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Futures Contracting and Dividend Uncertainty in Experimental Asset Markets*

Previous experimental investigation of the behavior of laboratory stock markets documents their tendency to bubble and crash relative to a declining expected dividend value with first-time subjects This pattern continues, but in abated form, for once-experienced subjects and essentially disappears for twice-experienced subjects The interpretation has been that common information on true asset value is not sufficient to induce common rational expectations Rational expectations, if it occurs, requires an experiential process through which participants come to have common expectations over time In this article, we investigate this interpretation by introducing a futures market that is predicted to dampen the bubble crash phenomena by providing market participants with information on later period price expectations

It has also been conjectured that risk aversion in the asset's uncertain dividend value explains why there is a universal tendency for prices to begin below dividend value, that this invites arbitrage purchases by some participants, and, ac-

Prices in experimental asset markets tend to bubble and then crash to dividend value at the end of the asset's useful life Explanations for this phenomenon are (1) that participants cannot form reliable future price expectations or (2) dividend risk aversion We report the results of experiments to test these hypotheses In one experimental series, a futures market is introduced so that participants can obtain information on future share prices In another series of experiments, the per-period dividend is known with certainty The futures market treatment reduced the bubble The certain dividend treatment had little effect on the character of bubbles with inexperienced traders

* We thank our "skeptical" colleagues, Colin Camerer, Arlington Williams, and Charles Plott for using their data from experiments at the University of Pennsylvania, Indiana University, and California Institute of Technology using our design and their subject pool Support by the National Science Foundation is gratefully acknowledged

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cording to this scenario, that the resulting rise in prices over time generates expectations of capital gains which until near the end, are self-fulfilling We test this hypothesis by running comparison experiments with a certain per-period dividend which should reduce the magnitude of, if not eliminate, bubbles, if the phenomenon has its origin in risk aversion

Both of these propositions are in need of further examination We report 13 new experiments designed specifically to provide direct tests of these two hypotheses The new experiments are integrated with 25 previous baseline experiments and are used to provide a comprehensive summary of the research program to date

I. Background Experiments and New Questions

Several investigations of the behavior of laboratory stock markets using an electronic version of the continuous double auction have documented the persistent tendency for assets to trade at prices that depart from fundamental dividend value In a typical laboratory asset market, at the end of each 15 trading periods a dividend, d, is drawn from a probability mass function in which each of four different dividends occurs with equal probability These parameters are common information for all subject traders Traders are also informed as to the expected value, $E(\tilde{d})$, of each period's dividend based on this dividend distribution The instructions explicitly inform the subjects that, in the first period of trading, shares have a dividend "holding" value of $15E(\tilde{d})$ since each share traded in that period carries the right to receive 15 draws from the dividend distribution At the end of each trading period, t, following the announcement of that period's dividend realization and its payment into the account of each subject,[1] everyone is informed of the next period's dividend holding value by calculating $(15 - t)E(\tilde{d})$ Thus the horizon length dividend structure, and opportunity cost implications of these parameters are made explicit common information each period for all subjects But it is also common information that each subject will be paid at the end of the experiment a cash sum equal to his or her initial cash endowment (cash and share endowments are private information) plus all dividend realizations applied to shares held at the end of each period plus all capital gains less losses on shares sold Although dividends are the sole source of positive value, and capital gains must necessarily be zero sum across all trades, for inexperienced subjects hope springs eternal that big profits

1 Each subject's screen contained a running electronic update of his or her cash working capital balance inventory of shares and corresponding purchase price dividend earnings, and capital gains and losses

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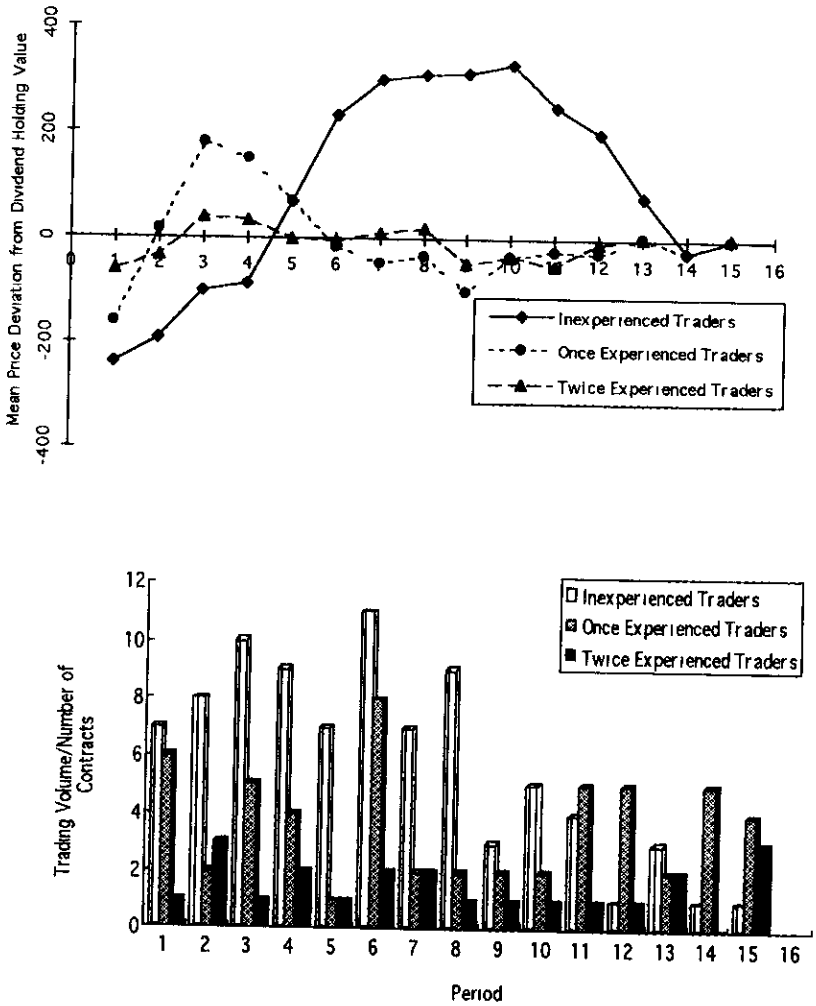

FIG 1 —Price and volume from experimental asset markets

will result from capital gains In fact, for some subjects, this is indeed the case

The pattern across time and repeat sessions can be broadly summarized as follows (see fig 1, which contains data from experiments with the structure defined above) (1) With inexperienced subjects, contract prices universally start below dividend value,[2] rise within and across

2 An exception, reported in King et al (1993), occurred in regulated markets that imposed a price change limit rule relative to the previous closing price in all periods beginning with period 2

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periods, move substantially above the (declining) dividend value peak out between periods 9–12, then crash to near dividend value in the last 1–3 periods volume is large with turnover of five to nine times the total shares outstanding Most of this volume occurs in the boom phase, the crash tends to occur on thinner volume (2) When the same subjects return for a second session, the pattern is qualitatively similar except that the boom phase is shorter, prices now peak out between periods 4 and 10, and turnover declines more than one-half the turnover of inexperienced subjects to two to five times outstanding shares (3) If the same subjects are brought back for a third session, trading becomes very thin, and prices do not deviate substantially from dividend value, if subjects from different groups return for a third session the result is a low-volume, moderate amplitude, bubble and crash Thus, convergence to fundamental dividend value is most pronounced when subjects have common experience across two previous markets

These results were initially reported in Smith, Suchanek and Williams (1988) In an attempt to get a better understanding of expectations in their bubble-crash markets, Smith Suchanek, and Williams required subjects to forecast the next period's mean price, beginning with period 2, in 10 of the 27 experiments they report The subject with the smallest cumulative absolute forecasting error received $1 00 in addition to his or her final cash balance Analysis of these forecasts showed (1) a pronounced tendency to underpredict in expansions and overpredict in contractions—the consensus (mean) forecast always missed turning points and jumps in the mean price, (2) lagged changes in forecasts were highly adaptive, (3) a strong tendency to converge across three levels of experience to rational (dividend value) expectations, and (4) individual forecasting error was negatively correlated with earnings in every experiment (in 6 of 10 experiments the regression coefficient was significant at 0 05 or better) [3] This is consistent with (but does not prove) the hypothesis that the better forecasters, acting on their forecasts, increased their earnings

The central conclusion of this work is that common information on fundamental share value is not sufficient to induce common expectations or "knowledge" an essential game theoretic requirement for equilibrium Common information is insufficient because there is still behavioral or strategic uncertainty about how others will utilize the information Common expectations are achieved through experience, not by logic applied to common information Thus, across successive

3 The forecasting software option for asset experiments has since been expanded so that subjects (*a*) forecast first-period prices in addition to all others and (*b*) forecast mean price 2 periods as well as 1 period ahead Experiments run with the new software show that the consensus (mean) forecast is always below dividend value in the first period This is consistent with risk aversion, i e subjects expect the market to begin at prices that discount the risk-neutral dividend value of a share

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sessions a given subject group comes to have common fundamental value expectations as both prices and forecasts converge to share dividend value This is consistent with rational expectations theory which does not articulate a dynamic process that predicts how long it takes to go from an initial state to a rational expectations equilibrium, nor does it articulate a procedure which tells us how to achieve common knowledge

