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Initial cash/asset ratio and asset prices: An experimental study

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ABSTRACT **A series of experiments, in which nine participants trade an asset over 15 periods, test the hypothesis that an initial imbalance of asset/cash will influence the trading price over an extended time. Participants know at the outset that the asset or "stock" pays a single dividend with fixed expectation value at the end of the 15th period. In experiments with a greater total value of cash at the start, the mean prices during the trading periods are higher, compared with those with greater amount of asset, with a high degree of statistical significance. The difference is most significant at the outset and gradually tapers near the end of the experiment. The results are very surprising from a rational expectations and classical game theory perspective, because the possession of a large amount of cash does not lead to a simple motivation for a trader to bid excessively on a financial instrument. The gradual erosion of the difference toward the end of trading, however, suggests that fundamental value is approached belatedly, offering some consolation to the rational expectations theory. It also suggests that there is a time scale on which an evolution toward fundamental value occurs. The experimental results are qualitatively compatible with the price dynamics predicted by a system of differential equations based on asset flow. The results have broad implications for the marketing of securities, particularly initial and secondary public offerings, government bonds, etc., where excess supply has been conjectured to suppress prices.**

Within the context of classical economics the supply/demand considerations for financial instruments usually differ from those of most commodities in two crucial ways. One is that financial instruments have no consumable value at any point, so that the sole rationale in purchasing is for financial gain. Consequently, the elasticity of the demand and supply are dependent solely upon value (with the possible exception of a risk/reward trade-off). Second, because all participants in a market are capable of possessing the same information, classical game theory stipulates a unique value for a financial instrument. Consequently, there is no reason to expect that the demand would be anything but perfectly elastic.

However, it is generally recognized by investment houses and traders that the submission of a large supply into the market place has a significant and long-term effect in terms of depressing prices and conversely for the removal of supply. There are many possible theoretical reasons for this. One is that each investment involves a particular type of risk, so that the increase of supply beyond a certain point entails the cooperation of additional investors who may demand a higher risk premium. A more fundamental aspect involves imperfect markets. If there is a surplus of cash in the system, some of the less-informed participants will be inclined to pay too much. While there will be some competition among the more informed investors, the relative scarcity of the financial instrument will mean that the informed investors will tend not to cross over to accept the bid. Consequently, a high asking price will tend to prevail.

The deviation from fundamental value due to excess supply has been noted in some practical instances such as the following: (*i*) Treasury bond offerings, (*ii*) initial public offerings (IPOs) and closed-end fund secondary offerings, and (*iii*) corporate takeovers that remove a large amount of stock investment opportunities.

In the Treasury bond market, market analysts frequently make comments in the media on the short-term supply/demand that influences price. For example, the fundamental value of a 30-year bond depends chiefly on the rate of inflation for the entire period. However, the practical belief is that a temporary budget surplus and a consequent shortage of supply of bonds will result in higher prices even if the long-term outlook has not changed. Analogous observations are made with secondary stock offerings that add a significant supply, and with corporate stock buybacks that remove supply. For the aggregate market, some market participants believe that high corporate takeover activity that removes a large quantity of stock supply (replaced by high-yield, or "junk," bonds, for example) results in higher average prices.

The persistent discount in closed-end funds, even in the absence of tax considerations, has presented a puzzle for economic theory. An explanation (1) that has been disputed suggests that the discount is correlated with investor sentiment. Of course, when the investment sentiment is low, there is a reduced supply of cash that tips the balance toward excess supply of shares.

A number of studies have provided some explanation for the price anomalies involved in IPOs, including those of closed-end funds (2–5). Deviations from realistic prices have been attributed to asymmetric information and uninformed investors (see, e.g., ref. 3 and references therein). It has been argued that in the after-market trading of an IPO, the underwriting syndicate effectively compensates the initial (uninformed) investors by buying back shares and preventing a decline in prices (3). However, a study (4) using data of the first 100 days of closed-end fund IPOs concludes that asymmetric information alone is not adequate to explain the initial overpricing and the subsequent decline. The authors concluded that the trading in the first 4 weeks is seller initiated and appears to be related to covering positions in a stabilization effort by the underwriters, while small investors make transactions in the mistaken belief that they are trading in an unmanaged market.

The role of underwriters in the price evolution in the aftermarket has also been addressed in a study (5) of all IPOs in the German market in the period 1983–1992. Initial return was found to be negatively correlated with competition among underwriters, and positively correlated with the fraction retained by the issuer. The authors find "clear indications" of aftermarket underwriter support.

Abbreviation: IPO, initial public offering.

