-(5*40) = -200$; his actual net payoff is $400 - 200 - 50 = 150$ ECU.}

{ST: Besides fixed salary, CEO also receives stock compensation. Specifically, he receives **40 stocks** at the beginning of the trading round. He is free to trade stocks, but is required to **retain a minimum of 40 stocks** in his inventory. In addition to the net salary, CEO may therefore also gain from trading stocks in his portfolio. Gain from holding stocks will vary according to **the change in the terminal values of additional stocks s'_t the CEO owns**, which in turn **varies according to $effort_t$ exerted** in that period. On top of the net salary received, CEO can also enjoy greater payoff if there is an increase in the terminal value of the asset.

Thus, the **overall payoff** for the CEO in period t therefore is:

$$\text{net payoff}_t = \text{net salary}_t + \text{change in the value of stocks held}_t$$

Table 2 shows the benefit, cost and net payoff of CEO choosing effort_t :

Table 2

<i>Effort</i>	Change in Terminal Value	Salary	Cost of Effort	Net Salary (deposited into your saving account at t)	Change in Stock Value	<i>Overall Payoff at t</i>
0	-10	400	0	400	-400 - $10s'_t$	-10s'_t
1	-5	400	50	350	-200 - $5s'_t$	150 - 5s'_t
2	0	400	200	200	0	200
3	5	400	450	-50	$200 + 5s'_t$	150 + 5 s'_t
4	10	400	800	-400	$400 + 10s'_t$	10s'_t

$$s'_t = s_t - 40$$

where s_t is the number of total stocks he has in his inventory at period t and s'_t is the additional stocks he has on top of the initial 40 stocks.

When CEO retains his stocks at 40 units and accumulates no additional stock ($s'_t=0$), the actual benefit, cost and payoff the CEO received is shown in Table 3:

Table 3

<i>Effort</i>	Change in Terminal Value	Salary	Cost of Effort	Net Salary (deposited into your saving account at t)	Change in Stock Value	<i>Overall Payoff at t</i>
0	-10	400	0	400	-400	0
1	-5	400	50	350	-200	150
2	0	400	200	200	0	200
3	5	400	450	-50	200	150
4	10	400	800	-400	400	0

For example, if the CEO chooses $\text{effort}_t = 1$ (see Table 3) when he holds 40 assets ($s'_t=0$), the change of terminal value is -5; his salary will be **400**; the cost incurred upon exerting $\text{effort}_t = 1$ is $50 \cdot (1^2) = 50$. Therefore, net salary deposited into saving

account is $400 - 50 = 350$ ECU. Since the change in the stock value is $-(5 \times 40) - (5 \times 0) = -200$; his actual net payoff is $400 - 200 - 50 = 150$ ECU.

{*L,LT*: In addition, CEO will also receive **4400 ECUs bonus** at the end of the round.} CEO has two different accounts: **cash account and saving account**. Cash account keeps CEO's cash endowment {*LT,ST*: that can be used for trading} while saving account keeps net salary and bonus received from effort exerted by the CEO. {*S,ST*: excluding the unrealized paper value of the stocks.} {*LT, ST*: Note that CEO is not able to use fund in the saving account for trading.}

Earnings

At the end of the market (after 10 periods), your stocks will be **purchased by the firm**, using a buy-out scheme where **each stock is valued according the terminal value in the last period (or the surrender value)**. The total money received from this purchase will be added to your total wealth.

If you are a CEO, your final wealth will be

$$\begin{aligned} \text{Final Wealth}_{CEO} &= \text{cash balance in the cash account} \\ &+ \text{total net salary in saving account } \{L, LT: + 4400 \text{ (bonus)}\} \{S: +40 \\ &\times \text{terminal value per stock}\} \{LT, ST: + \text{number of stocks you hold at the end} \\ &\times \text{terminal value per stock}\} \end{aligned}$$

If you are a trader, your final wealth will be

$$\begin{aligned} \text{Final Wealth}_{Trader} &= \text{cash balance at the end of the experiment} + \\ &\quad \text{number of stocks you hold at the end} \times \text{terminal value per stock} \end{aligned}$$

Summary Screen

At the end of each trading period, you will see a summary screen (*Diagram B*). It will provide information about: (i) **terminal value of the stock and effort chosen by the CEO** (*Box A1*), (ii) **the amount of cash and stocks in your inventories** (*Box B1*), (iii) **your current total wealth** (*Box C1*), and (iv) **the history of the average trading prices** (*Box A1*). CEO will also be informed about **his net salary** (*Box D1*) for effort elicited.

