CEO Incentives and Stock Price Dynamics: An Experimental Approach[1]

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ABSTRACT

We investigate experimentally how granting a firm's CEO with *stock ownership* and *the opportunity to trade* influence the CEO's effort and the price of the firm's stock. In our design, CEO effort affects the fundamental value of the firm. The findings suggest that, contrary to a widely held belief, stock ownership alone does not significantly increase the CEO's effort. However, CEOs tend to accumulate additional shares when they are given the opportunity to trade, and this leads to greater CEO effort. In all treatments, stock prices tend to reflect underlying fundamentals and bubbles are rare. When CEOs can trade shares, the asset exhibits somewhat greater mispricing and volatility.

THE ECONOMIC ANALYSIS OF CEO COMPENSATION has become more important, as the world has witnessed a sharp increase in CEO renumeration over the last few decades. According to the Economic Policy Institute (Mishel and Sabadish, 2012), the average ratio between CEO

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salaries and median employee compensation in the same company has increased from roughly 20 in the 1960s to about 200 in the 2010s[2]. This trend has stimulated discussion among researchers regarding whether such high payments to CEOs are justified. The empirical evidence is mixed. While Jensen and Murphy (1990b) find a positive relationship between CEO compensation and firm performance, Core et al. (1999) find that CEO pay is correlated with poor corporate governance, perhaps reflecting revenue extraction by insiders.

The structure of CEO compensation has also changed. Many firms now offer compensation in terms of stock shares and options. Theoretically, these incentives are an appropriate response to the agency problem between the CEO and shareholders (Jensen and Meckling, 1976; Jensen and Murphy, 1990a). Granting stock shares to the CEO aligns her incentives with those of shareholders. Indeed, Mehran (1995) finds that firm performance is positively correlated with the percentage of compensation that is equity-based. Moreover, equity ownership might induce a sense of proprietorship (Wasserman, 2006; Pierce et al., 2001), leading the CEO to behave more like a "steward" of the firm (Davis et al., 1997), who maximizes the objective function of the organization.

In this paper, we use an experimental approach to study how the incentive structure that a CEO faces affects her effort and resulting stock prices. The research questions that we address are the following. *First*, do CEOs invest greater effort to increase stock value when they receive shares or when they receive cash bonuses? *Second*, is the market able to price the CEO's effort correctly by incorporating effort information, which may include expectations of future effort, into share prices? *Third*, how does allowing the CEO's to trade the shares of his own firm matter for his effort? In other words, will he work harder when he can profit from trading shares? *Fourth,* how does permitting the CEO to trade affect asset prices?

In our experiment, there is a firm whose shares can be traded over a number of periods. Shares do not pay dividends. Rather, all profits are automatically reinvested and paid to shareholders at the end of the last period of trading. Transactions for shares are concluded in a continuous double

[2] Bloomberg (2013): Top CEO Pay Ratios, http://go.bloomberg.com/multimedia/ceo-pay-ratio/

auction market (Smith, 1962). The experimental design follows a 2x2 structure. The treatment dimensions are (1) whether the CEO receives a bonus in cash or in shares, and (2) whether or not the CEO is allowed to trade shares in the open market. If the CEOs invest greater effort in the stock ownership treatments, it would suggest that ownership motivates CEOs better than a cash bonus does. If permitting the CEO's to trade increases effort and market stability it would support the contention that prohibitions on insider trading by executives may be inappropriate.[3]

Our results show that stock ownership does not significantly increase managerial effort. We do not find evidence of an effect of ownership itself on effort. Asset prices do respond to CEO effort. CEOs tend to accumulate additional shares of stock when they are given the opportunity to trade, and greater shareholdings lead to higher CEO effort. The gaps between market prices and the liquidation values are generally quite small, suggesting that markets for assets with endogenously determined liquidation values are not conducive to price bubbles. In this regard, the behavior of our markets contrast sharply with experiments studying long-lived assets with exogenous liquidation values (Smith et al., 1988; Palan, 2013), and are in accord with experiments on portfolio choice and IPO of bonds where asset prices converge to the equilibrium (Bossaerts and Plott, 2002, 2004, Bossaerts et al., 2007, Crockett and Duffy, 2013, Asparouhova et al., 2015, 2016, and Weber et al., 2017).

Our study is related to several recent studies in experimental finance. Lefebvre and Vieider (2014) conduct an experiment to compare the effect of compensation with stock options versus cash bonuses, on risk taking by CEOs making investment decisions. They find that CEOs paid with stock options take more risk than those paid with cash bonuses. Similar results are reported by Holmen et al. (2014) and Kleinlercher et al. (2014). They observe that fund managers in experimental markets buy more shares when they are paid under option-like incentives, and that this behavior leads to greater asset price overvaluation. Fullbrunn and Haruvy (2013) conduct an experiment on the dividend puzzle, and the initial endowment of shares of the management team

[3] CEOs are usually forbidden to trade stock in their own firms. The typical rationale for such restrictions is that the CEO may behave opportunistically by using his insider information to trade advantageously, or by selling off shares if he expects to shirk.

is a key dimension of the experimental design. They study whether the management team votes more in the interest of shareholders (such as voting to pay dividends instead of reinvesting profits or conducting self-dealing) if they own more shares themselves. However, they find the opposite result. Pferiffer and Shields (2015) study the effect of a CEO's choice between performance-based and non-performance-based compensation on the market price of the stock. They find that the choice reflects the CEO's private information about the firm's future profitability, and the market is able to correctly incorporate the private information into the asset prices.[4] Jaworski and Kimbrough (2016) conduct an experiment in which the dividend of a monopoly firm is contingent upon the pricing decision of the CEO. They find that introducing endogenous liquidation values leads to slightly larger price bubbles and a slower process of bubble mitigation as subjects become more experienced.

Our study is also related to the experimental literature on insider trading. Plott and Sunder (1982) and Oechssler et al. (2011) investigate situations in which insiders have an informational advantage regarding an asset's liquidation value over other traders. In this literature, the liquidation value is exogenous. In our paper, we study the situation where the CEO, as the corporate insider, will always know the liquidation price of the stock, as it is endogenously determined by the CEO's effort.

This paper is organized as follows. Section I presents our experimental design and procedure. Section II discusses the results of our experiment, and Section III concludes the paper.

[4] In their experiment, there is also a treatment where the dividend of the firm depends on the effort of the CEO, but there are only two levels of effort (zero or one), and the CEO can not overinvest in effort due to the nature of the design.

I. Experimental Design and Procedure

A. General Structure

The experiment was conducted at the Nanyang Technological University in Singapore and all 236 subjects were students at the university. The average duration of a session was 2.5 hours.The experiment consisted of four treatments, called L, S, LT and ST. In each experimental session, exactly one treatment was in effect. In every treatment, a group of traders could exchange shares of a company over three consecutive ten-period markets. We refer to each consecutive ten-period market as a round. Each investor was endowed with cash and shares of stock at the outset of each market, and the market was organized under continuous double auction rules (Smith, 1962). In the LT and ST treatments, the CEO could also trade shares.

In each session, either 21 or 24 subjects participated, depending on the treatment. Nine were designated as CEOs. There were three markets operating in parallel, so that there were a total of nine markets conducted in each session. Each market had a duration of 10 periods. Non-CEOs participated in one market at a time and three markets in total in the session. Each CEO only participated in one market, but could observe the operation of one market in the other two rounds passively.[5] The market was reinitialized at the start of each round. Our data consist of 92 total markets: 24 markets each of Treatments L and LT, and 22 markets each of Treatment S and ST each.

Each period lasts for one hundred seconds, within which all subjects are free to purchase and/or sell, provided that they do not violate the short-selling constraint and maintain a positive cash balance. At the end of each period *t*, subjects receive a summary of (i) their own wealth and (ii) the CEO's effort and assets the CEO held at the end of period *t*. The CEO is also informed of (iii) his accumulated salary up to the current period.

[5] We allow the inactive CEOs to observe the market, to ensure that the incoming CEO is as experienced as the investors in the second and the third rounds.