Two studies have extended the work of Smith and his colleagues by examining treatments designed to eliminate the propensity for these markets to bubble and crash using inexperienced and once-experienced subjects King et al (1993) ask and provide experiments to answer the following questions are bubbles significantly reduced if (1) we introduce a capacity for each subject to sell short, or buy on margin, or both? (The answer is no) (2) subjects are given identical endowments? (The answer is no) (3) we introduce an explicit brokerage cost of transacting? (The answer is no) (4) we use middle-level business executives as subjects, or over-the-counter stock traders as subjects? (The answer is no) (5) we impose price change limit rules that place a floor and ceiling on prices equal to the previous period's closing price plus or minus twice the 1-period expected dividend value? (The answer is no) (6) at least a quarter of the subjects are informed insiders who have read Smith, Suchanek, and Williams? (The answer is yes, if they are given short selling capacities equal to the total shares held by noninformed outsiders, the answer is no, if they are not given the capacity to sell short)

Schwartz and Aug (1989) investigate whether it makes a difference if subjects must use their own money ($20 each) to fund their initial balances Although economic and financial theory suggests that the source of the initial endowments should not matter (if income effects are negligible), Thaler and Johnson (1990) have argued for a "house money" effect based primarily on survey data The proposition is reminiscent of Milton Friedman's behavioral hypothesis distinguishing permanent from transitory income The experiments reported by Schwartz and Aug (1989) still show a strong tendency to bubble and crash, and therefore the house money effect is negligible Of special interest are the reported comments and responses of subjects to questions that explore their trading strategies and how well they executed such strategies One subject stated that his/her strategy was to buy below dividend value and sell above The market, however, rose rapidly The subject was unable to execute a purchase at prices below dividend value but bought anyway in "hopes" that it would rise further! As noted perceptively by one subject, "prices rise without cause " Our subjects report a tendency to think that if the market turns they will be able to sell ahead of the others, but then are "amazed" at the speed with which the crash occurs

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Since nearly all of the experiments using inexperienced subjects exhibit a crash to dividend value near the end game, it follows from backward induction that all trading period prices should be near dividend value. Smith, Suchanek, and Williams argue that this fails to occur because subjects do not have common expectations in the middle and earlier periods and not because of a failure to backward induct (Smith, Suchanek, and Williams 1988, p. 1148). This proposition, which is supported by the evidence cited in their paper, is in need of further investigation by a different independent test. Accordingly, in this article, we report five new experiments that examine this proposition by introducing a futures market for period 8—the midhorizon point. Why should this help to produce common expectations and dampen bubbles? If during periods 1–8 subjects have the opportunity to trade futures contracts on asset value in period 8, as well as ordinary shares in the spot market, then the futures market prices will give all traders a reading on the group's consensus expectations of midhorizon asset value. This is predicted to speed up the process whereby subjects come to have common expectations, although it does not guarantee that such expectations will correspond to the rational fundamental value. This is because in period 8 the futures and spot contracts are identical claims and, rationally, should not differ from each other, but unless expectations also support dividend value, the two contracts may trade at a level other than the period 8 dividend value. In repeated 2-period environments (in which different subjects receive different certain dividends within each period to induce trade), it has been demonstrated that a second-period futures market hastens "learning," which we interpret to mean the creation of common rational expectations (Forsythe, Palfrey, and Platt 1982; Friedman, Harrison, and Salmon 1984).

A second hypothesis, conjectured but not examined, by Smith and colleagues, is that the observed phenomenon of bubbles in these experiments is ignited by the way subjects respond through the market over time to their heterogeneous attitude toward dividend risk. To wit, "In every market bubble experiment (Group III, Table IV), the mean price in the first period was below (dividend value). This suggests the possibility that risk aversion plays a role in market bubbles by depressing prices at first, with the subsequent recovery helping to create or confirm expectations of capital gains" (Smith, Suchanek, and Williams 1988, p. 1149). Think of a story such as the following: given their disparate initial portfolios and attitudes toward risk, those most eager to balance their portfolios in line with their risk attitude trade at discount prices that provide a premium to the more risk-averse buyers. At these low initial prices, other subjects start to execute arbitrage purchases. The resulting price increase sets up expectations of capital gains from a further rise in prices. Self-fulfilling capital gains expecta-

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tions then drive the bubble to ever higher prices until near the end when it becomes transparent that a correction is in order If this is a correct interpretation, then experiments in which the 1-period dividend value is certain should yield prices significantly closer to dividend value than in previous experiments

We report 13 new experiments using either the futures or the dividend certainty treatments, which we compare with earlier baseline experiments without these conditions

II. Experimental Design

Our design consists of the baseline asset market structure, an asset market with a single *futures* market and an asset market with *dividend certainty*

A Baseline Asset Market

The asset was traded in a double auction market[4] and had the following characteristics which were provided to all participants as *common information*

i) The asset had a finite life of 15 periods and expired worthless at the end of the experiment
ii) At the end of every period, each share of the asset would earn a dividend based on a draw from the distribution given in table 1 [5]

Thus, it was common information that the dividend was the same for all participants and a dividend draw would be made at the end of each period to determine the dividend income for the period The dividend income from a participant's inventory of shares was added to his/her cash position at the end of each period Participants in this market could buy and sell units of the security during each trading period, provided they had sufficient units in their inventory to make the sale or sufficient cash in their account to purchase the share

Therefore, the *fundamental value* of the asset in this market should start at $3 60 ($0 24 times 15 periods) and decline by $0 24 each period until period 15 as shown in figure 2 All participants were informed of this declining cumulative value Specifically, before the beginning of every period, subjects were provided with a table describing the maximum, minimum, and expected dividend value of a share of stock if it were held from the current period until the end of the experiment In addition, subjects were given information concerning the expected

4 This is a real-time continuous process in which traders submit bids and asks with the spread determined by a standard bid-ask improvement rule

5 Several of the experiments contained in the baseline asset market database we use have a dividend structure with an expected value of $2 40

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TABLE 1 Dividend Structure of the Security

Dividend in Cents	Probability of Occurrence
0	25
8	25
28	25
60	25

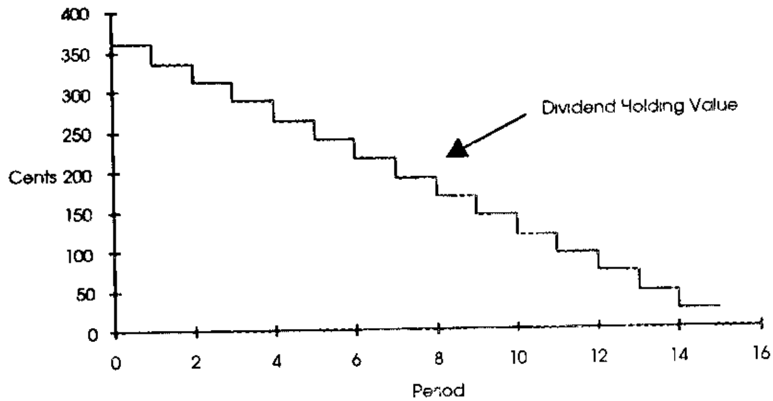

Fig. 2.—Declining fundamental asset value

value of their current portfolio of shares and cash if they held their current position.

Initially, each trader was endowed with one of three portfolios of cash and shares (see table 2). In several baseline experiments margin buying was allowed, that is, in addition to their cash endowments, traders were given an interest-free loan of cash at the beginning of the experiment which was deducted from their gross cash balance at the end of the experiment. An abbreviated set of the screens from the computerized instructions used in the experiments can be found in appendix A.

B. Futures Market Treatment

Each trader, in addition to his "spot" inventory of securities, was given a capacity to trade units of future shares that would expire at the end of the eighth period of trading. Thus, stock futures would not earn any dividend income until after period 8 when the futures market was closed and all positions were cleared (a trader's net futures position was transferred to his spot holdings at the end of period 8).[6] Thus,

6. Operationally, at the end of period 8, if a trader accumulated net units in his futures inventory above his initial capacity, then those added units would be transferred to the trader's spot inventory to be used for trading and dividend income for the remainder of

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TABLE 2 Initial Trader Portfolios

Portfolio Type	Initial Stock (Units)	Initial Cash ($)	Margin Account* ($)	Expected Earnings ($)
1	1	9 45	10 00	13 05
2	2	5 85	10 00	13 05
3	3	2 25	10 00	13 05

* Must be repaid at the end of the experiment

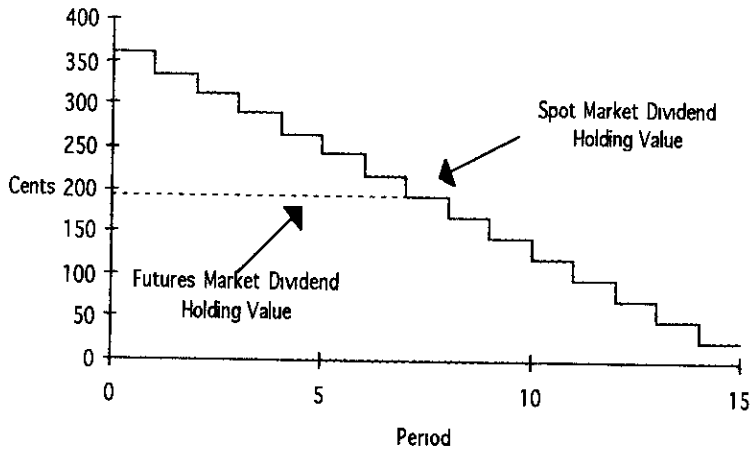

FIG 3 —Spot and futures market fundamental asset values

the spot and futures instruments represent the same security during the eighth period of trading We also provided margin funds to traders so that there would not be a liquidity problem in futures/spot trading