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The thrust of these empirical studies is that the supply/demand balance and efforts to adjust or stabilize it have a profound influence in the price dynamics for a significant time period. In this paper we report on a series of experiments that test the key issue of whether the initial endowment ratio of cash to (earning) assets has any effect on the price dynamics. By varying this initial ratio we examine its effect on the price evolution for a clearly defined asset.

Hence we test the practical expectations against those of rational markets in a laboratory setting by allowing participants to trade an (earning) asset or "stock" whose expected value is a known fixed value. In three of the experiments there is an initial distribution that consists of more cash than the asset, while four experiments contain the opposite mix. Because all participants know in advance that the asset will pay a single terminal dividend with an expected value of \$3.60 per share, classical theory would predict an initial trading price near that price with a constant evolution with some random fluctuations about that price. Within the realm of rational expectations, there is no mechanism for an excess of cash or asset to induce buying or selling far from fundamental value.

The results are most easily displayed in the composite graphs of Fig. 1, which consist of the means for each period for the "cash rich" experiments on the upper curve and the "asset rich" experiments on the lower curve. As the curves show, the prices for each period are always higher for the cash rich experiments. The difference between the two sets of experiments is highest at the outset and narrows as the experiment nears the end. In the next section, we perform a set of statistical tests that indicate that the aggregate mean of the cash rich experiments is higher than that of the asset rich with a statistical significance at a level of at least $p = 0.03$ and possibly as strong as $p = 10^{-4}$. In other words, this difference between means in these seven experiments would be observed less than 3% (and perhaps less than 10^{-4}) of the time if the result were due to randomness.

As with many of the bubbles experiments (see refs. 6 and 7 and references therein), the emerging conclusion offers some support to both the supporters and opponents of the rational expectations theory. The trading price at the end of the experiment is not far from the fundamental value. However, the very slow approach to that value, given that all of the information is known in advance of the trading, suggests that the rational expectations are only part of the underlying motivations of traders. The experiments offer a simple perspective toward establishing a time scale in the return to equilibrium after an excess supply or demand is introduced. From a practical standpoint, a quantitative understanding of the time scale and the nature of the return to equilibrium is important in terms of initial and secondary offerings of stocks. Using a much larger data set of experiments, we hope to be able to derive a detailed quantitative relationship between excess supply, distribution of shares, and the elapsed trading time.

In three of the asset rich experiments, there was a considerable difference between the relative distribution of cash and asset among the participants, which did not appear to have a pronounced effect in terms of the price evolution. However, further experimentation is needed before one can make any assertions on this issue.

ANALYSIS OF EXPERIMENTS

In each of seven experiments, nine subjects were given the opportunity to trade an asset whose sole value consisted of a dividend with expectation value of \$3.60 at the end of trading on a computer network. The participants were given a distribution of cash and asset so that each subject had some of each except in the last experiment in which some had all cash and others had just the asset.

Participants were given 15 periods in which they could trade the shares in a double auction. They were told that each share of asset would pay a dividend with expected value of \$3.60 at the end of the 15th period. The distribution was a 25% probability for each for \$2.60 and \$4.60, and a 50% probability for \$3.60. In three of the experiments there was an initial excess supply of asset, whereas four started with excess cash. We define the ratio