The sequence of events in a session is as follows. Upon arrival, subjects are seated at visually isolated computer workstations and given a copy of the instructions[6]. After the instructions are read aloud, subjects have to complete a quiz about the experimental procedure, before proceeding to a practice period that does not count toward subject earnings. The experiment continues only after subjects have answered all questions correctly. Subjects are given randomly assigned trading IDs and also an assignment as a CEO or an investor in the practice round, and they retain the same roles in the actual market. At the end of the session, each trader is rewarded based on his final wealth in a randomly selected trading round. Subjects also complete the Holt and Laury (2002) risk aversion measurement task just before the end of the experimental session.

B. The Asset

In all treatments, at the end of period 10, the asset paid out a final liquidation value on each share. This liquidation value was a function of the CEO's effort over the 10-period life of the asset. The value created by the CEO in period *t* is given by

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

where Y_t is the additional value of the firm created in period *t* and e_t is the effort she chooses in period *t*. The total number of shares issued by the firm is $N = 200$, so that the additional value per share created by the CEO in one period is equal to $y_t = \frac{Y_t}{N}$. Note that Y_t is negative if $e_t < 2$, and equals 0 if e_t=2. An effort choice of $e_t < 2$ is interpreted as shirking, since it lowers the value of the company.

[6] 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 instructions, to help subject see the intuition behind/make sense of the mathematical formula presented for CEO's net payoff.

The CEO faces a convex cost function for effort given by:

$$c_t(e_t) = 50{e_t}^2 \tag{2}$$

The stock does not pay dividends, and the entire value created by the CEO is added to, or subtracted from, the value of the firm. The stock has an initial value of V_0 = 110 ECU. We shall use the term *Liquidation Value* at time *t*, V_t, to denote the initial value of a share, plus any additional value that the CEO has created up to time *t*.[7] The liquidation value evolves according to the following process:

$$V_t = V_{t-1} + y_t = V_{t-1} + \frac{(1000e_t - 2000)}{200} = V_{t-1} + 5e_t - 10 \tag{3}$$

The liquidation value V_t remains unchanged from its level in period *t* - 1 if $e_t = 2$ in all periods t. V_t increases (decreases) in period t if e_t is greater (smaller) than 2. At the time the market is operating in period t, the CEO's current effort e_t, is private information. Otherwise, all parties have equal information.

C. The Treatments

The treatments differ only in the manner in which CEO is compensated and whether she is permitted to trade shares. Exactly one compensation scheme is in effect in each session. In the L (Linear Compensation) treatment, she is compensated with a linear wage compensation plan. In the S (Stock Ownership) treatment, a stock ownership plan is in effect. The CEO is permitted to trade the stock of his firm in the LT (Linear Compensation with Trading) and the ST (Stock

[7] As we describe later in the paper, the liquidation value does not necessarily correspond to the price at which trade occurs.

Ownership Plan with Trading) treatments, respectively. Thus, our experiment employs a 2x2 design.

Table I
Structure of CEO Compensation in Treatments L and S

The subjects in the role of CEO can choose from five different effort levels as shown in the first column. The second through fifth columns report the change in the liquidation value, the cost, the benefit, and utility (benefit minus cost) associated with each effort level, respectively.

Effort (e_t)	Change in LiquidationValue (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

The CEO receives a fixed salary $a_t = 400$ in each period. Depending on the treatment, he may also receive a cash bonus b_t, and/or a capital gain or loss through changes in his ownership value $s_t y_t$ for holding shares. In both cases, the cash bonus and capital gain/loss are proportional to the firm's profit Y_t. In treatment L, we let

$$b_t = 0.2Y_t \tag{4}$$

This means that the cash bonus to the CEO is equivalent to 20% of the profit of the firm. This bonus is credited to the CEO's salary in addition to her salary in each period.

In Treatment S, the CEO has an initial endowment of $s_0 = 40$ shares, and the CEO is not allowed to sell this endowment. A change in the value of shares at time *t* generates a capital gain/loss of

$$\frac{s_0}{N} Y_t = \frac{40}{200} Y_t = 0.2 Y_t \tag{5}$$

in each period to the CEO. This implies that, without the possibility of share trading and, holding the CEO's effort e_t equal, the cash bonus in treatment L and capital gain in treatment S are exactly identical. However, unlike the cash bonus in treatment L, the ownership value is not credited as salary to the CEO in each period. Instead, it is only realized at the end of the market after period 10.[8]

Therefore, in both treatments L and S, the utility of the CEO can be written as:

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

The *payoffs* to the CEO for different levels of effort are shown in Table I. If the CEO purely maximizes his individual payoff, he would always choose $e_t = 2$, in which case Y_t=0, and the liquidation V_t of the stock shares would stay unchanged at 110 over the ten periods. In other words, the optimal effort e_t^* in treatment L and S always equals 2.

[8] We provide information about the appreciation or depreciation of traders' shares in the summary screen at the end of each period, so that all traders, including the CEO, can track their capital gain in each period.

Table II
CEO Compensation in LT and ST

The subjects in the role of CEO can choose from five different effort levels as shown in the first column. The second through fifth columns report the change in the liquidation value, the cost, the benefit, and the payoff/ utility (benefit minus cost) associated with each effort level, respectively. Different from L and S, the payoff of the subjects in these treatments depend on the additional shares that they accumulated, s'_t.

Effort (e_t)	Change in Liquidation Value (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	$600 + 5s'_t$	$150 + 5\ s'_t$
4	10	800	$800 + 10s'_t$	$10s'_t$

The CEO's incentives in the LT and ST treatments differed from those in L and S. 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 in period t, then $s'_t = s_t$. Similarly, if s_t is the stock position held in treatment ST, then $s'_t = s_t - 40$ (40 is the CEOs initial endowment in ST). The net utility gained from choosing effort e_t can be expressed as a function of effort (e_t) and the number of assets held before the stock trading begins (s'_t):

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

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

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

The total utility she receives over a ten-period market is therefore:

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

Table II shows that an effort level of 2 is the optimal effort for the CEO at the initial level of share holdings. That is, $e_t^*({s'}_{t=1} = 0) = 2$. Consequently, the liquidation value of a share 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 III
Optimal Effort as a Function of Shares Held

The optimal effort level changes with the number of additional shares accumulated s_t'. The first and the second columns give the intervals of asset holdings and their definitions. The third column gives the corresponding optimal CEO effort levels.

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

In LT and ST, the CEO has an incentive to purchase and accumulate shares over time and then exert high effort to increase the value of her holdings. When the CEO owns more stock shares, it is optimal for her to invest effort greater than $e = 2$. More generally, the optimal effort in period *t* varies depending on ${s'}_t$.[9] Table III summarizes the relationship between optimal effort and CEO share holdings.

[9] Investors are able to derive how the optimal effort of the CEO changes with 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).

D. The Parameters

All investors other than the CEO start period 1 of each market with an endowment of 40 shares[10]. Given that the initial share value is 110 ECUs[11], an investor's stake in the firm is 4400 ECUs per trader. In addition, each trader other than the CEO receives an initial cash endowment of 4000 ECUs. Thus, the initial endowment of each non-CEO investor, evaluated at the initial liquidation value, is 8400 ECUs.[12] All CEOs also receive initial cash amounting to 4000 ECUs at the beginning. In LT and ST, this cash can be used for purchases. In *L* and *S,* this cash is stored in a saving account.[13]

The initial value of the CEO's shares in each market in treatments S and ST is 4400 ECUs, given the initial endowment of 40 shares. To make the total initial wealth of CEOs in L and LT comparable with S and ST, we endow 4400 ECUs in cash to CEOs in L and LT. This yields a total of 8400 ECUs of initial wealth for all CEOs, which is equal to the initial wealth of a non-CEO investor. The cash endowment of CEOs in L and LT cannot be used for trading, but converts to earnings at the end of the market. In LT and ST, the salary account is separate from the trading account so that the CEOs in treatment LT and ST cannot use their salary income to trade, which ensures that the cash-asset ratio does not vary over time in our experiment.[14] Table IV summarizes the initial endowment of CEO and investors.

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

[11] As the asset value can fall by at most 10 ECU in each period, we set 110 ECU as the starting value of asset. This is to ensure that the asset's terminal value can never be negative.

[12] The CEO and each investor is equally wealthy at the beginning of the session.

[13] This cash endowment means that expected payoff of a CEO in L and S is identical to LT and ST if the latter groups do not change their share holdings.