A trader in this market could make bids, asks and contracts in both a spot (periods 1–15) and futures market (periods 1–8) Since a futures contract converts to a spot share that can only earn dividends from period 8 to period 15, the fundamental value of a futures contract is $1 92 (see fig 3) The futures market in this environment supplies an advance reading on expectations of share value in period 8 Table 3 lists the portfolio types used in our futures experiment

the experiment If the trader had fewer units in his futures inventory than his initial capacity, then he had to cover the shortfall from units in his spot inventory In the event that a trader could not cover his futures position with his spot inventory, he would pay a $4 00-per-share penalty, which is approximately equal to the value of the stock if it paid the highest possible dividend realization ($0 60) for the remainder of its life (7 periods) A large penalty was levied to assure full compliance and thereby control for any effects due to the failure of the futures market to clear (the penalty was paid only once for 1 unit)

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TABLE 3 Initial Portfolio Conditions for Futures Treatment

Portfolio Type	Initial Spot Inventory (Units)	Futures Capacity* (Units)	Initial Cash ($)	Margin Account ($)
1	1	3	9 45	10 00
2	2	2	5 85	10 00
3	3	1	2 25	10 00

* Spot plus futures inventories at end of period 8 must be greater than zero or a $4 00-per share penalty must be paid

C Dividend Certainty Treatment

This treatment changes the baseline distribution of dividends to one in which all the probability mass is at $0 24 Hence, if market bubbles are ignited by low initial prices due to dividend risk aversion (liquidity preference), this treatment should reduce the severity of bubbles In addition to the set of dividend certainty experiments we conducted two "switch" treatment experiments In these cases, two different groups were run twice with a certain dividend—inexperienced then experienced They were then recruited for a third session in which the dividend was uncertain The research question here was whether dividend uncertainty could ignite a bubble with subjects who were twice previously experienced with a certain dividend environment

D Computer Trading Network

The experiments employed for this study used two different computer networks and software designs Most of the baseline experiments used the PLATO system while all of the futures treatments used a local area network (LAN) [7]

III. Experimental Procedures

In each experiment, the initial assignment of portfolio types was symmetric, an equal number of agents were assigned to each portfolio type [8] In the futures market treatment, subjects were first trained in a series of independent 2-period securities markets, with a futures contract coming due at the end of each second period This allowed subjects to become familiar with the accounting procedures for a futures

7 The LAN was used because the software allows for multiple market simultaneous trading that is required to conduct a spot and futures market (see Johnson, Lee, and Plott 1989) Our database contains three baseline asset market experiments using LAN

8 Rarely, the number of subjects was not divisible by three and any remainder was added to the type 2 portfolios so that the average number of spot and futures shares per trader was always two

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market, without exposing them to a bubble condition. Because there was a possibility of losses in the futures market experiments, subjects were recruited with the understanding that they would be in two experiments during the week and their earnings would be the total from the two experiments. A "bankruptcy" condition was never encountered in any of our experiments.

Most of the subjects were recruited from undergraduate sections of economics and business classes at the University of Arizona, but some of the baseline and the certain dividend experiments used subjects at the University of Pennsylvania, California Institute of Technology, and Indiana University. Subjects were recruited for a "decision making experiment in economics," were paid $3 for arriving on time, and paid their accumulated earnings in the experiment at the end.

To date, in the laboratory, trader experience and informed insiders have been the only factors identified in eliminating bubbles. In King et al. (1993), experience means that traders were in a security market previously with the same subjects, that is, they experienced the same initial phenomena together. Thus, in our experiments, care was taken to make sure that the same subjects in an experiment returned for the second and subsequent experiments. Table 4 supplies a list of the pertinent facts for each experiment.

TABLE 4 **List of Experiments**

Treatment	Subject Pool	Experienced	Total Stock	Trading System	Time*
Futures	Arizona	No	18	LAN	300
Futures	Arizona	No	18	LAN	300
Futures	Arizona	No	18	LAN	300
Futures	Arizona	Yes	16	LAN	300
Futures	Arizona	Yes	18	LAN	300
Certain	Arizona	No	22	LAN	240
Certain	Arizona	Yes	18	LAN	240
Certain	Arizona	No	22	LAN	240
Certain	Indiana	No	18	PLATO	240
Certain	Arizona	Yes	16	LAN	240
Certain	Indiana	Yes	16	PLATO	240
Switch†	Arizona	Yes	16	LAN	240
Switch†	Indiana	Yes	16	PLATO	240

NOTE.—For statistical comparisons, in addition to the experiments listed above, we use 25 baseline experiments from the University of Arizona database of asset market experiments. The database consists of 10 PLATO inexperienced experiments, 8 PLATO once-experienced experiments, 3 PLATO inexperienced with margin buying, 1 PLATO once-inexperienced with margin buying, and 3 LAN baseline experiments with University of Pennsylvania and California Institute of Technology subject pools.

* Market period trading length in seconds. More time was allowed in the futures treatment because subjects had to trade simultaneously in two markets.

† The switch treatment used subjects that were twice experienced in the certain dividend market before recruiting them for the baseline treatment where dividends were uncertain.

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IV. Experimental Results

The futures market and the certain dividend treatments will be analyzed first in terms of their effects on price amplitude, duration, and stock turnover relative to baseline. In addition, a Walrasian price-adjustment model is estimated to determine if the treatments affect the price expectations dynamics.

A. *Measurement Variables*

We focus our attention on the following empirical measures of a bubble.

i) *Duration.* The number of periods in which there is an observed increase in market prices relative to fundamental value. Specifically, if f_t is fundamental value in period t and P_t is the mean spot price, then duration is defined as

$$\max\{m: P_t - f_t < P_{t+1} - f_{t+1} < \cdots < P_{t+m} - f_{t+m}\}.$$

For example, suppose mean prices rise steadily relative to fundamental value for periods 3–8 and fall thereafter. Then $t = 3$, $m = 5$, and duration is 5.

ii) *Turnover.* The total volume of trade divided by the total shares outstanding across all trading periods. This number is a normalized index of trading activity.

iii) *Amplitude.* This measures the trough to peak change in market asset value relative to fundamental value. Formally, amplitude is given by

$$\max\left\{\frac{P_t - f_t}{360}: t = 1, \ldots, 15\right\} - \min\left\{\frac{P_t - f_t}{360}: t = 1, \ldots, 15\right\},$$

where 360 is the expected dividend value over the life of the asset.

B. *Treatment Effects*

Table 5 shows the summary statistics of the treatment effects on the measurement variables discussed earlier. An analysis of variance (ANOVA) model was used to evaluate the treatments in our sample. Specifically, we estimate a regression model of dummy variables for each of our treatments, and for subject experience, as independent variables. The dependent variables are represented by each of the bubble characteristics—amplitude, duration, and turnover. Charts of the time series of mean contract prices and volume, by trading period, are displayed in appendix B.

From the estimated coefficients and standard errors of the regression model reported in appendix C we conclude as follows ("significance" refers to the 0.05 level).

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TABLE 5 Summary Statistics by Treatment (Mean Values)

	Inexperienced			Once Experienced		
Treatment	Amplitude	Duration	Turnover	Amplitude	Duration	Turnover
Baseline	1 53	10 15	5 49	86	4 75	2 98
Futures	92	10 00	6 85	60	5 5	2 63
Certain dividend	1 09	11 00	8 85	52	9 7	2 71
Margin buying	3 21	10 00	5 40	1 12	6 5	4 61
Switch	N A	N A	N A	40	4 5	2 59

NOTE —N A = not applicable

1 A futures market reduces bubble amplitude (t = 3 26 with inexperienced trades, but − 40 relative to experienced traders) Duration and turnover are not significantly affected with inexperienced traders in the futures market, but turnover is significantly reduced with experienced futures traders (t = 3 05)
2 The elimination of dividend uncertainty has no (significant) effect on the bubble characteristics with inexperienced traders
3 Once traders are twice experienced in the certain dividend environment, adding uncertainty to the dividend structure does not rekindle a price bubble In fact, the results are indistinguishable from those of traders who are twice experienced in the uncertain dividend environment
4 The use of margin buying (significantly) increases the amplitude of the bubble with inexperienced traders
5 The LAN trading program significantly affects the turnover of the stock, that is, there is more churning in the LAN treatment Since this is an unintended treatment, it is important that its effect be taken out before evaluating the marginal impact of the controlled treatment variables

Thus, we have uncovered two central findings from these experiments Although a futures market does not entirely eliminate bubbles (we can reject the hypothesis that prices track the fundamental value line), it does dampen bubble amplitude with inexperienced traders and reduces turnover with experienced traders Since we have only one futures in our market, the period 8 futures, an open question is whether a complete set of futures markets (one for each period) or options would dampen bubbles more fully On the other hand, dividend uncertainty provides little explanation for the occurrence of bubbles in these asset markets The argument in Smith Suchanek, and Williams that bubbles might arise fundamentally because of dividend risk aversion

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is not supported by our results. This affirms more strongly the proposition that asset price bubbles are driven by behavioral or strategic uncertainty, which subsides with common experience, as subjects become more certain across trading sessions that trades away from fundamental value will not be profitable.