$$q = (S - D)/S,$$

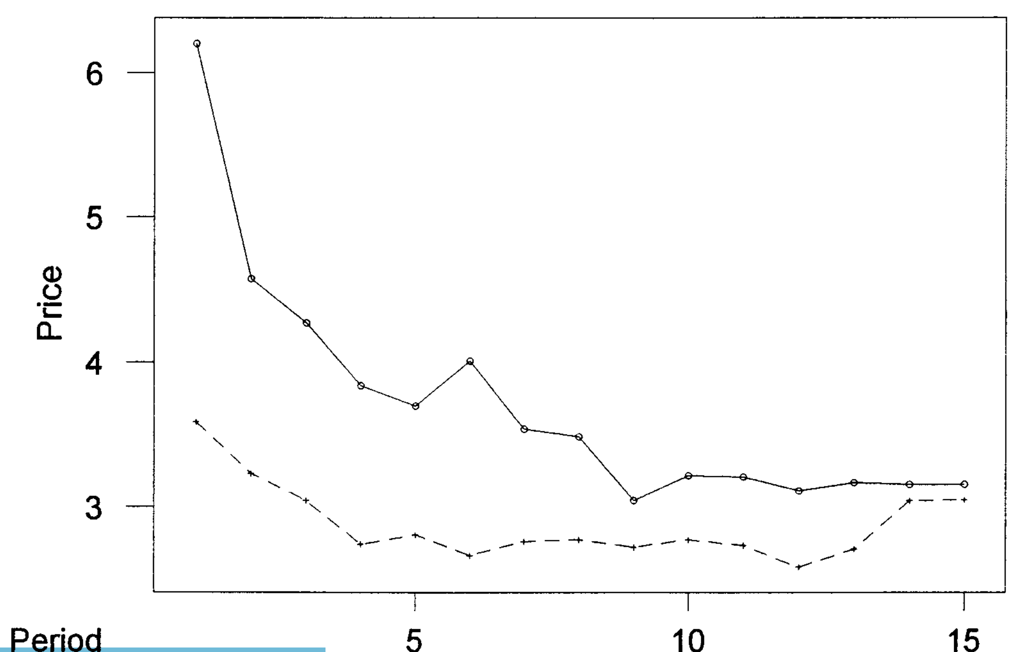

FIG. 1. Mean period prices for experiments. For each period the mean of all of the experiments entailing an initial surplus of cash relative to asset is computed and displayed by the solid line. Similarly, the means for the experiments with an initial surplus of asset are displayed by the dashed line. The mean cash rich values are higher for the duration of the experiment, though the difference is most pronounced at the outset.

Table 1. Experimental data: Trading prices ($) for each of 15 periods

Period	Exp. 1 AR Mar 96	Exp. 2 CR Mar 96	Exp. 3 CR May 97	Exp. 4 CR May 97	Exp. 5 AR Jul 97A	Exp. 6 AR Jul 97B	Exp. 7 AR Jul 97E
1	4.99	5.91	5.05	7.64	4.03	2.88	2.89
2	3.59	4.28	4.86	4.58	4.22	3.06	3.04
3	3.29	3.93	4.56	4.32	3.83	2.81	3.03
4	2.88	3.36	4.23	3.91	3.00	2.26	3.09
5	2.91	3.45	4.08	3.56	2.65	2.40	3.12
6	2.80	4.11	3.95	3.96	3.03	2.12	3.08
7	2.87	3.27	3.73	3.62	3.08	2.33	3.09
8	2.79	2.98	3.53	3.95	3.54	2.43	3.11
9	2.74	2.71	3.42	3.00	3.60	2.34	3.09
10	2.74	2.76	3.36	3.53	3.06	2.43	3.16
11	2.71	2.93	3.16	3.53	3.12	2.42	3.07
12	2.72	2.94	3.00	3.39	3.22	1.96	3.07
13	2.7	2.85	3.12	3.53	3.12	2.44	2.99
14	3.00	2.97	2.99	3.50	3.25	3.10	3.03
15	2.74	2.95	2.92	3.60	3.11	3.30	3.11

The data for each of the 15 periods of the seven experiments are displayed, with CR denoting the experiments with an initial cash rich endowments and AR the asset rich. The prices for the cash rich experiments are generally higher than those of the asset rich.

where S_i is the total initial value of shares (supply) and D_i is total initial holdings of cash (demand). In experiments 1, 5, 6, and 7 the value of q is 0.125, so that there is a small degree of oversupply of the asset. In experiment 2, $q = -0.8125$, whereas $q = -0.86$ in experiments 3 and 4, so that there is considerable surplus of cash at the outset (see Tables 2 and 3).

The "trading price" for each period refers to the mean of the prices at which trades occurred during that period. These trading prices for each period of each experiment are displayed in Table 1.

We focus on the role the initial cash/asset ratio has in the price evolution. In each experiment we tabulate the mean of the full set of 15 trading prices, the mean of the last eight period prices, and the prices for the first and the last periods (Table 2).

We perform the following series of statistical tests on the data from the seven experiments: (*i*) Grouping the data as cash rich (i.e., experiments 2, 3, and 4) or asset rich (i.e., experiments 1, 5, 6, and 7), we perform tests to determine whether the mean and median of the cash rich experiments exceed those of the asset rich. (*ii*) We compare the means of each experiment as well as the first and last values of the experiments in each group to determine whether there is a statistically significant difference between the two groups in terms of these values. (*iii*) We do a similar comparison with the second half of each experiment. (*iv*) We use linear regression to estimate the coefficient linking the mean of the experiments with the relative excess supply.

To compare the means of two sets we use a standard t test. Because this test assumes a normal distribution, we also use the nonparametric Mann–Whitney test to compare two population medians (8, 9).

Combining the price data from each of the three cash rich experiments, we obtain 45 numbers, while 60 are obtained from the four asset rich experiments. Applying the standard two-sample t test for these data, we find a mean of \$3.71 for the cash rich experiments with a standard deviation of \$0.9, whereas the asset rich group has a mean of \$2.99 and a standard deviation of \$0.49. The 95% confidence interval for the difference is \$0.42 to \$1.01. The hypothesis that the mean of the cash rich group is greater than that of the asset rich has very strong statistical support with $T = 4.83$ and $p < 10^{-4}$.