[14] The cash-to-asset ratio is the ratio of the total amount of cash held by investors divided by the total value of the assets in market, evaluated at their intrinsic value. Greater cash-to-asset ratios have been associated with higher prices (Caginalp et al., 1999; Haruvy and Noussair, 2006; Kirchler et al., 2012).

Table IV

Initial Endowment of CEO and Non-CEOs in Each of the Three Markets

Initial Cash means the cash that the participant can use to purchase stock shares. *Free Gift* means the "gift" from the experimenter to the subjects to make sure the CEOs on expectation earn the same payoff across the treatments. *Ownership Value* means the initial value of the endowment in terms of stock shares.

					CEO			
Treatment:	L		LT		S		ST	
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%	

	Investors (Non-CEO Traders)			
Treatment:	L	LT	S	ST
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%

We also standardize the market parameters as much as possible in order to facilitate the comparison across treatments. To create an identical number of shareholders in each market, we set the number of investors in treatment S and ST to four (instead of five as in L and LT), as the CEO in S and ST also acts as one of the company shareholders. Thus, Treatment S and ST have five subjects participating (four non CEO investors and one CEO with share ownership), while L

and LT have six participants (with five non CEO investors and one CEO either without share ownership, which is always the case in Treatment L and at least initially in Treatment LT).

E. Determination of the Fundamental Value Models

The liquidation values in our experiment are *endogenously* determined by the CEO's decisions. In treatments L and S, the liquidation value remains at 110 as long as CEO does not depart from the choices that maximize her own earnings. However, once the CEO deviates from the optimal choices in any of the trading period, the liquidation value also changes.

In treatments LT and ST, the liquidation value does not necessarily remain at 110, even if the CEO chooses her effort optimally given her holdings, because the CEO may accumulate or de-cumulate shares of the asset. The variables e_t , s'_t, and V_t are not observable to the investors when they trade in period *t*. Investors, however, can utilize the information about V_{t-1} and s'_{t-1}, given to them at the end of trading in period *t-1*, to compute a fundamental value model at period t, $\widetilde{FV}_t$. As such, we propose *four* plausible candidates for $\widetilde{FV}_t$.

The first candidate model, called *Naïve Expectations* (NE), is based on the assumption that the CEO purchases as many shares as she can using her initial cash endowments. However, we also assume that other investors are not aware that the CEO plans to acumulate units, and sell their shares to the CEO at any price greater than or equal to 110. In other words, the non-CEO investors have Naive Expectations. If the CEO uses all his cash to buy assets at the price 110, he can buy 36 additional shares (market value equals 36*110=3960). When he holds 36 additional shares, his optimal effort is 4, and this increases the liquidation value by 10 in each period. Accordingly, the time trajectory of the fundamental value is given by

$$\widetilde{FV}_t = \{110, 120, 130, \dots, 210\} \quad \text{for} \quad t \in \{1,2,3, \dots, 10\}$$

The second model, *Rational Expectations* (RE), is also based on the assumption that the CEO attempts to accumulate all the shares that he can. Non-CEO investors, however, have Rational Expectations, and thus anticipate this behavior. Consequently, they try to obtain better prices for their shares.[15] When this happens, the shares become more expensive, and the CEO cannot buy enough shares to make his optimal effort equal to 4. The CEO accumulates as many units as possible, and it is optimal for the CEO to choose effort 3 for all the periods. Because the CEO is given 4000 ECUs worth of cash before trading in the first period commences, the CEO can only purchase 4000/160 = 25 additional shares. The optimal effort $e^*(s_t' = 25) = 3$ when $s_t' = 25$. Therefore, the fundamental value trajectory under the RE model is:

$$\widetilde{FV}_t = \{110, 115, 120, \dots, 160\} \quad \text{for} \quad t \in \{1,2,3, \dots,10\}$$

Under the third model, *Backward-Looking Expectations* (BL), we assume that investors use only the previously prevailing liquidation value V_{t-1}, which becomes observable in period *t*, to estimate the intrinsic value of asset exchanged in period *t*. That is,

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

Such a *backward-looking* rule of estimating the liquidation value is especially applicable for investors who observe $s'_{t-1} = 0$. They might reasonably anticipate no change in the CEO's effort in any later period.

[15] There are two possible better prices, one is 160 ECUs, which is realized when the CEO's effort is equal to 3 for all periods, and the other is 210 ECU's when the CEO's effort is equal to 4 for all periods. However, when the price is 210 ECUs, the cash endowment of the CEO is insufficient to buy enough shares (30 shares) for *e*=4 to be conditionally optimal. So 160 ECUs is the only feasible better price, where the CEO will buy 25 additional shares, and his optimal effort is equal to $e_t^* = 3$ when he has accumulated this number of shares.

The last candidate for $\widetilde{FV}_t$, called *Forward-Looking Expectations* (FE), assumes that traders believe that the CEO will behave rationally in her future purchase and effort decisions. The expected *optimal* change in the liquidation value between periods $t - 1$ and t (hereby denoted as $dV^*(s'_{t-1})$) follows rule:

(i) $dV^*(s'_{t-1}) = 0$ if $s'_{t-1} < 10$,

(ii) $dV^*(s'_{t-1}) = 5$ if $10 \leq s'_{t-1} < 30$, and

(iii) $dV^*(s'_{t-1}) = 10$ if $s'_{t-1} > 30$.

Thus $\widetilde{FV}_t$ follows the trajectory:

$$\widetilde{FV}_t = V_{t-1} + dV^*(s'_{t-1}).$$

The first two notions *NE* and *RE* represent the pre-determined fundamental value models for the 10-period life of the asset that are independent of history. The last two candidates, *BL* and *FL*, are the 1 period ahead, extrapolative models that depend on the history of CEOs' activities. Unlike the *RE* and *NE* rules, the *BL* and *FL* rules can adjust in the sense that it can be satisfied in any period *t*, even though they were not at $t - 1$. In our subsequent discussions in this paper, we use the term 'liquidation value' to denote the *actual* liquidation value. We use the term 'extrapolative fundamental value model' to denote the BL and FL models, and the term 'static fundamental value model' to denote the RE and NE models.

F. Testable Hypotheses

The hypotheses that we test in our experiment are based on the arguments above regarding optimal behavior. The first two hypotheses concern CEO behavior. In the L and S treatments, the effort that yields the highest payoff to the CEO is always 2, and the resulting liquidation value is 110. We take as our null hypothesis that the average effort will equal this level. Stating the

hypothesis in terms of average behavior allows for some unbiased noise in the effort decisions. The hypotheses would be supported if CEO tended to make optimal decisions

HYPOTHESIS 1: In treatments L and S, the CEO chooses an average effort $e = 2$, and the liquidation value of the asset averages 110 over the life of the asset.

Rejection of Hypothesis 1 would indicate that the CEO exhibits biases in her choice of effort. Such a pattern would suggest that the CEO's decision problem is too difficult for our subjects.

The parameter values in the experiment were chosen so that CEO incentives to exert effort and accumulate units, as well as their capacity to purchase units, are identical under LT and ST. Therefore, we hypothesize that there would be no difference in effort in the two conditions.

HYPOTHESIS 2: CEOs exert similar effort when they are paid by stock ownership and when they receive cash bonuses. Thus, average effort is similar between L and S, as well as between LT and ST.

Rejection of Hypothesis 2 would suggest that the CEOs are indeed motivated by the stock ownership program. Greater effort in the S than the L treatment, and more effort in the ST than the LT treatment, would be consistent with a feeling of responsibility or stewardship.

In the LT and ST treatments, the CEO's optimal effort $e^*(s'_t)$ is increasing in her holdings s'_t. We thus expect that some CEOs accumulate shares and then exert high effort to increase their value, while other CEOs sell their shares and subsequently shirk. The consequence is a positive relationship between share holdings and effort.

HYPOTHESIS 3: In LT or ST, there is a positive correlation between CEO share holdings and CEO effort.

The last hypothesis concerns market prices. In the L and S treatments, there is an unambiguous prediction about market prices. These should equal 110, the liquidation value under optimal CEO decision making. For the LT and ST treatments, we do not advance a hypothesis about which of the expectation rules described above would apply, but rather compare their relative performance. We advance a hypothesis about price level, only for the L and S treatments, for which we have a clear prediction. While bubbles have been observed in other experimental designs, we do not know whether they would occur here. Thus, we hypothesize that prices would track liquidation values in the treatments where the liquidation value is unambiguous.