C. Descriptive Behavior of Futures Prices

In period 8 of our futures market experiments, a spot and futures contract are identical. Thus, we would expect very little difference between the period 8 spot and futures contract prices. In most experiments the mean spot and futures prices in period 8 are almost identical. The pooled mean contract price for a futures contract was 226.1 with a standard deviation of 95.7, while the pooled mean spot contract price for period 8 was 226.4 with a standard deviation of 66.7. The relationship between spot and futures prices will of course depend on traders' expectations of future price conditions in period 8. If the asset were to trade at fundamental value, we would expect to see the spot contracts trading at a $1.68 premium over futures contracts in period 1 and decline by $0.24 each period until the futures contracts are called. Figure 4 shows the difference between the spot and futures prices in our experiments. There seems to be no discernible pattern in this data. Qualitatively, this difference should be positive, in periods 1–7, since spot shares contain more dividend value than futures. Clearly, this minimal rationality condition is satisfied.

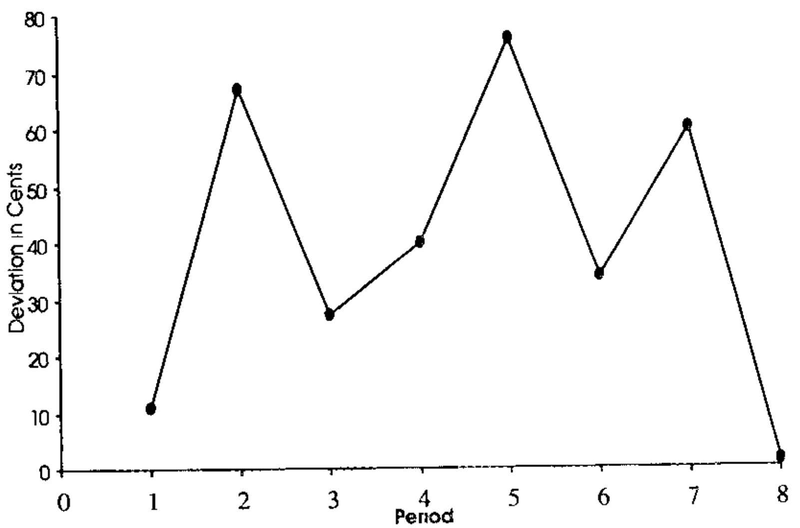

FIG. 4.—Pooled mean deviation of spot-futures closing prices

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D Walrasian Price Changes

Smith, Suchanek, and Williams develop the following statistical model to characterize the period-to-period changes in contract prices

$$P_t - P_{t-1} = \alpha + \beta(B_{t-1} - O_{t-1}) + \epsilon_{t-1}, \qquad (1)$$

where P_t is the mean contract price in period t, B_t is the number of bids tendered in period t, and O_t is the number of asks submitted in period t This equation uses the level of lagged excess bids as a proxy for excess demand arising from endogenous capital gains expectations Under this interpretation, the change in mean price is decomposed into three parts a constant component due to the reduction in dividend value each period, a component proportional to excess bids arising from capital gains expectations, and a random component Thus we should observe $\alpha = -0\ 24$ (if agents are risk neutral) and $\beta > 0$ if traders self-generate capital gains (losses) expectations Smith, Suchanek, and Williams report that, in all except one of their bubble-crash experiments, β is significantly greater than zero and α does not differ significantly from the 1-period expected dividend The R^2 for (1) computed for individual bubble-crash experiments, varies from 0 04 to 0 63, 10 of 14 have an R^2 of at least 0 25 However, the variance in the estimate of α is large in every experiment

We estimated the pooled Walrasian model from baseline data with a dummy variable for both slope and intercept terms for experienced subjects, that is, we estimate

$$P_t - P_{t-1} = \alpha + \gamma E + \beta(B_{t-1} - O_{t-1}) + \lambda E(B_{t-1} - O_{t-1}) + \epsilon_{t-1}, \qquad (2)$$

where $E = 1$ if the subject pool is experienced and 0 otherwise Table 6 summarizes the results of the regression and shows (i) $\alpha = -0\ 24$ *cannot* be rejected and $\beta = 0$ *can* be rejected (one-tailed test) for both inexperienced and experienced traders, and (ii) experience causes a significant decrease in the capital gains expectations coefficient

TABLE 6 Walrasian Price Adjustment Estimates with Experience

Treatment	Coefficient	Standard Error
Baseline inexperienced		
Expected dividend (α)	− 127	070
Capital gains expectation (β)	033	005
Baseline experienced		
Expected dividend (γ)	− 012	094
Capital gains expectation (λ)	− 007	004
N	154	
R^2	22	

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We now estimate the Walrasian price-adjustment model for all the treatments in an ANOVA (dummy variable regression) model with experience interaction. The estimates for certain dividend, switch, and futures treatments can be found in appendix D. From the estimates of that model, we reach several conclusions.

1. None of the treatments has a significant effect on the intercept. We cannot reject the null hypothesis that there is a constant decline in asset value equal to −\$0.24, the 1-period expected dividend value, for all treatments.
2. The futures market and experience treatments significantly reduce the capital gains expectation coefficient.
3. In the case of the switch and experienced futures market treatments, we cannot reject the hypothesis that the capital gains expectation coefficient is zero.

V. Summary and Conclusions

The ubiquitous tendency for laboratory assets with a well-defined declining fundamental value to trade at prices below this value, then rise above it, and crash near the end of the horizon, has launched experimental inquiries designed to investigate why this is so.[9] Since the participants themselves are mystified by this pattern, interrogating them has not been a source of great insight beyond establishing that they are indeed baffled, much as stock market investors in the economy. All subject groups—undergraduates, graduates, business persons, and over-the-counter traders—produce broadly similar patterns.

Experimental studies have established that the phenomenon disappears with experience, that is, the third time they return, any given group of subjects will trade at prices near fundamental value. Thus the endogenous expectations of positive capital gains do not persist as experienced subjects find that it is unprofitable to buy above or sell below fundamental value, although initially such trades may have been profitable. Also, such bubbles are much reduced if the group includes informed insiders with sufficient short-selling capacity to sell against

9. Caginalp and Ermentrout (1990) and Caginalp and Balenovich (1993) offer a differential equation supply/demand model of this dynamic process based on a hypothesized kinetic reaction (as in a chemical transformation) among investor holdings of assets whose behavior is characterized by a fundamental value component—buy (sell) when prices are below (above) fundamental value—and a trend-based component—buy (sell) in a recently rising (falling) market. The parameters of the model determine the speed of adjustment to under- or overvaluation and the memory length of recently rising or falling prices. By choosing one of the experiments in this article to calculate the parameters of the model, the price path of any other experiment is predicted given its initial price and fundamental value. Caginalp and Balenovich (1993) report their predictions of peak prices in nine of our experiments and find errors ranging from 1% to 20%.

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the boom This action prevents the emergence and full play of self-fulfilling capital gains expectations However, supplying ordinary uninformed subjects with a short-selling capacity helps not at all to suppress the bubble and can even exacerbate it when subjects sometimes sell short too soon, then nervously buy to cover near the top It does not help to impose price change limit rules like these instituted after the worldwide crash of stock markets on October 19, 1987 Nor are bubbles suppressed by requiring subjects to bring their own money, bubbles are not a house money artifact

In this article, we have tested the claim that bubbles get started because of dividend risk aversion that prices are initially depressed because of liquidity preference as people use the market for insurance, and that this sets up arbitrage buying, which in turn fuels self-fulfilling expectations of rising prices Contrary to this, we find that bubbles are not significantly reduced when the dividend is certain each period, and all subjects know this The importance of this finding is that it reinforces the idea that bubbles fundamentally self-generate because of behavioral or strategic uncertainty, that is, each trader has common information on dividend value but is not certain that others will act on this information by refusing to trade away from dividend value Such belief certainty is formed only out of experience—after participating in two asset markets with the same group so that all know that all had the same history

We have also argued that a futures market should help to break the cycle of self-fulfilling capital gains expectations Since the bull market invariably crashes near the end, and settles in to trading at dividend value in the last (or last few) periods, it is clear that subjects have common expectations of such values toward the end Therefore, we allowed trading in a futures contract at midhorizon (period 8) during the first 8 periods This, we thought, should force spot market traders to focus on their expectations of spot value in period 8 The resulting prices at which futures trade reveal common information about traders' expectations in period 8 The idea is to subvert the hypothesized tendency for expectations to be myopic currently rising prices beget expectations of higher prices in the next period, until near the end The futures treatment was successful in that it significantly reduced, although did not eliminate, bubbles Our interpretation of this finding is that an important function of a futures market is to reduce each individual's uncertainty about other peoples' expectations Even though the prices of the futures contracts are variable, that variability has a center that can help to convey to all a consensus expectation The evidence for this is our result that the coefficient of period-to-period myopic capital gains expectations in equation (2) is reduced significantly by the introduction of the futures market treatment