Reward scheme (Stage 3)

At the end of the session, **trader** will be rewarded based on his **final wealth** in a **randomly selected trading round**. **CEO** will be rewarded based on his final wealth in **the round he participates in**. The currency used in this market is called ECU (Experimental Currency Unit). We will convert your final wealth (ECUs) into Singapore Dollar according the exchange rate shown in the screen.

If you have a question that was not fully answered by the instruction please raise your hand and ask the experiment monitor before proceeding.

BEWARE! YOUR EARNINGS MAY SUFFER IF YOU PROCEED INTO THE MARKETPLACE WITHOUT UNDERSTANDING THE INSTRUCTIONS!

DIAGRAM A

Period: 1

A

Round: 1

B

Remaining Time [sec]: 7

Cash: 3982

C

Shares: 40

Table of Bids (Buying Orders)

Select the chosen order before clicking 'buy' or 'withdraw'

Price	Volume
P1	V1
P2	V2

E

Execution Quantity

Withdraw Bid

Sell

Table of Asks (Selling Orders)

Select the chosen order before clicking 'buy' or 'withdraw'

Price	Volume
P3	V3
P4	V4
P5	V5

F

Execution Quantity

Buy

Withdraw Ask

Current Price :

H

Price

Volume

Submit Bid

Submit Ask

D

G

Transactions(s) History

Price	Volume	Status of Transaction(s)

History of Withdrawn/Invalidated Order(s)

Order Price	Order Volume	Type	Withdrawn Order	Invalidated Order
				I

DIAGRAM B

Period: 1	Round: 1	Remaining Time (sec): 0
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Bibliography

- Akiyama, Eizo, Nobuyuki Hanaki, and Ryuichiro Ishikawa, 2014, How do experienced traders respond to inflows of inexperienced traders? An experimental analysis, *Journal of Economic Dynamics and Control* 45, 1-18.
- Asparouhova, E., Peter Bossaerts, and Charles R. Plott, 2003, Excess demand and equilibration in multi-security financial markets: the empirical evidence, *Journal of Financial Markets* 6, 1-21.
- Asparouhova, E., Peter Bossaerts, Nilanjan Roy, and William Zame, 2016, 'Lucas' in the laboratory, *Journal of Finance* 71, 2727-2780.
- Ausubel, Lawrence M., 1990, Insider Trading in a Rational Expectations Economy, *American Economic Review* 80, 1022-1041.
- Balvers, Ronald J., Thomas F. Cosimano, and Bill McDonald, 1990, Predicting stock returns in an efficient market, *Journal of Finance* 45, 1109-1128.
- Beck, N., Katz, J., 1995, What to Do (and not to Do) with Time-Series Cross-Section Data, *American Political Science Review* 89, 634-647.
- Benabou, Roland, and Guy Laroque, 1992, Using Privileged Information to Manipulate Markets: Insiders, Gurus, and Credibility, *Quarterly Journal of Economics* 107, 921-958.
- Bernard, Victor L. and Jacob K. Thomas, 1989, Post-Earnings-Announcement Drift: Delayed Price Response or Risk Premium?, *Journal of Accounting Research* 27, 1-36.
- Bettis, J. C, J. L. Coles, and M. L. Lemmon, 2000, Corporate policies restricting trading by insiders, *Journal of Financial Economics* 57, 191-220.
- Bhattacharya, U., and M. Spiegel, 1991, Insiders, Outsiders, and Market Breakdowns, *Review of Financial Studies* 4, 255-282.
- Biais, Bruno, Denis Hilton, Karine Mazurier, and Sébastien Pouget, 2005, Judgemental Overconfidence, Self-Monitoring, and Trading Performance in an Experimental Financial Market, *Review of Economic Studies* 72, 287-312.
- Blanchard, Olivier J., and Mark W. Watson, 1982, Bubbles, Rational Expectations, and Financial Markets, in Paul Wachtel, eds: *Crises in the Economic and Financial Structure* (Lexington, Mass.: Lexington Press).
- Boening, Mark V. Van, Arlington W. Williams, and Shawn LaMaster, 1993, Price bubbles and crashes in experimental call markets, *Economics Letters* 41, 179-185.