HYPOTHESIS 4: In the L and S treatments, prices equal the liquidation value of 110.

II. Results

A. Effort Decisions in the L and S Treatments

Table V reports the average CEO effort, by treatment, with the average effort exerted by each individual in one market taken as a unit of observation. In the L and S treatments, the average effort by the CEO is close to the predicted level of 2. In particular, CEOs choose effort that modestly exceeds the optimal level of 2 by 11% and 8%, respectively. The first difference is significant ($t = 2.63$, $p < .05$, two-tailed test), while the second is marginally significant ($t = 1.91$, $0.05 < p < .1$, two-tailed test). A similar pattern of significance is observed under signed-rank tests. We are unable to reject the null hypothesis that the average effort in treatment L is statistically distinct from treatment S, with either a t-test or a signed rank test.

Table V
The Summary Statistics of Effort of CEOs

The first column reports the name of the treatments, and the second through sixth columns report the mean, standard deviation, the *p*-value of the t-test and the signed rank test against the predicted effort of 2, and the number of observations.

Treatment	mean	sd	Average Effort Exerted t-test *p*-value (*H0*: Mean Effort = 2)	Signed Rank *p*-value (*H0*: Mean Effort = 2)	n
L	2.22	0.41	0.0151	0.0136	24
LT	2.53	0.54	0.0001	0.0002	24
S	2.16	0.4	0.0694	0.0759	22
ST	2.39	0.77	0.0039	0.003	22
			t-test *p*-value	Mann-Whitney *p*-value	n
H0: L = LT			0.0286	0.034	48
H0: S = ST			0.0724	0.1372	44
H0: L = S			0.6671	0.69	46
H0: LT = ST			0.8195	0.6197	46

We thus obtain Result 1 in relation to Hypothesis 1:

Result 1: In the L and S treatments, in which the CEO cannot trade shares, the CEOs' effort is close to, though modestly exceeding, the optimal level of 2. The difference is small but significant. Hypothesis 1 receives partial support.

B. The Impact of Allowing the CEO to Trade on the CEO's Effort Choices

In this subsection, we examine the effort decisions in Treatments LT and ST, where the CEO can participate in share trading. Table VI reports the average value of s'_t in the final period of Treatments LT and ST. The table shows that the CEOs hold on average 18.5 and 18 more shares, in LT and ST respectively, than their initial share endowments. While there is no significant difference between the final s' in LT and ST, both figures are significantly different from zero under both the t-test and the signed rank test. 90% of CEOs hold more assets at the end of the market than at the beginning.

Table VI
CEOs' Asset Holdings

This table reports the mean and standard deviation of the average CEO's accumulation of share holdings s'_t. It also contains the *p*-values of the t-test and the signed rank test against a mean value of zero, and the number of observations.

	CEO's Final s'_t				
Treatment	mean	sd	t-test *p*-value (H0: Final $s'_t = 0$)	Signed Rank *p*-value (H0: Final $s'_t = 0$)	n
LT	18.46	17.52	< 0.0001	< 0.0001	24
ST	18	12.53	< 0.0001	< 0.0001	22
			t-test *p*-value	Mann-Whitney *p*-value	n
H0: LT = ST			0.9198	0.7495	46

Table VII
Average Difference between Observed and Optimal Effort

The first column lists the name of the treatments, and the second through sixth columns report the mean, standard deviation, the *p*-values of t-test and signed rank test of the hypothesis that observed and optimal efforts are equal, and the number of observations.

Treatment	mean	sd	Average of $e_t - e^*(s'_t)$ t-test *p*-value (H0: Deviation = 0)	Signed Rank *p*-value (H0: Deviation = 0)	n
LT	0.08	0.74	0.6030	0.4913	24
ST	-0.09	0.61	0.4929	0.4447	22
			t-test *p*-value	Mann-Whitney *p*-value	n
H0: LT = ST			0.4006	0.3269	46

The increase in the CEO's holding of assets in LT and ST means that the optimal effort exceeds the level of 2 that would prevail if there were no accumulation of assets. As such, the analysis in Table V provides little insight as to whether CEOs over-or under-exert effort relative to the optimal level in LT and ST. Table VII displays 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 first and the second row of Table VII, we are not able to reject the null hypothesis that the difference between observed and optimal effort is equal to zero in either treatment LT and ST with either t-tests or signed rank tests. In other words, our results suggest that CEOs in both LT and ST exert optimal effort. Nevertheless, the standard deviation in treatment LT (ST) is greater than under L (S), are, respectively, 0.74 (0.61) and 0.41 (0.17). Thus, when the CEO is able to trade, the variation in the effort levels are higher.

We are not able to reject the null hypothesis that the effort deviation in LT is statistically distinct from that in ST, with either a t-test or a signed rank test. The result, coupled with the lack

of difference between L and S, indicates that stock ownership does not significantly increase managerial effort, relative to an equivalent cash bonus. There is no evidence that the CEO behaves like a steward of the firm when he possesses more equity. As stated in result 2, hypothesis 2 is supported.

Result 2: Average effort is not significantly different between L and S. Average effort is not significantly different between LT and ST.

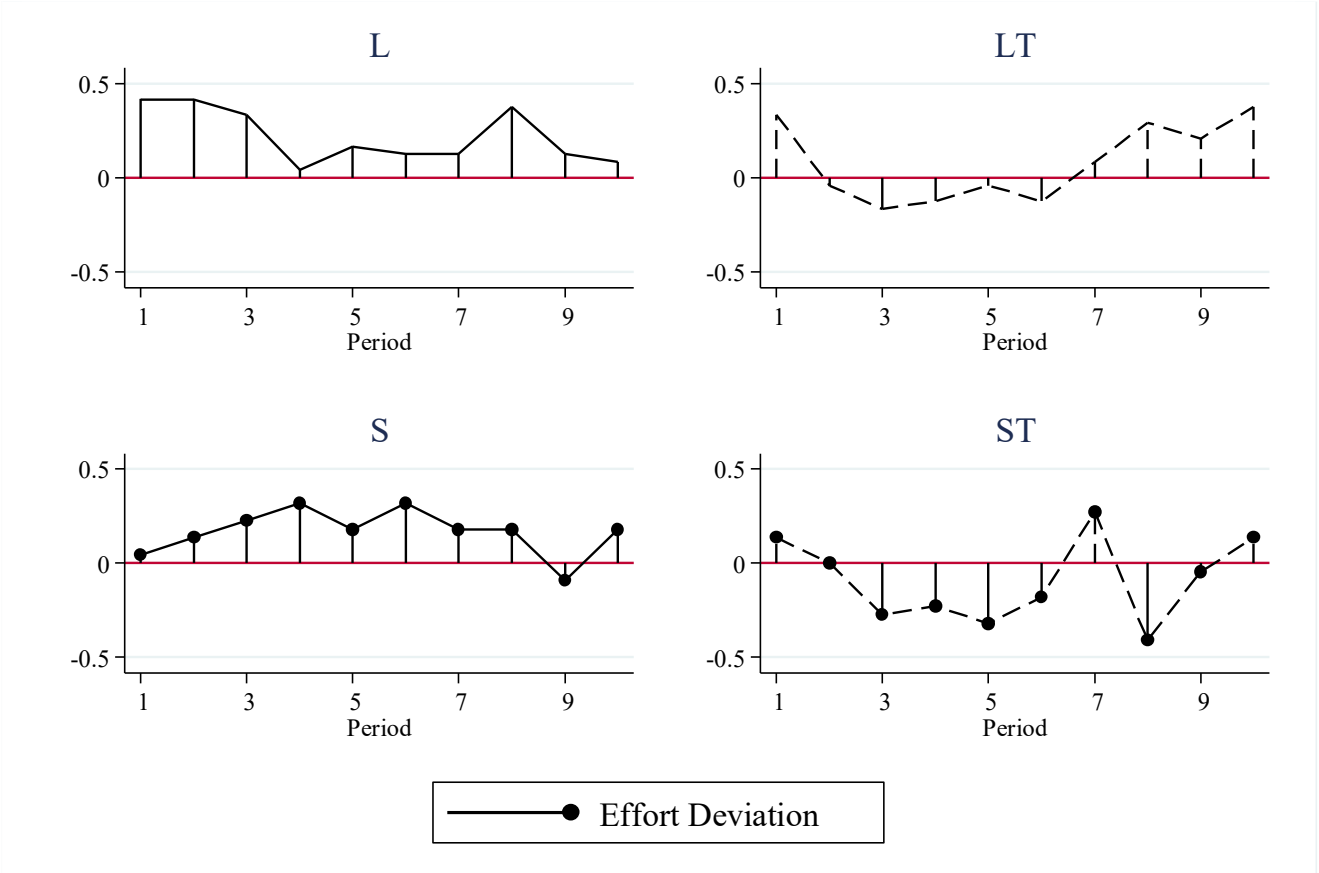

Figure 1: Average Difference between Observed and Optimal Effort. The vertical axis measures the average effort deviations from the conditionally optimal trajectory across all sessions in the same treatment, while the horizontal axis measures the market period for treatment L (top left), S (bottom left), LT (top right) and ST (bottom right). The data series are the average differences between observed and optimal effort in each treatment.