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Appendix A

Abbreviated Instructions (Subject Screens)

Instructions

This is an experiment in the economics of decision making Various research foundations have provided funds to conduct this study The instructions are simple, and if you follow them carefully, YOU MAY EARN A CONSIDERABLE AMOUNT OF MONEY which will be PAID TO YOU IN CASH at the end of the experiment

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 a dividend over a series of trading periods that can be thought of as 'market days " All communication during the experiment will be done through your computer terminal The computer is completely passive in the sense that it is used solely to store and transmit information on decisions made by participants in the market

Press Enter to Continue

Before we begin, let's find out which economic agent you are in the experimental market Above is a market screen with your trader number (ID) in the upper left-hand corner of the screen [See fig A1] This number allows for the accounting of your transactions in this market

Press Enter to Continue or Home to go Back

The current period in which you will be trading can be found in the second box on your screen Each trading period will run for five minutes and then will close so that data can be recorded and then a new period will begin The time remaining in a period can be found in the third box on your screen This experiment will run for FIFTEEN periods

Press Enter to Continue or Home to go Back

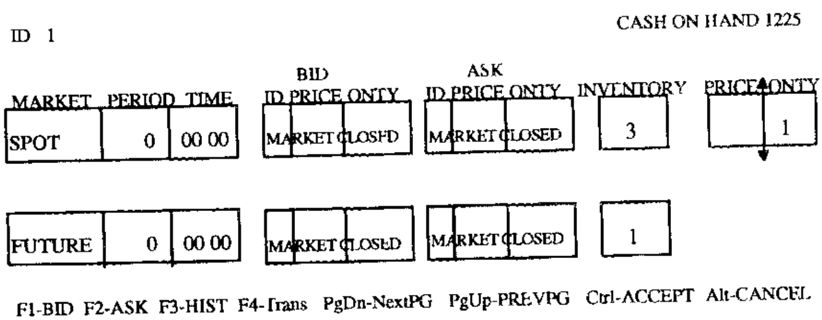

FIG A1

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Your CASH ON HAND is a running total of your current cash position in the experiment Your CASH ON HAND will be updated continuously based on your decisions in the marketplace as follows

CASH ON HAND = starting capital + sales revenue − purchase cost
+ borrowed funds (1000 cents)

All borrowed funds must be returned at the end of the experiment!

Press Enter to Continue or Home to go Back

Your inventory of asset units appears under the box labeled INVENTORY and will be updated continuously by subtracting units sold and adding units bought Note that you have been given an INVENTORY ENDOWMENT of 3 units in the market labeled SPOT and 1 unit in the market labeled FUTURE The FUTURE market inventory must be returned at the end of period 8 That is, at the end of period 8 the sum of your inventory in the SPOT and FUTURE markets must be equal to at least 1 unit or you will pay a penalty In addition, you have been given a STARTING CAPITAL of 225 plus we are lending you 1000 cents of BORROWED funds

Press Enter to Continue or Home to go Back

During the experiment you may purchase an asset unit for your inventory by spending cash on hand equal to the purchase price, or you may sell an inventory unit and increase your cash on hand by an amount equal to the unit's selling price At the END of each trading period you will receive a DIVIDEND on EACH UNIT in your inventory You will be given more information on the end-of-period per-unit dividend soon

Press Enter to Continue or Home to go Back

Your decision regarding the purchase and sale of asset units and your end-of-period inventory level (dividend earnings = dividend per unit times end-of-period inventory) should rest on the fact that at the end of the experiment your cash earnings will be calculated as

Experiment Earnings = (225 cents starting capital) + (dividend earnings)
+ (sales revenue − purchase cost)

Press Enter to Continue or Home to go Back

The purchase and sale of asset units will be done through your computer keyboard by entering BIDS to buy units of asset and ASKS to sell units of asset To make all of this more clear, let's work through some examples which will familiarize you with the rules of our experimental market and your record sheet Please note that the transactions prices used in the following instructive

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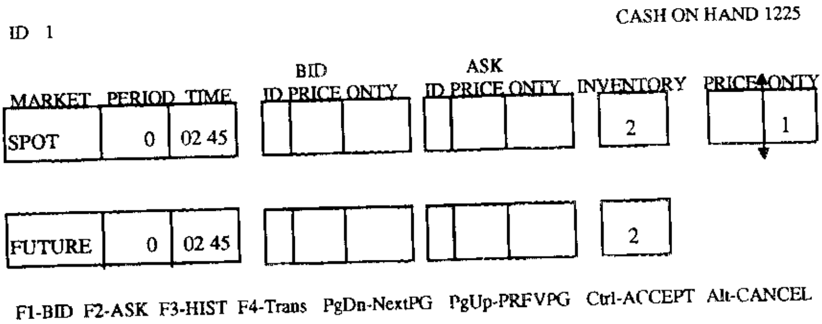

FIG. A2

examples are chosen RANDOMLY. Prices in the actual experiment may be different!

Press Enter to Continue or Home to go Back

You will not know the exact value of your dividend per unit prior to the end of each trading period. [See fig. A2.] At the end of each period you will be told the value of your dividend per unit and your dividend earnings (inventory units × dividend per unit) will be calculated and added to your earnings. Your dividends will be drawn randomly each period. The values of the dividend per unit and associated probability of occurrence can be found by pressing Enter.

Press Enter to Continue or Home to go Back

Your cash on hand and inventory will be carried over to the next trading period. The value of your dividend per unit for a trading period is a very important piece of information. We turn to it now.

Press Enter to Continue or Home to go Back

Dividend → 00 08 28 60 cents
Probability → 1/4 1/4 1/4 1/4
Thus, the average dividend per period over many draws = 24 cents

---

The above information will be displayed on the board in front of the room. Thus, we see that if you have 6 units in inventory at the end of a trading period and the dividend draw was 8 cents (which we know has a 1/4 probability), then your EARNINGS would increase by

6 units × 8 cents = 48 cents

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Your dividends in every period will be determined from your inventory in the SPOT market and the dividend draw Your dividend income from period 8 on will be determined from your inventory in the SPOT market and the FUTURE market Specifically, at the end of period 8 your inventory in the FUTURE market above your borrowed units will be added to your SPOT inventory and will earn dividends and can be traded from the end of period 8 to the end of period 15 Thus at the end of period 8 your SPOT inventory will be updated as follows

SPOT inventory + FUTURE inventory − Borrowed FUTURE inventory

Press Enter to Continue or Home to go Back

If the sum of your inventory in the SPOT and FUTURE markets do not sum to at least 1 unit at the end of period 8, you will be assessed a penalty of 400 cents for each unit until your inventory reaches 1 unit The penalty will come out of your earnings for the experiment Your penalty payment will be paid to a randomly selected trader who has sufficient inventory to be transferred to you until you have 1 unit in your inventory

Press Enter to Continue or Home to go Back

During a trading period you can look at the past contract prices among participants who have made trades in both the SPOT and FUTURE markets In order to view this information you must press F3 Please do this now

DIVIDEND ACCOUNTING SHEET

END of PERIOD	SPOT INVENTORY	+	FUTURE INVENTORY	−	BORROWED INVENTORY	=	UNITS HELD	×	DIVIDEND DRAW	−	PENALTY COST	=	DIVIDEND INCOME
1	____	+	____	−	____	=	____	×	____	−	____	=	____
2	____	+	____	−	____	=	____	×	____	−	____	=	____
8	____	+	____	−	____	=	____	×	____	−	____	=	____
9	____	+	____	−	____	=	____	×	____	−	____	=	____

In order to determine your current earnings in this experiment you will have to maintain your own account records To begin, your dividends from your asset holdings must be calculated each period Your Dividend Accounting Sheet will be used to determine your dividend income For example, if at the end of period 1 you had 2 units of SPOT INVENTORY and the dividend draw was 8 cents, your dividend income for period 1 would be 16 cents (2 × 8 cents) Suppose that at the end of period 8 your SPOT inventory was 2 units and your FUTURE inventory was 2 units, then 1 unit of your FUTURES would be added to your SPOT inventory and earn a dividend in period 8 Your new SPOT inventory will be carried over for periods 9–15

Press Enter to Continue or Home to go Back

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AVERAGE HOLDING VALUE TABLE

END PERIOD	BEGIN PERIOD	PERIODS HELD	×	AVERAGE per PERIOD DIVIDEND VALUE	=	AVERAGE per UNIT INVENTORY VALUE
15	1	15	×	24	=	360
15	2	14	×	24	=	333
15	3	13	×	24	=	312
15	4	12	×	24	=	288
15	5	11	×	24	=	264
15	6	10	×	24	=	240
15	7	9	×	24	=	216
15	8	8	×	24	=	192
15	9	7	×	24	=	168
15	10	6	×	24	=	144
15	11	5	×	24	=	120
15	12	4	×	24	=	96
15	13	3	×	24	=	72
15	14	2	×	24	=	48
15	15	1	×	24	=	24