- Bossaerts, Peter, and Charles R. Plott, 2002, The CAPM in Thin Experimental Financial Markets, *Journal of Economic Dynamics and Control*, 26, 1093-1112.
- Bossaerts, P., Charles R. Plott, and William Zame, 2007, Prices and Portfolio Choices in Financial Markets: Theory, Econometrics, Experiments, *Econometrica* 75, 993-1038.
- Bossaerts, Peter, Cary Frydman, and John Ledyard, 2014, The Speed of Information Revelation and Eventual Price Quality in Markets with Insiders: Comparing Two Theories, *Review of Finance* 18, 1-22.
- Breeden, Douglas T., 1979, An Intertemporal Asset Pricing Model with Stochastic Consumption and Investment Opportunities, *Journal of Financial Economics* 7, 265-296.
- Cadsby, C. Bram, and Elizabeth Maynes, 1998, Corporate Takeovers in the Laboratory when Shareholders Own More Than One Share, *Journal of Business* 71, 537-572.
- Caginalp, Gunduz, David Porter, and Vernon L. Smith, 1998, Initial Cash/Asset Ratio and Asset Prices: an Experimental Study, *Proceedings of the National Academy of Sciences* 95, 756-761.
- Caginalp, Gunduz, David Porter, and Vernon Smith, 2001, Financial Bubbles: Excess Cash, Momentum, and Incomplete Information, *Journal of Psychology & Financial Markets* 2, 80-99.
- Calvo, Guillermo A., and Pablo E. Guidotti, 1992, Optimal Maturity of Nominal Government Debt: an Infinite-Horizon Model, *International Economic Review* 33, 895-919.
- Camerer, C. F. and Keith Weigelt, 1996, An Asset Market Test of a Mechanism for Inducing Stochastic Horizons in Experiments in R.M. Isaac, eds: *Research in Experimental Economics* (JAI Press: Greenwich).
- Campbell, John Y., and Robert J. Shiller, 1988, The Dividend-Price Ratio and Expectations of Future Dividends and Discount Factors, *Review of Financial Studies* 1, 195-228.
- Cecchetti, Stephen G., Pok-Sang Lam, and Nelson C. Mark, 1990, Mean Reversion in Equilibrium Asset Prices, *American Economic Review* 80, 398-418.
- Core, John E., Robert W. Holthausen, and David F. Larcker, 1999, Corporate Governance, Chief Executive Officer Compensation, and Firm Performance, *Journal of Financial Economics* 51, 371-406.
- Crockett, Sean and John Duffy, 2015, An Experimental Test of the Lucas Asset Pricing Model, *Working paper*.