The time profile of effort in LT and ST is shown in Figure 1. In the figure, the vertical axis measures the average effort deviations from the conditionally optimal trajectory 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 close to, though slightly above the horizontal line. This suggests that CEOs consistently exert close to optimal effort throughout the session. While the dashed line (treatment LT and ST) fluctuates above and below the zero deviation line, it remains very close to the optimal trajectory.

Overall, hypothesis 3 is supported, as stated in result 3.

Result 3: In LT and ST, CEOs accumulate assets over time. Effort levels are close to optimal given CEOs' asset holdings.

C. Market Responses to Endogenously Determined Liquidation Values

In this section we investigate the dynamics of the liquidation values, as well as the relationship between prices and the fundamental value models. We first evaluate how well the the fundamental value models track the liquidation values. Recall that there are two types of model; 1) the extrapolative models (BL and FL) and 2) the static models (RE and NE). In the subsequent analysis, we also include the neutral fundamental value of 110 ECUs as one of the static models, to obtain a more coherent picture with regards to hypothesis 1 and 2.

Figure 2 presents the time series of the average differences between the fundamental value models and the actual liquidation values, with the average of all markets within a treatment taken as a unit of observation. The vertical axis measures ($\widetilde{FV}_t - V_t$), while the horizontal axis measures the market period. The closer the time series line is to zero, the smaller the difference between the data and the particular model in question, and thus the better the fit between the model and the actual liquidation values.

As shown in the left side of Figure 2, the series marked with hollow circles is closer to the 0-line than is the dark-square line in treatment L and S. Similarly, the hollow-circle and light-

diamond lines are closer to the 0-line than the dashed, cross-dashed, and dark-square lines in treatment LT and ST, shown in the right side of Figure 2. Our result thus suggests that the extrapolative models (BL and FL) correspond more closely to the trajectory of the liquidation value than do the static models (RE and NE).

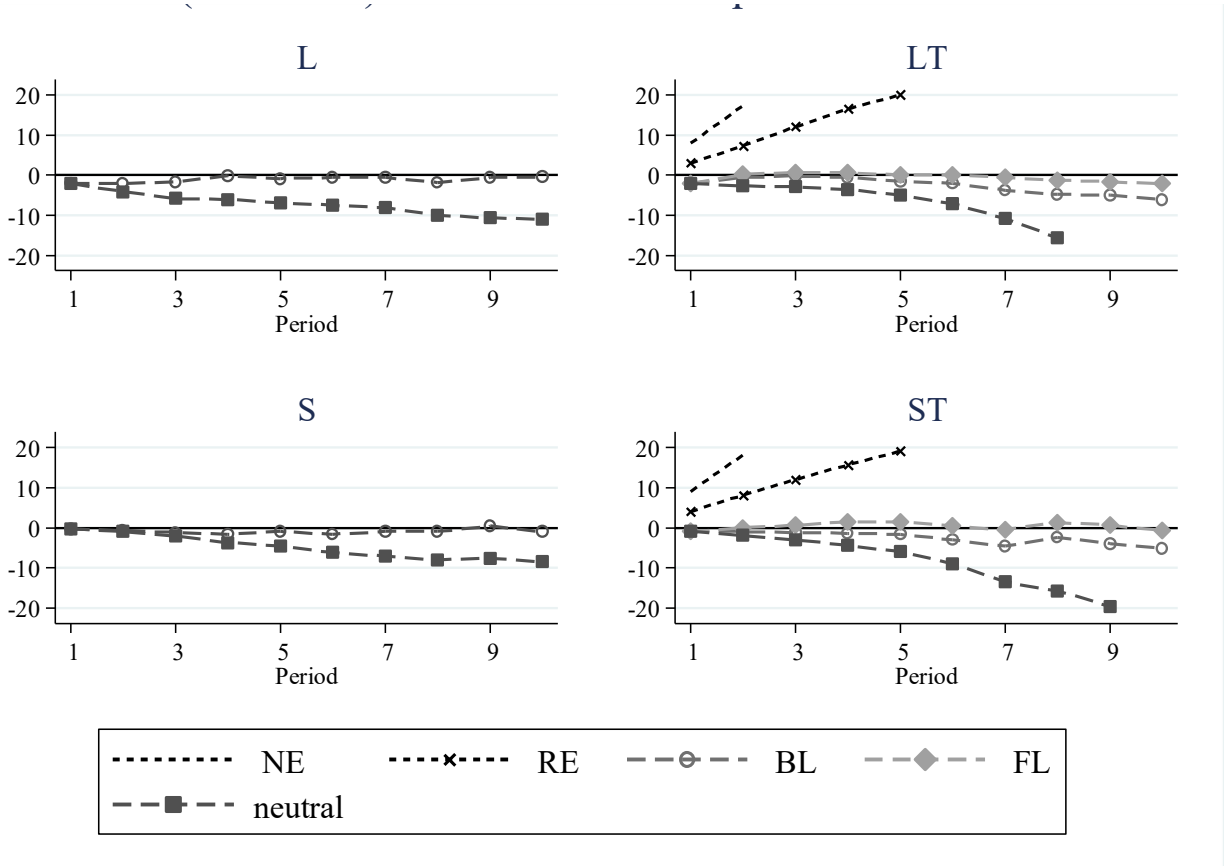

Figure 2: Difference Between Fundamental Value Models from the Liquidation Values. The vertical axis measures ($\widetilde{FV}_t - V_t$), while the horizontal axis is the market period. The data is the average of all markets within a treatment. The closer the time series line is to the zero, the better the fit of the model to the liquidation value data.

Table VIII

Average Difference between the Fundamental Value Models and the Liquidation Value

The first column lists the name of the treatments, and the second through tenth columns report the mean, the *p*-values of t-tests and signed rank tests of the hypothesis that the difference equals zero, and the number of observations.

Liquidation Value Dispersion from *NE*					Liquidation Value Dispersion from *RE*				Liquidation Value Dispersion from 110			
		H0: Dispersion = 0				*H0:* Dispersion = 0				*H0:* Dispersion = 0		
Treatment	mean	t-test *p*-value	Signed Rank *p*-value	n	mean	t-test *p*-value	Signed Rank *p*-value	n	mean	t-test *p*-value	Signed Rank *p*-value	n
									-7.23	0.0087	0.0078	24
LT	45.29	< 0.0001	< 0.0001	24	17.79	0.0001	0.0002	24	-9.71	0.0152	0.0150	24
									-4.84	0.0855	0.0844	22
ST	45.20	< 0.0001	< 0.0001	22	17.70	0.0007	0.0010	22	-9.80	0.0388	0.0459	22

Liquidation Value Dispersion from *BL*					Liquidation Value Dispersion from *FL*					
		H0: Dispersion = 0				*H0:* Dispersion = 0			*H0:* BL = FL	
Treatment	mean	t-test *p*-value	Signed Rank *p*-value	n	mean	t-test *p*-value	Signed Rank *p*-value	n	t-test *p*-value	Signed Rank *p*-value
L	-1.10	0.0151	0.0106	24						
LT	-2.67	0.0001	0.0002	24	-0.63	0.3877	0.4056	24	0.0001	0.0002
S	-0.84	0.0694	0.0730	22						
ST	-2.45	0.0039	0.0033	22	0.43	0.5163	0.6137	22	< 0.0001	0.0001

We compile the numerical entries of the gap between each model and the liquidation values in Table VIII, and find statistical evidence showing that the gap between the extrapolative models and the liquidation values is the smallest among the fundamental value models. We infer that CEOs utilize information about the history of their activities and their corresponding asset holdings, instead of following rational or naïve expectations in determining their efforts. Consequently, traders' close adherence to the BL and FL models is expected to help market prices better track the liquidation values.