Each participant in this experiment will be given a table called AVERAGE HOLDING VALUE TABLE which describes the value (in cents) of average dividends by holding a unit of the asset from the current period until the end of the experiment (period 15) We have reproduced this Table above

Press Enter to Continue or Home to go Back

EARNINGS ACCOUNTING SHEET

PERIOD	ENDING CASH	–	BEGINNING CASH	=	SALES – PURCHASES	+	DIVIDEND INCOME	+	STARTING CAPITAL	=	PERIOD EARNINGS
1	1250	–	1225	=	25	+	16	+	225	=	266
2	1200	–	1250	=	–50	+	84	+	0	=	34
3			1200								
4											

Your current period earnings can be found by filling out your EARNINGS ACCOUNTING SHEET To fill-out this sheet you must first calculate your sales – purchases This is done by subtracting your BEGINNING CASH ON HAND from your ENDING CASH ON HAND for the period You then add this number to your dividend income for the period and your starting capital (only in the first period) For example, suppose that at the end of period 2 your cash level was 1200 then your sales minus purchases would be 1200 – 1250 = –50 as calculated above Add to that your dividend income of 84 to find your first period earnings of 34 cents This sheet should be filled out at the end of each period

Press Enter to Continue or Home to go Back

SHORT REVIEW OF INSTRUCTIONS

To enter a BID to buy type the bid you wish to submit in PC cents
To have your bid broadcast to all the other traders press F1

To enter an ASK to sell type the ask you wish to submit in PC cents
To have your ask broadcast to all other traders press F2

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Remember, in order for your bid (ask) to be accepted it must be above (below) the standing per unit bid (ask) In addition you must have adequate cash on hand (inventory) to make your bid (ask)

To accept a bid to sell a unit press Ctrl and F1 together To accept an ask to buy a unit press Ctrl and F2 together

You will be paid in cash an amount equal to your starting capital + (sales revenue − expenditures) + dividend earnings Dividend earnings = end-of-period inventory units × dividend per unit for that period

If you have a question that you would like answered verbally don't hesitate to raise your hand and contact the monitor

At the end of period EIGHT the sum of your inventory in the SPOT and FUTURE markets must be equal to one unit or you will pay a penalty of 400 cents for each unit until your total inventory reaches 1 unit

Press Enter to Continue

Appendix B

Time-Series Data

The following graphs (figs B1–B13) show the mean contract price and trading volume for each period and certain dividend switch, and futures market experiments

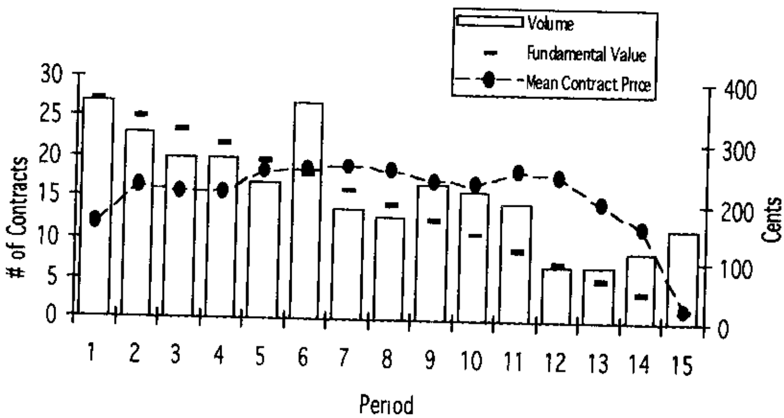

FIG B1 —Certain dividend inexperienced

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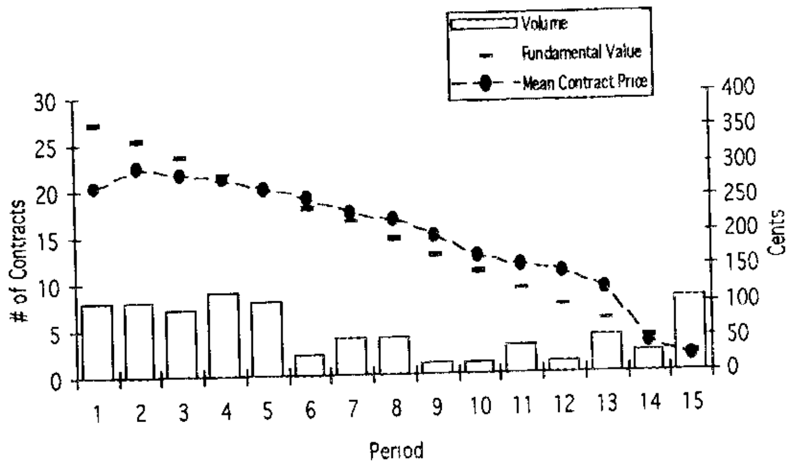

FIG B2 —Certain dividend experienced

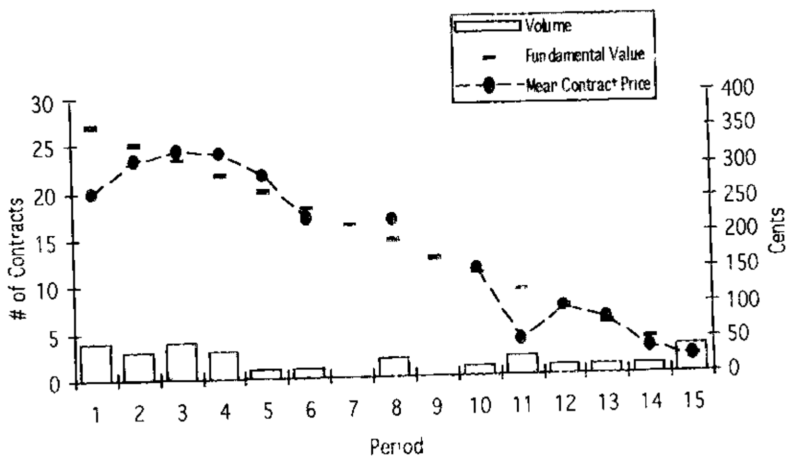

FIG B3 —Certain/uncertain dividend switch

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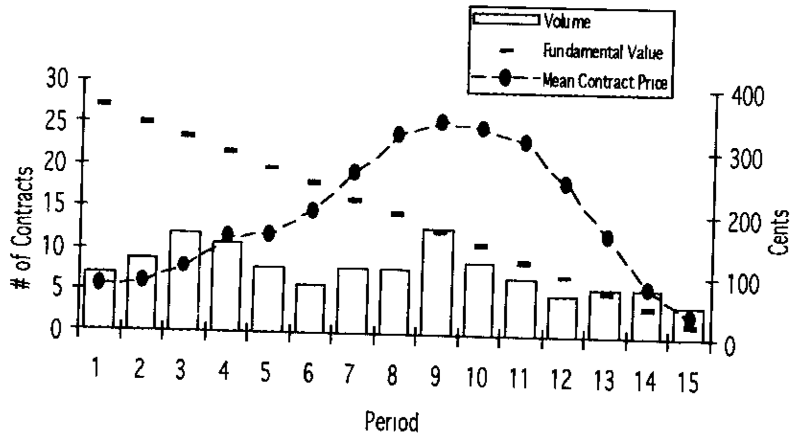

FIG B4 —Certain dividend inexperienced

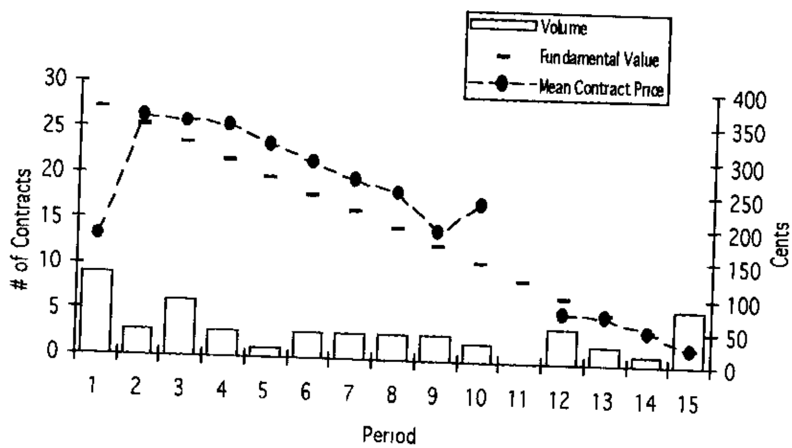

FIG B5 —Certain dividend inexperienced

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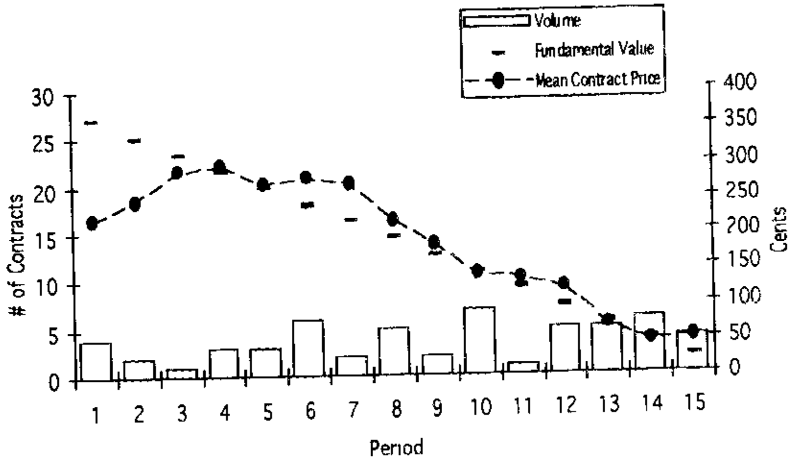