- Croson, Rachel T. A. and Armando Gomes, and Kathleen L. McGinn. and Markus Nöth, 2004, Mergers and Acquisitions: An Experimental Analysis of Synergies, Externalities and Dynamics, *Review of Finance* 8, 481-514.
- Dai, Yun, Sebastian Gryglewicz, Han T.J. Smit, and Wouter De Maeseneire, 2013, Similar Bidders in Takeover Contests, *Games and Economic Behavior* 82, 544-561.
- Damodaran, Aswath, and Crocker H. Liu, 1993, Insider Trading as a Signal of Private Information, *Review of Financial Studies* 6, 79-119.
- Daniel, Kent, David Hirshleifer, and Avanidhar Subrahmanyam, 1998, Investor Psychology and Security Market Under- and Overreactions, *Journal of Finance* 53, 1839-1885.
- De Bondt, Werner F. M. and Richard Thaler, 1985, Does the Stock Market Overreact?, *Journal of Finance* 40, 793-805.
- De Long, J. B., Andrei Shleifer, Lawrence H. Summers, and Robert J. Waldmann, 1990, Positive Feedback Investment Strategies and Destabilizing Rational Speculation, *Journal of Finance* 45, 379-395.
- Deaves, Richard, Erik Luders, and Luo Guo Ying, 2009, An Experimental Test of the Impact of Overconfidence and Gender on Trading Activity, *Review of Finance* 13, 555-575.
- Dittmann, Ingolf, Dorothea Kübler, Ernst Maug, and Lydia Mechtenberg, 2014. Why Votes Have Value: Instrumental Voting with Overconfidence and Overestimation of Others' Errors, *Games and Economic Behavior* 84, 17-38.
- Dufwenberg, Martin, Tobias Lindqvist, and Evan Moore, 2005, Bubbles and Experience: An Experiment, *American Economic Review* 95, 1731-1737.
- Duxbury, Darren, 1995, Experimental Asset Markets within Finance, *Journal of Economic Surveys* 9, 331-371.
- Eckel, Catherine C., and Sacha C. Füllbrunn, 2015. Thar SHE Blows? Gender, Competition, and Bubbles in Experimental Asset Markets, *American Economic Review* 105, 906-920.
- Fama, Eugene F., 1970, Efficient capital markets: A review of theory and empirical work, *Journal of Finance* 25, 383-417.
- Fama, Eugene F., 1990, Stock Returns, Expected Returns, and Real Activity, *Journal of Finance* 45, 1089-1108.
- Fama, Eugene F., and Kenneth R. French, 1988, Dividend Yields and Expected Stock Returns, *Journal of Financial Economics* 22, 3-25.

- Fischbacher, Urs, 2007, z-Tree: Zurich toolbox for ready-made economic experiments, *Experimental Economics* 10, 171-178.
- Fishman, Michael J., and Kathleen M. Hagerty, 1995, The Mandatory Disclosure of Trades and Market Liquidity, *Review of Financial Studies* 8, 637-676.
- Forsythe, Robert, Thomas R. Palfrey, and Charles R. Plott, 1982, Asset Valuation in an Experimental Market, *Econometrica* 50, 537-567.
- Friedman, Milton, 1957, The Permanent Income Hypothesis, in *A Theory of The Consumption Function* (Princeton University Press).
- Friedman, Daniel, Glenn W. Harrison, and Jon W. Salmon, 1984, The Informational Efficiency of Experimental Asset Markets, *Journal of Political Economy* 92, 349-408.
- Füllbrunn, Sacha C., and Ernan Haruvy, 2013, The Dividend Puzzle: A Laboratory Investigation, *Research in Experimental Economics* 16, 87-110.
- Haruvy, Ernan, Charles N. Noussair, 2006, The Effect of Short Selling on Bubbles and Crashes in Experimental Spot Asset Markets, *Journal of Finance* 61, 1119-1157.
- Haruvy, Ernan, Yaron Lahav, and Charles N. Noussair, 2007, Traders' Expectations in Asset Markets: Experimental Evidence, *American Economic Review* 97, 1901-1920.
- Haruvy, Ernan, Charles N. Noussair, and Owen Powell, 2014, The Impact of Asset Repurchases and Issues in an Experimental Market, *Review of Finance* 18, 681-713.
- Holmen, Martin, Michael Kirchler, and Daniel Kleinlercher, 2014, Do Option-like Incentives Induce Overvaluation? Evidence from Experimental Asset Markets, *Journal of Economic Dynamics and Control* 40, 179-194.
- Holt, Charles A., and Susan K. Laury, 2002, Risk Aversion and Incentive Effects, *American Economic Review* 92, 1644-1655.
- Hong, Harrison, Jose Scheinkman, and Wei Xiong, 2006, Asset Float and Speculative Bubbles, *Journal of Finance* 61, 1073-1117.
- Huang, Hui, 2008, Risk aversion, mandatory disclosure and the concealment of information, *Economics Letters* 99, 2-9.
- Huddart, Steven, John S. Hughes, and Carolyn B. Levine, 2001, Public Disclosure and Dissimulation of Insider Trades, *Econometrica* 69, 665-681.
- Hussam, Reshmaan N., David Porter, and Vernon L. Smith, 2008, Thar She Blows: Can Bubbles be Rekindled with Experienced Subjects?, *American Economic Review* 98, 924-937.
- Jaffe, Jeffrey P., 1974, Special Information and Insider Trading, *Journal of Business* 47, 410-428.