Next, we look at the relationship between market prices and the fundamental value models. Figure 3 presents the time series of the average price and $\widetilde{FV}_t$. The vertical axis measures the fundamental value models and the prices, while the horizontal axis measures the market period. The data are averages of all markets within a treatment. As can be seen in all panels of Figure 3, the gap between the solid line (the average price) and the dotted line (NE, RE and $\widetilde{FV}_t$=110) increases, while the gap between the solid line (average price) and the dashed-circle line ($\widetilde{FV}_t$=*BL*) and the dashed-diamond line ($\widetilde{FV}_t$ =*FL*) closes as the market proceeds. The market price seems to increasingly deviate away from the $\widetilde{FV}_t$ = 110, and converges towards the *BL* and *FL* models rather than the *NE* or *RE* models.

Table IX 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. The gap between market prices and $\widetilde{FV}_t$ = 110 is larger than the mean price difference from *BL* in treatments L and S. In other words, investors utilize the previously prevailing liquidation value V_{t-1} to anticipate the current liquidation value.

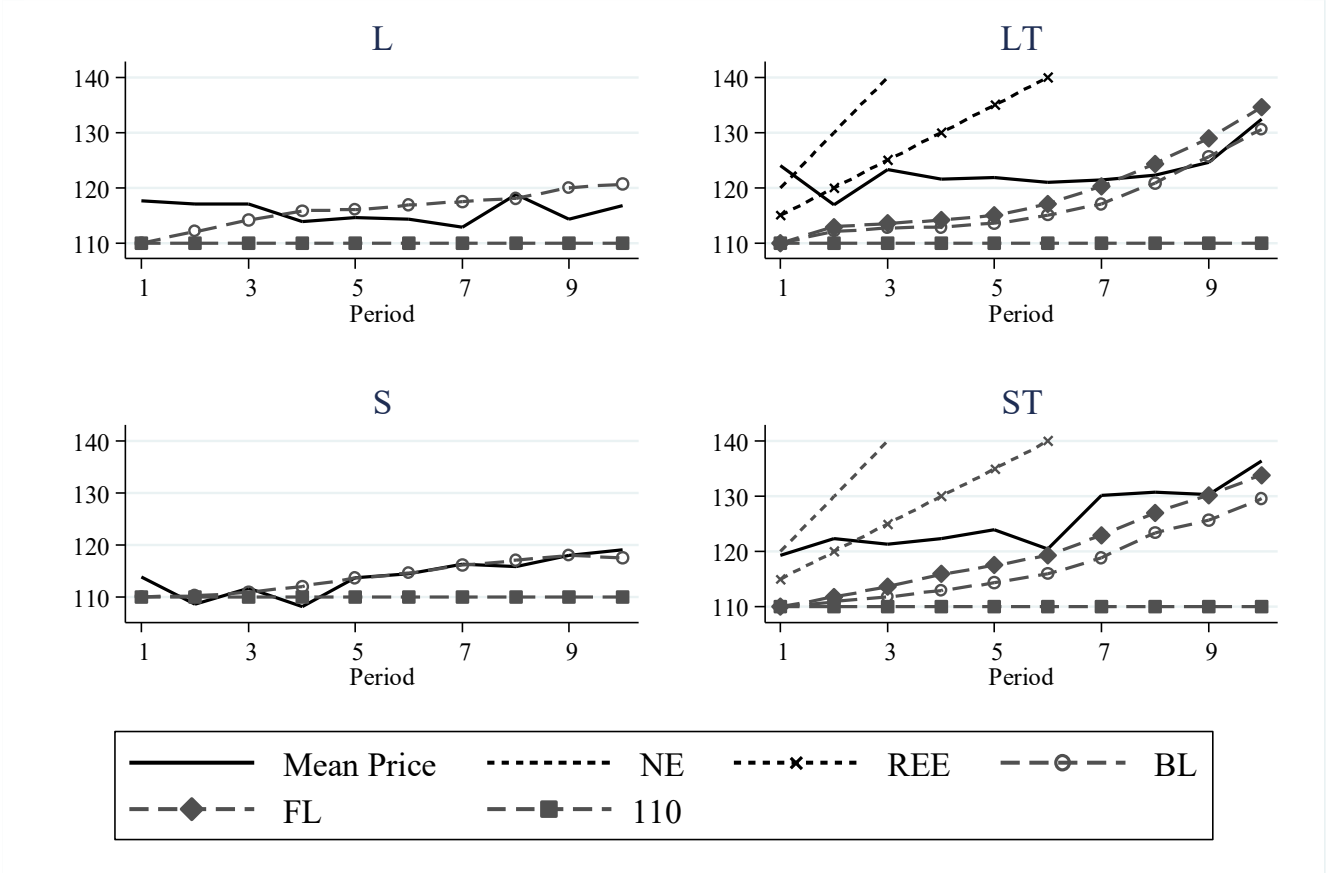

Figure 3: Average Price and Fundamental Values Models. The vertical axis measures the predictions of the fundamental value models and observed prices, while the horizontal axis measures the market period. The data are averages of all markets within a treatment. The solid line is the mean realized price, the dashed line is the fundamental value model under naïve expectations, and the cross-dashed line is the value under rational expectations. The line marked with hollow circles indicates the fundamental value under the backward-looking model, the line marked with light diamonds is the forward-looking model, and that with dark squares corresponds to the neutral effort level of two.

Table IX

Mean Price Dispersion from Different Fundamental Value Model Predictions

We report the mean of the difference between the realized market price and the prediction of each of the fundamental value models, the *p*-values of t-tests of the hypotheses of these means are equal to zero, and the number of observations. NE, RE, and 110 represent the static models, while BL and FL represent the extrapolative models.

Mean Price Dispersion from *NE*					Mean Price Dispersion from *RE*				Mean Price Dispersion from 110			
		H0: Difference = 0				*H0:* Difference = 0				*H0:* Difference = 0		
Treatment	mean	t-test *p*-value	Signed Rank *p*-value	n	mean	t-test *p*-value	Signed Rank *p*-value	n	mean	t-test *p*-value	Signed Rank *p*-value	n
									5.14	0.1595	0.0520	24
LT	-41.07	< 0.0001	< 0.0001	24	-13.87	0.0007	0.0011	24	13.33	0.0008	0.0022	24
									4.21	0.1082	0.0768	22
ST	-38.93	< 0.0001	0.0001	22	-11.93	0.0176	0.0170	22	15.07	0.0029	0.0022	22

Mean Price Dispersion from *BL*					Mean Price Dispersion from *FL*					
		H0: Difference = 0				*H0:* Difference = 0			H0: BL = FL	
Treatment	mean	t-test *p*-value	Signed Rank *p*-value	n	mean	t-test *p*-value	Signed Rank *p*-value	n	t-test *p*-value	Signed Rank *p*-value
L	-0.90	0.7653	0.2904	24						
LT	6.42	0.0416	0.0011	24	4.39	0.1384	0.0047	24	0.0001	0.0002
S	0.22	0.8460	0.0824	22						
ST	8.13	0.0466	0.0108	22	5.31	0.2003	0.5057	22	< 0.0001	0.0001

Unlike investors in L and S, investors in LT and ST are likely to observe variation in s'_{t-1} over time. From Table IX, we observe that prices follow the extrapolative models more closely than the static models, as demonstrated by the smaller dispersion of market prices from the former. Indeed, investors price their transactions closer to $V_{t-1} + dV^*(s'_{t-1})$ than to V_{t-1}. The difference between the mean price error of *BL* is statistically significantly larger than that of *FL* in both treatments, suggesting that investors utilize the information about s'_{t-1} (on top of the information regarding V_{t-1}). That is, investors adopt a *forward looking* strategy in estimating the value of their assets, when the CEO is able to trade. It is interesting to note that the price divergence from the *BL* and *FL* models is less than 5% of the actual value of V_{t-1} and $V_{t-1} + dV^*(s'_{t-1})$, respectively.