Fig B6 —Certain/uncertain dividend switch

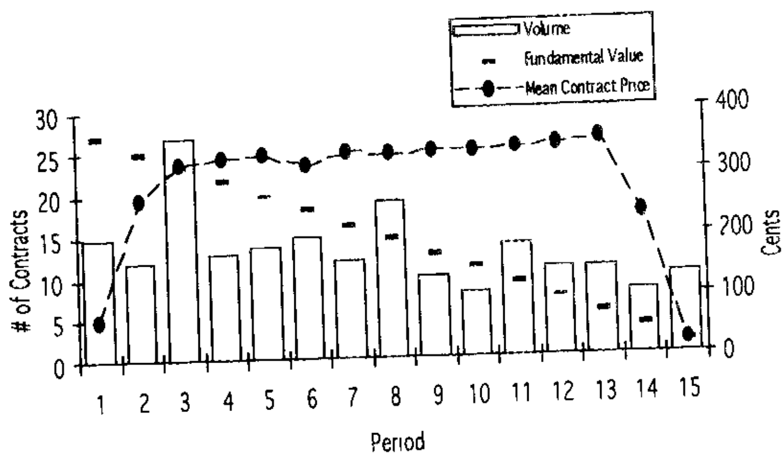

Fig B7 —Certain dividend inexperienced

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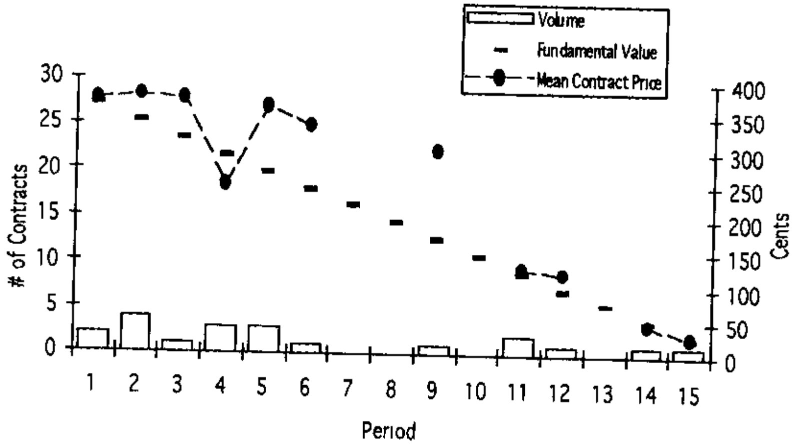

FIG B8 —Certain dividend experienced

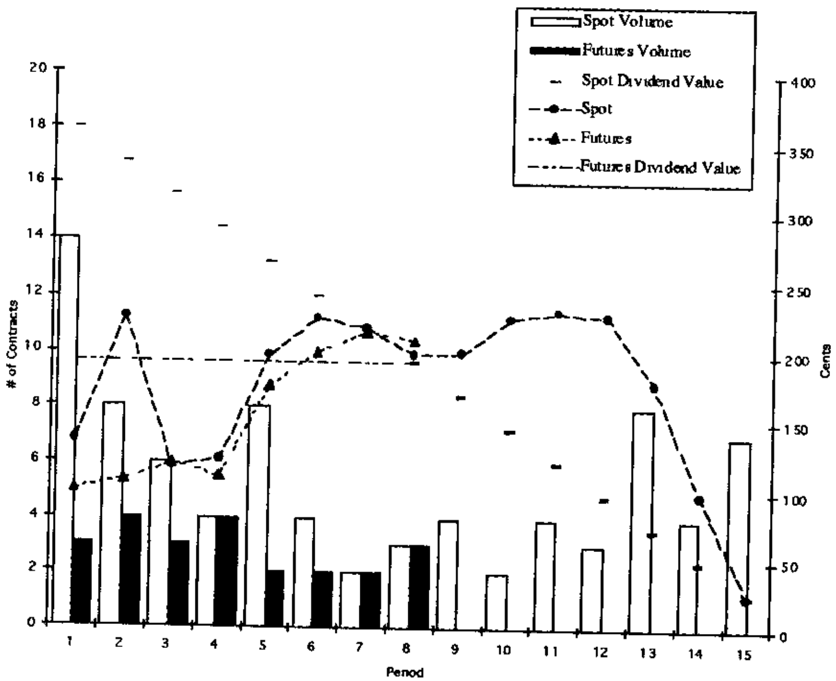

FIG B9 —Futures market inexperienced

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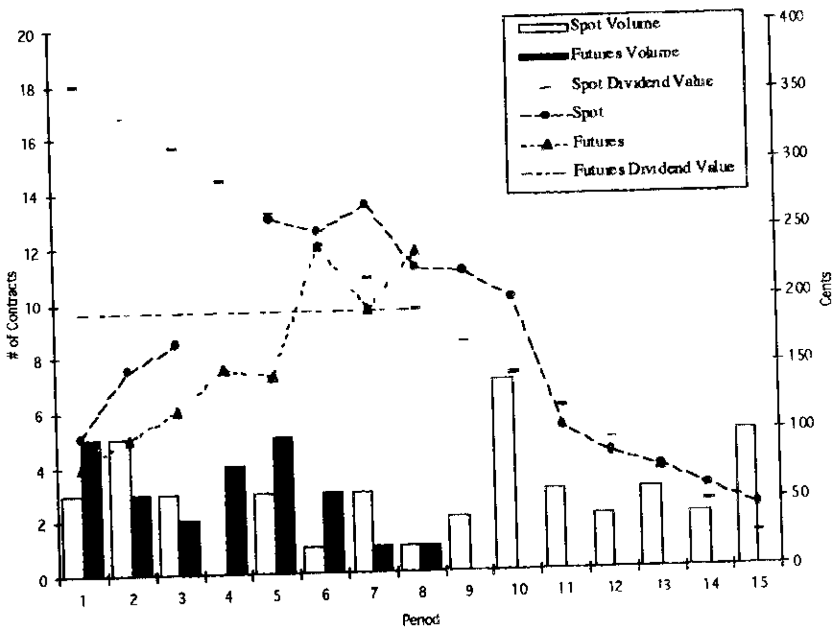

FIG B10 —Futures market experienced

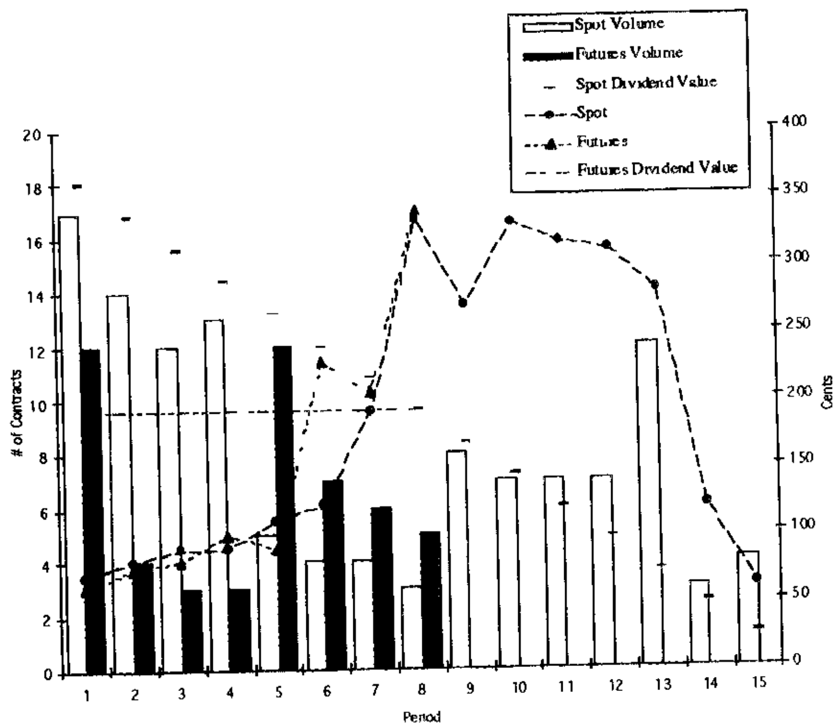

FIG B11 —Futures market inexperienced

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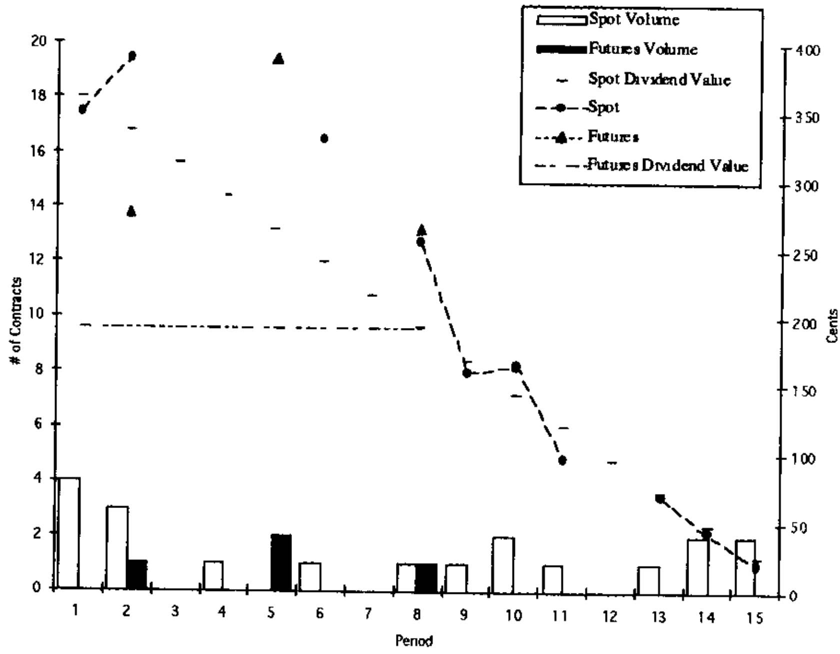