- Jaworski, Taylor, and Erik O. Kimbrough, 2016, Bubbles, Crashes, and Endogenous Uncertainty in Linked Asset and Product Markets, *International Economic Review* 57, 155-176.
- Jensen, Michael C., and William H. Meckling, 1976, Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure, *Journal of Financial Economics* 3, 305-360.
- Jensen, Michael C., and Kevin J. Murphy, 1990a, CEO Incentives - It's Not How Much You Pay, But How, *Journal of Applied Corporate Finance* 3, 36-49.
- Jensen, Michael C., and Kevin J. Murphy, 1990b, Performance Pay and Top Management Incentives, *Journal of Political Economy* 98, 225-264.
- John, Kose, and Ranga Narayanan, 1997, Market Manipulation and the Role of Insider Trading Regulations, *Journal of Business* 70, 217-247.
- Judd, Kenneth L., Felix Kubler, and Karl Schmedders, 2011, Bond Ladders and Optimal Portfolios, *Review of Financial Studies* 24, 4123-4166.
- Kale, Jayant R., and Thomas H. Noe, 1997, Unconditional and Conditional Takeover Offers: Experimental Evidence, *Review of Financial Studies* 10, 735-766.
- King, Ronald R., Vernon L. Smith, Arlington W. Williams, and Mark Van Boening, 1993, The Robustness of Bubbles and Crashes in Experimental Stock Markets, in R. Day and P. Chen, eds: *Nonlinear Dynamics and Evolutionary Economics* (Oxford University Press).
- Kirchler, Michael, Jürgen Huber, and Thomas Stöckl, 2012, Thar She Bursts: Reducing Confusion Reduces Bubbles, *American Economic Review* 102, 865-883.
- Kleinlercher, Daniel, Jürgen Huber, and Michael Kirchler, 2014, The Impact of Different Incentive Schemes on Asset Prices, *European Economic Review* 68, 137-150.
- Kyle, Albert S., 1984, Market Structure, Information, Futures Markets, and Price Formation, in *International Agricultural Trade: Advanced Readings in Price Formation, Market Structure, and Price Instability* (London: Westview Press).
- Kyle, Albert S., 1985, Continuous Auctions and Insider Trading, *Econometrica* 53, 1315-1335.
- Laffont, Jean-Jacques, and Eric S. Maskin, 1990, The Efficient Market Hypothesis and Insider Trading on the Stock Market, *Journal of Political Economy* 98, 70-93.
- Lefebvre, Mathieu, and Ferdinand M. Vieider, 2014, Risk Taking of Executives under Different Incentive Contracts: Experimental Evidence, *Journal of Economic Behavior and Organization* 97, 27-36.