The relative performance of the different models in predicting the trajectory of the actual liquidation value is reported in result 4a. On the basis of the above analysis, we also reject the null in hypothesis 4. This is reported as result 4b, which describes the tendency for the CEO to increase firm value both when she does, and does not, have an opportunity to trade.

Result 4a: The extrapolative fundamental value models (BL and FL) describe the trajectory of the liquidation values more accurately than the static models (RE and NE). The CEOs utilize information about the history of past activity and their corresponding asset holdings, instead of adopting rational or naïve expectations in choosing their effort.

Result 4b: In the L and S treatments, where CEO trading is prohibited, the backward looking model fits the price data best. In LT and ST, market prices correctly anticipate the CEO exerting high effort and increasing firm value.

To gain insight on the impact of SOP on investors' attitude towards the extrapolative trajectory, we analyze the likelihood of the market pricing the assets according to the extrapolative models. Columns (1) and (2) of Table X present the probit and logit estimation of the variable of interest, a dummy variable that equals

1 if the minimum gap between market prices and the extrapolative models (BL and FL) is smaller than the minimum gap between market prices and the static models (RE, NE, 110) in period *t*, and 0 if the gap of the extrapolative models is larger than the gap of the static models.[16] The standard errors are clustered at the market level. As shown in the first row of columns (1) and (2), the coefficient of the SOP variable is statistically significantly positive, suggesting that stock ownership enhances the likelihood of market prices following the extrapolative trajectory.

We also run another estimation to check for robustness. Column (3) of Table X presents the OLS estimation where the variable of interest is the ratio of periods where the minimum gap between the market price and the extrapolative models (BL and FL) is smaller than the minimum gap between the market price and the static models (RE, NE, 110), within one market. As shown in the first row of column (3), the coefficient of the SOP dummy variable is statistically positive, reiterating the inference from the probit and logit estimation results. The result indicates that investors follow the extrapolative models more frequently when the CEO is compensated with the stock ownership plan than the linear compensation scheme. This happens despite the stock ownership plan producing negligible improvement of the actual effort decisions, as demonstrated earlier. We speculate that the stock ownership plan might instill greater confidence among the investors in the CEO's tendency to behave more rationally in her choice of effort. Thus, traders are more likely to maintain the assumption that the CEO will make rational decisions in the future, and that the CEO's past activities reflected optimal behavior. These beliefs may serve to stabilize the market.

[16] We do not include cases where the minimum gap of an extrapolative model is identical to the minimum gap of a neutral static model. There are 168 such cases. The vast majority are in the L and S treatments, in which the predictions of the models coincide.

Table X

Mean Price Dispersion from the Fundamental Value Models

Column (1) and (2) of Table X presents the probit and logit estimation of the variable of interest, a dummy variable that equals 1 if the minimum gap between market prices and the extrapolative models (BL and FL) is smaller than the minimum gap between market prices and the static models (RE, NE, 110) in period *t*, and 0 if the gap of the extrapolative models is larger than the gap of the static models. The standard errors are clustered at the market level. Column (3) of Table X presents the OLS estimation where the variable of interest is the ratio of periods where the gap between the market price and the extrapolative models is smaller than the gap of the static models, within one market.

	(1)	(2)	(3)
	PROBIT	LOGIT	OLS
VARIABLES	L(Price at period *t* follows the Extrapolative Models)		Frequency of Prices Following Extrapolative Models within one market
SOP (Stock Ownership)	0.515***	0.907**	0.147***
	(0.199)	(0.369)	(0.0480)
CEO is Able to Trade	-0.0872	-0.135	-0.0279
	(0.183)	(0.320)	(0.0489)
Constant	0.682***	1.104***	0.743***
	(0.172)	(0.301)	(0.0504)
Observations	686	686	86
Cluster	96	96	
R^2			0.099
Standard errors clustered at the level of the market			Robust Standard Errors

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

The following statement summarizes our findings in this subsection:

Result 5: CEOs invest similar effort when they are paid by stock ownership or a cash bonus. However, market prices are more likely to follow the extrapolative models (BL and FL) than the static models (RE, NE, and the neutral value) when CEOs receive stock ownership compensation than linear compensation.

D. Market Efficiency and Price Quality

In our final analysis, we study how the two compensation schemes affect market prices. We evaluate: (i) asset mispricing relative to the liquidation values, (ii) the bid-ask spread and (iii) the price volatility. We measure the extent of mispricing relative to the current liquidation values using the *Relative Absolute Deviation (RAD), Total Dispersion (TD)*, and *Price Amplitude* (*PA*) indexes (Stöckl et al., 2010; Haruvy and Noussair, 2006; King et al., 1993). The cost of transactions is measured by the *Absolute Spread* (*AS*) and *Relative Spread* (*RS*); and price volatility by the *VOLA* index (Stöckl et al., 2015).

Table XI presents the average value of each index. As shown in Panels A to C, all three bubble measures (*RAD*, *TD*, and *PA*) are statistically significantly higher in L (LT) than in S (ST) under the Mann-Whitney test, indicating that the stock ownership plan reduces the absolute price deviation from the *actual* liquidation values. The bid-ask spread measures *AS* and *RS* are statistically lower in S (ST) than in L (LT). Moreover, *VOLA* is statistically significantly higher in treatment L (LT) than in S (ST) under the Mann-Whitney test, suggesting that prices are more volatile in markets where CEO receives linear compensation. We attribute the improvement in market stability to the greater alignment between CEO's effort and share prices, in markets with a Stock Ownership Program, made possible through the preservation of investors' confidence in the extrapolative fundamental value models.

Table XI

Market Efficiency and Price Quality

This table summarizes the means, standard deviations, and the p-values of t-tests and signed rank tests against zero for commonly used bubble or mispricing measures: RAD, Total Dispersion (TD), Price Amplitude (PA), Absolute Spread (AS), Relative Spread (RS), and the VOLA index.

	(A) RAD				(B) TD				(C) PA				
			H0: RAD=0				*H0:* TD=0				*H0:* PA=0		
Treatment	mean	sd	t-test *p*-value	Signed Rank *p*-value	mean	sd	t-test *p*-value	Signed Rank *p*-value	mean	sd	t-test *p*-value	Signed Rank *p*-value	n
L	0.09	0.11	0.0005	< 0.0001	89	116	0.001	< 0.0001	0.26	0.29	0.0002	< 0.0001	24
LT	0.12	0.09	< 0.0001	< 0.0001	124	106	< 0.0001	< 0.0001	0.37	0.23	< 0.0001	< 0.0001	24
S	0.04	0.04	< 0.0001	< 0.0001	48	49	0.0002	< 0.0001	0.15	0.15	0.0001	< 0.0001	22
ST	0.11	0.17	0.0058	< 0.0001	110	164	0.0049	< 0.0001	0.21	0.13	< 0.0001	< 0.0001	22
			t-test *p*-value	Mann-Whitney *p*-value			t-test *p*-value	Mann-Whitney *p*-value			t-test *p*-value	Mann-Whitney *p*-value	n
H0: L=LT			0.3466	0.016			0.2845	0.002			0.135	0.004	48
H0: S=ST			0.0779	0.018			0.0951	0.010			0.1588	0.016	44
H0: L=S			0.0697	0.037			0.1272	0.033			0.1156	0.039	46
H0: LT=ST			0.8891	0.059			0.7375	0.082			0.0047	0.003	46
Kruskal-Wallis $\chi 2$	17.827				21.075				22.113				
p-value	0.0005				0.0001				0.0001				