FIG B12 —Futures market experienced

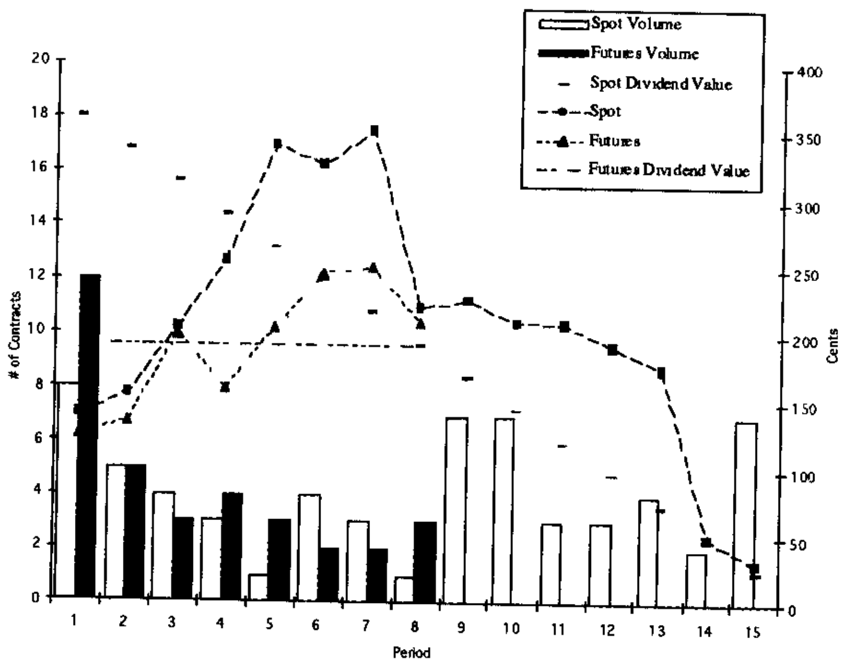

FIG B13 —Futures market inexperienced

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Appendix C

ANOVA Estimates of Treatments for Bubble Amplitude, Duration, and Turnover

The seemingly unrelated regression estimates in this appendix come from the following model

$$a = \alpha B + \beta C + \delta Cx + \phi F + \gamma Fx + \eta M + \mu L + \nu S + \theta X + \vartheta X2 + \epsilon_a$$

$$d = \alpha B + \beta C + \delta Cx + \phi F + \gamma Fx + \eta M + \mu L + \nu S + \theta X + \vartheta X2 + \epsilon_d$$

$$t = \alpha B + \beta C + \delta Cx + \phi F + \gamma Fx + \eta M + \mu L + \nu S + \theta X + \vartheta X2 + \epsilon_t$$

where

a = amplitude,
d = duration,
t = turnover,
B = baseline (inexperienced) asset market dummy,
C = certain dividend (inexperienced) treatment dummy,
Cx = certain dividend (once-experienced) treatment dummy,
F = futures market (inexperienced) treatment dummy,
Fx = futures market (once-experienced) treatment dummy
S = switch treatment dummy,
M = margin buying treatment dummy,
L = LAN market treatment dummy
X = baseline (once-experienced) traders dummy,
$X2$ = baseline (twice-experienced) traders dummy

The results in tables C1–C3 are based on seemingly unrelated regression estimates of the amplitude, duration and turnover simultaneous equations

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TABLE C1 **Regression Estimates**
Equation 1 Dependent Variable = Amplitude

Treatment	Coefficient	Standard Error	t-Statistic
Baseline inexperienced	1 5323	1366	11 2143
Certain dividend	− 1082	3618	− 2991
Certain dividend experienced	− 6883	3619	1 9019
Futures	−1 6826	5166	−3 2567
Futures experienced	−2 0059	5619	−3 5699
Margin buying	1 5647	3411	4 5871
Local area network	− 4911	3603	1 3529
Switch	− 8868	4128	−2 1481
Once experienced	−1 0609	3039	−3 4912
Twice experienced	−1 4273	4063	−3 5130
N	38		
R^2	68		
Sum of squared residuals	8 198		
Standard error of the regression	5411		
Durbin-Watson	1 883		

TABLE C2 **Regression Estimates**
Equation 2 Dependent Variable = Duration

Treatment	Coefficient	Standard Error	t-Statistic
Baseline inexperienced	10 1501	5569	18 2274
Certain dividend	0614	1 4747	0416
Certain dividend experienced	−1 2719	1 4369	− 8851
Futures	8673	2 1055	4199
Futures experienced	−3 6327	2 2899	−1 5864
Margin buying	−2 2001	1 3901	−1 5826
Local area network	1 1827	1 0609	1 1147
Switch	−6 2415	1 6825	−3 7097
Once experienced	−4 8501	1 2385	−3 9160
Twice experienced	−7 1501	1 6558	−4 3182
N	38		
R^2	66		
Sum of squared residuals	136 17		
Standard error of the regression	2 205		
Durbin-Watson	2 493		

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TABLE C3 **Regression Estimates**
Equation 3 Dependent Variable = Turnover

Treatment	Coefficient	Standard Error	t-Statistic
Baseline inexperienced	5 4938	4139	13 2725
Certain dividend	1 2533	1 0962	1 1433
Certain dividend experienced	−4 8867	1 1123	−4 3933
Futures	−1 3613	1 5631	− 8710
Futures experienced	−5 5831	1 7022	−3 2800
Margin buying	− 4300	1 0333	4162
Local area network	3 1494	7886	3 9934
Switch	−4 4785	1 2506	3 5811
Once experienced	−2 4013	9206	−2 6084
Twice experienced	−3 7988	1 2308	−3 0865
N	38		
R^2	72		
Sum of squared residual	75 24		
Standard error of the regression	1 6939		
Durbin-Watson	2 215		

Appendix D

ANOVA Estimates of Treatments for Walrasian Price Adjustment

The model that is estimated in this appendix is as follows

$$
\begin{aligned}
P_t - P_{t-1} = \alpha &+ \omega X + \delta C + \phi Cx + \varphi F + \gamma Fx \\
&+ \eta S + \lambda L + \beta (B_{t-1} - O_{t-1}) + \rho [X (B_{t-1} - O_{t-1})] \\
&+ \mu [C (B_{t-1} - O_{t-1})] + \nu [Cx (B_{t-1} - O_{t-1})] \\
&+ \theta [F (B_{t-1} - O_{t-1})] + \vartheta Fx [(B_{t-1} - O_{t-1})] \\
&+ \varsigma [S (B_{t-1} - O_{t-1})] + \tau [L (B_{t-1} - O_{t-1})] + \epsilon,
\end{aligned}
$$

where

P = mean contract price,
B = number of bids tendered,
O = number of offers tendered,
X = experienced baseline
C = certain dividend treatment dummy
Cx = experienced certain dividend treatment dummy
F = futures market treatment dummy,
Fx = experienced futures market treatment dummy,
S = switch treatment dummy,
L = LAN market treatment dummy

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TABLE D1 Regression Estimates
Dependent Variable Δ Mean Contract Price

Treatment	Coefficient	Standard Error	*t*-Statistic
α	− 1273	0697	− 1 8249
Baseline experienced	− 0118	0942	− 1249
Certain dividend	0056	1185	0477
Certain dividend experienced	− 0082	1229	− 0674
Futures market	− 0512	1299	− 3944
Futures market experienced	- 0188	1512	− 1246
Switch	0065	1631	0399
Local area network	0041	0305	1357
β	0329	0050	6 5923
Baseline experienced	− 0071	0036	− 1 9722
Certain dividend	− 0136	0091	− 1 4981
Certain dividend experienced	− 0146	0093	− 1 5577
Futures market	− 0237	0062	− 3 7882
Futures market experienced	− 0278	0095	− 2 9072
Switch	− 0312	0135	− 2 3012
Local area network	− 0021	0946	− 0211
N	364		
R^2	2571		
Sum of squared residuals	0113		
Standard error of regression	5782		
Durbin-Watson	2 0679		

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