- Lei, Vivian, Charles N. Noussair, and Charles R. Plott, 2001, Nonspeculative Bubbles in Experimental Asset Markets: Lack of Common Knowledge of Rationality vs. Actual Irrationality, *Econometrica* 69, 831-859.
- LeRoy, Stephen F. and Richard D. Porter, 1981, The Present Value Relation: Tests based on Implied Variance Bounds, *Econometrica* 49, 555-574.
- Lo, Andrew W., and A. Craig MacKinlay, 1988, Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test, *Review of Financial Studies* 1, 41-66.
- Long, J. Bradford De, Andrei Shleifer, Lawrence H. Summers, and Robert J. Waldmann, 1990, Noise Trader Risk in Financial Markets, *Journal of Political Economy* 98, 703-738.
- Lucas, Robert E. Jr., 1978, Asset Prices in an Exchange Economy, *Econometrica* 46, 1429-1445.
- Malkiel, B. G., 1999, *A Random Walk Down Wall Street*, W.W. Norton, New York, NY.
- Manove, Michael, 1989, The Harm from Insider Trading and Informed Speculation, *Quarterly Journal of Economics* 104, 823-845.
- Mehran, Hamid, 1995, Executive Compensation Structure, Ownership, and Firm Performance. *Journal of Financial Economics* 38, 163-184.
- Mishel, Lawrence, and Natalie Sabadish, 2012, CEO Pay and the Top 1%: How Executive Compensation and Financial-Sector Pay have Fueled Income Inequality, *Economic Policy Institute*, Issue Brief 331.
- Noussair, Charles N., and Steven Tucker, 2016, Cash Inflows and Bubbles in Asset Markets with Constant Fundamental Values, *Economic Inquiry* 54, 1596-1606.
- Oechssler, Jörg, Carsten Schmidt, and Wendelin Schnedler, 2011, On the Ingredients for Bubble Formation: Informed Traders and Communication, *Journal of Economic Dynamics and Control* 35, 1831-1851.
- Oprea, Ryan, 2008, Free Cash Flow and Takeover Threats: An Experimental Study, *Southern Economic Journal* 75, 351-366.
- Plott, Charles R., and Shyman Sunder, 1982, Efficiency of Experimental Security Markets with Insider Information: An Application of Rational-Expectations Models, *Journal of Political Economy* 90, 663-698.
- Plott, Charles R. and Vernon L. Smith, 2008, in *Handbook of Experimental Economic Results* Vol. 1 (Amsterdam: North Holland).

- Porter, David P., and Vernon L. Smith, 1995, Futures Contracting and Dividend Uncertainty in Experimental Asset Markets, *Journal of Business* 68, 509-541.
- Samuelson, Paul A., 1973, Proof that Properly Discounted Present Values of Assets Vibrate Randomly, *The Bell Journal of Economics and Management Science* 4, 369-374.
- Scheinkman, Jose A., and Xiong Wei, 2003, Overconfidence and Speculative Bubbles, *Journal of Political Economy* 111, 1183-1219.
- Schnitzlein, Charles R., 2002, Price Formation and Market Quality When the Number and Presence of Insiders Is Unknown, *Review of Financial Studies* 15, 1077-1109.
- Seyhun, H. Nejat, 1986, Insiders' Profits, Costs of Trading, and Market Efficiency, *Journal of Financial Economics* 16, 189-212.
- Shiller, Robert J., 1981, Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?, *American Economic Review* 71, 421-436.
- Smith, Vernon L., 1962, An Experimental Study of Competitive Market Behavior, *Journal of Political Economy* 70, 111-137.
- Smith, Vernon L., Gerry L. Suchanek, and Arlington W. Williams, 1988, Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets, *Econometrica* 56, 1119-1151.
- Stiglitz, Joseph E., 1970, A Consumption-Oriented Theory of the Demand for Financial Assets and the Term Structure of Interest Rates, *Review of Economic Studies* 37, 321-351.
- Stöckl, Thomas, Jürgen Huber, and Michael Kirchler, 2010, Bubble measures in experimental asset markets, *Experimental Economics* 13, 284-298.
- Stöckl, Thomas, Jürgen Huber, and Michael Kirchler, 2015, Multi-Period Experimental Asset Markets with Distinct Fundamental Value Regimes, *Experimental Economics* 18, 314-334.
- Sunder, Shyam, 1995, Experimental Asset Markets: a Survey, in A. E. Roth and J. H. Kagel, eds: *The Handbook of Experimental Economics* Vol. 1, (Princeton University Press).
- Sutter, Matthias, Jürgen Huber, and Michael Kirchler, 2012, Bubbles and Information: An Experiment, *Management Science* 58, 384-393.
- Thompson, James H., 2013, A Global Comparison of Insider Trading Regulations, *International Journal of Accounting and Financial Reporting* 3, 1-23.

Van Boening, Mark V., Arlington W. Williams, and Shawn LaMaster, 1993, Price Bubbles and Crashes in Experimental Call Markets, *Economics Letters* 41, 179-185.

Zhang, Wei David, 2008, Impact of outsiders and disclosed insider trades, *Finance Research Letters* 5, 137-145.