	(D) Absolute Spread				(E) Relative Spread				(F) VOLA				
			H0: AS=0				*H0:* RS=0				*H0:* VOLA=0		
Treatment	mean	sd	t-test *p*-value	Signed Rank *p*-value	mean	sd	t-test *p*-value	Signed Rank *p*-value	mean	sd	t-test *p*-value	Signed Rank *p*-value	n
L	14.72	13.97	< 0.0001	< 0.0001	0.12	0.12	< 0.0001	< 0.0001	0.052	0.11	0.034	< 0.0001	24
LT	17.75	9.66	< 0.0001	< 0.0001	0.15	0.10	< 0.0001	< 0.0001	0.070	0.08	0.0001	< 0.0001	24
S	8.91	10.41	0.0006	< 0.0001	0.08	0.10	0.0012	< 0.0001	0.029	0.10	0.1741	0.0001	22
ST	11.98	9.83	< 0.0001	< 0.0001	0.10	0.08	< 0.0001	< 0.0001	0.023	0.02	< 0.0001	< 0.0001	22
			t-test *p*-value	Mann-Whitney *p*-value			t-test *p*-value	Mann-Whitney *p*-value			t-test *p*-value	Mann-Whitney *p*-value	n
H0: L=LT			0.3873	0.0163			0.4374	0.0392			0.5256	0.017	46
H0: S=ST			0.3204	0.0689			0.5598	0.1661			0.7783	0.0013	44
H0: L=S			0.1195	0.0073			0.2121	0.0147			0.4587	0.0207	44
H0: LT=ST			0.0509	0.003			0.0662	0.0046			0.0069	0.0012	46
Kruskal-Wallis $\chi 2$	22.324				18.836				24.926				
p-value	0.0001				0.0003				0.0001				

Comparing treatment L (S) and LT (ST), we can also see that allowing the CEO to trade induces changes that undermine market pricing, as evident in the higher bubble measures, bid-ask spread, and the price volatility indexes. We attribute this to the higher incidence of changes in effort discussed earlier. Our experimental result implies that frequent changes in the liquidation values, which occur in LT and ST, because the CEO's optimal effort exhibits changes, hinder price discovery.

Nevertheless, it should be noted that in all four of our treatments, prices are close to the liquidation values. It may be the case that asset price bubbles are moderated in markets where the liquidation values are endogenously determined. Investors follow the extrapolative models closely, enabling them to anticipate the evolving liquidation values more accurately. Our results on market behavior are summarized as result 6.

Result 6: Compensating the CEO with a stock ownership plan improves market efficiency and reduces volatility. However, granting the CEO with an opportunity to trade exacerbates mispricing and induces greater price volatility.

III. Conclusion

Executive compensation has always been at the heart of research in corporate finance and corporate governance. This paper investigated two commonly held beliefs about CEO compensation. The *first* is that a stock ownership program provides stronger incentives for CEOs to increase the value of the firm than a cash bonus equivalent in magnitude. The *second* is that CEOs should be forbidden to trade stock in their own firms because of the incentive problems resulting from the possibility of insider trading.

Our study allows us to draw four conclusions. The first is that in our environment, the CEO tends to make close to optimal effort choices given her incentives. Under the L and T treatments, average effort is close to the optimal level of 2 units in each period. Furthermore, in ST and LT, in which CEOs tend to accumulate units, they tend to choose the optimal effort level given their current asset holdings. The performance of a model of optimal decision making in predicting effort levels observed is quite impressive, and suggests that CEOs

understand the decision environment very well. In our view, this suggests that our data is of high quality and lends credibility to the other conclusions that we draw.

Secondly, prices in our markets adhere closely to liquidation values in all four of our treatments. Unlike in some other experimental paradigms, such as that of Smith et al. (1988) prices do not tend to exhibit bubbles and crashes. Liquidation values follow those predicted by extrapolative models, and prices in turn reflect the underlying liquidation values. One key difference between our environment and the one studied by Smith et al. (1988) is that the liquidation values are endogenously determined rather than being exogenously specified by the experimenter and independent of the behavior of market participants. Whether this is the key variable influencing whether mispricing arises is one that can be taken up in follow-up research.

The third main insight from our work is that we observe that allowing the CEO to trade raises the value of the firm. The typical behavior of our CEOs is to accumulate units and then exert the optimal level of effort given her increased holdings. This raises the value of the company and benefits other shareholders. There is no evidence of the CEO selling her shares on inside information that she is planning to exert low effort and then shirking afterwards. Rather almost all CEO are net purchasers of shares in their company.

The fourth result is that awarding stock options increases price stability. Though the CEOs effort is no greater under a stock option than under a cash bonus plan, we do find that price volatility is lower, with prices tracking liquidation values more closely. It may be the case that the effort decisions of CEOs are followed more closely, and analyzed more carefully by other traders, when the CEO has a stake in the value of the firm.

REFERENCES

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, Elena, Peter Bossaerts, Jon Eguia, and William Zame, 2015, Asset pricing and asymmetric reasoning, *Journal of Political Economy* 123, 66-122.

Asparouhova, Elena, Peter Bossaerts, Nilanjan Roy, and William Zame, 2016, "Lucas" in the Laboratory, *Journal of Finance* 71, 2727-2780.

Bossaerts, Peter, and Charles Plott, 2002, The CAPM in thin experimental financial markets, *Journal of Economic Dynamics and Control* 26, 1093-1112.

Bossaerts, Peter, and Charles Plott, 2004, Basic principles of asset pricing theory: Evidence from large-scale experimental financial markets, *Review of Finance* 8, 135-169.

Bossaerts, Peter, Charles Plott, and William Zame, 2007, Prices and portfolio choices in financial markets: Theory, econometrics, experiments, *Econometrica* 75, 993-1038.

Bloomberg, 2013, Top CEO Pay Ratios, downloaded from http://go.bloomberg.com/multimedia/ceo-pay-ratio/

Caginalp, Gunduz, David Porter, and Vernon Smith, 1998, Initial cash/asset ratio and asset prices: An experimental study, *Proceedings of the National Academy of Sciences* 95, 756-761.

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, 2013, An experimental test of the Lucas asset pricing model. Working paper.

Davis, James H., F. David Schoorman, and Lex Donaldson, 1997, Toward a stewardship theory of management, *Academy of Management Review* 22, 20-47.

Dufwenberg, Martin, Tobias Lindqvist, and Evan Moore, 2005, Bubbles and experience: An experiment, *American Economic Review* 95, 1731-1737.

Eckel, Catherine C., and Sascha C. Füllbrunn, 2015, Thar she blows? Gender, competition, and bubbles in experimental asset markets, *American Economic Review* 105, 906-920.

Füllbrunn, Sascha, and Ernan Haruvy, 2013, The Dividend Puzzle: A Laboratory Investigation, in S. M. Collins, R. M. Isaac, D. A. Norton, eds.: *Research in Experimental Economics* 16 (Emerald Group Publishing Limited, Bingley, UK).

Haruvy, Ernan, and 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.

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.

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.

King, Ronald, Vernon Smith, Arlington Williams, and Mark Van Boening, 1993, The robustness of bubbles and crashes in experimental stock markets, in I. Prigogine, R. Day, and P. Chen, eds.:*Nonlinear Dynamics and Evolutionary Economics* (Oxford University Press, New York).

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.

Lefebvre, Mathieu, and Ferdinand M. Vieider, 2014, Risk taking of executives under different incentive contracts: Experimental evidence, *Journal of Economic Behavior & 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.

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, 2014, 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.

Pfeiffer, Glenn M., Timothy W. Shields, 2015, Performance-Based Compensation and Firm Value – Experimental Evidence, *Accounting Horizons* 29, 777-798.

Pierce, Jon L., Tatiana Kostova, and Kurt T. Dirks, 2001, Toward a theory of psychological ownership in organizations, *Academy of Management Review* 26, 298-310.

Plott, Charles R., and Shyam Sunder, 1982, Efficiency of experimental security markets with insider information: An application of rational-expectations models, *Journal of Political Economy* 90, 663-698.

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.

Stöckl, Thomas, Jürgen Huber, and Michael Kirchler, 2010, Bubble measures in experimental asset markets, *Experimental Economics* 13, 284-298.

Sutter, Matthias, Jurgen Huber, and Michael Kirchler, 2012, Bubbles and information: An experiment, *Management Science* 58, 384–393.

Stöckl, Thomas, Jürgen Huber, and Michael Kirchler, 2015, Multi-period experimental asset markets with distinct fundamental value regimes, *Experimental Economics* 18, 314-334.

Wasserman, Noam, 2006, Stewards, agents, and the founder discount: Executive compensation in new ventures, *Academy of Management Journal* 49, 960-976.

Weber, Matthias, John Duffy, Arthur J. H. C. Schram, 2017, An Experimental Study of Bond Market Pricing, *Journal of Finance*, forthcoming.