Applying the Mann–Whitney test to the same data, we find a median of \$3.53 for the cash rich and \$3.03 for the asset rich with a 95% confidence interval for the difference of \$0.38 to \$0.83. The hypothesis that the median of the cash rich group is greater than that of the asset rich is again confirmed with $p < 10^{-4}$ and $W = 3146.5$.

An issue that arises from a theoretical perspective as well as an examination of the composite shown in Fig. 1 is whether the difference between the two groups disappears after a short time. This is addressed by examining the last eight trading periods of each experiment. This provides us with 24 and 32 data points, respectively, so that a similar statistical analysis is possible. The means for the two groups are \$3.19 and \$2.91 with standard deviations of \$0.325 and \$0.361 with a 95% confidence interval of \$0.095 to \$0.464. The hypothesis that the cash rich group has higher mean is confirmed with $T = 3.04$ and $p = 0.0037$. The medians determined by the Mann–Whitney test are closer together, with values of \$3.06 and

Table 2. Excess supply and data of experiments

Exp.	$(S - D)/S$	Price, \$ Mean	Mean last 8	Last value	First value
1 AR Mar 96	0.125	3.03	2.77	2.74	4.99
2 CR Mar 96	−0.8125	3.43	2.89	2.95	5.91
3 CR May 96A	−0.86	3.73	3.19	2.92	5.05
4 CR May 96B	−0.86	3.97	3.50	3.60	7.64
5 AR Jul 97A	0.125	3.32	3.25	3.11	4.03
6 AR Jul 97B	0.125	2.55	2.55	3.30	2.88
7 AR Jul 97E	0.125	3.06	3.07	3.11	2.89

For each experiment, the excess relative supply $(S - D)/S = q$ is listed along with the overall mean, the mean for the last eight periods, and the last and first values. In the last experiment (AR Jul 97E), each of the participants received an identical distribution, whereas the previous two experiments allotted different distributions to the traders, though the ratio of total cash to asset was identical in the three experiments.

\$3.045 for the cash rich and asset rich groups, respectively. The statistical significance is at the level of $p = 0.02$.

An implicit assumption in the analysis above is that each price is a statistically independent quantity. Technically, there is some dependence between the data points, because all 15 prices in one experiment are generated by the same participants. This issue is most clearly confronted by comparing the means of each experiment, which of course results in just seven data points. The means of each of the seven experiments are shown in Table 2. We group these means into the cash rich and asset rich categories in Table 3, and we determine whether there is a statistically significant difference between the samples of three and four data points. We note first of all that the lowest of the means for the cash rich experiments is still higher than the highest mean of the asset rich experiments. The aggregate mean for the cash rich experiments is \$3.71, whereas the asset rich experiments have the mean \$2.99, with standard deviations of \$0.27 and \$0.32, respectively.

The t test shows a 95% confidence interval of \$0.10 to \$1.34 with $T = 3.22$ and $p = 0.032$, so there is strong support for the hypothesis that the cash rich experiments as a whole had higher means than the asset rich despite the small number of data points. Similarly, the Mann–Whitney test results in medians of \$3.73 and \$3.05 with a 95% confidence interval of \$0.11 to \$1.42 for the difference with $W = 18$, again yielding the same conclusion. Consequently, we obtain very strong results despite the small number of data points that one obtains by considering a truly independent set of means.

Finally, we perform a similar analysis of the first and last prices in the experiments. These sets are also small and are subject to more noise than the means of the entire experiments. The three initial prices in the cash rich experiments have a mean of \$6.20, whereas the four initial prices in the asset rich experiments have a mean of \$3.70, yielding a 95% confidence interval of $-$\$0.41 to \$5.42 with a p value of 0.072 and T value of 2.73, indicating a significant difference in the means. The Mann–Whitney test indicates medians of \$5.91 and \$3.46, respectively, with a 95% confidence interval of \$0.059 to \$4.76 with a significance at the level of 0.051 that the medians differ.

A similar analysis on the last values shows means of \$3.16 and \$3.06 with $T = 0.37$ and $p = 0.74$, indicating that the difference may or may not be statistically significant, which is not surprising due to the small number of data points. The medians determined by the Mann–Whitney test are \$3.19 and \$2.92, respectively, with a 95% confidence interval of $-$\$0.36 to \$0.95), resulting in $W = 15$ and $p = 0.38$, so there is limited statistical evidence that the last values are significantly different.

Another aspect of interest in these experiments is the role of the distribution of shares among the traders. The ratio of total cash to asset was the same in the last three experiments. In the first two, six traders received \$13.05 plus two shares, whereas the other three traders received \$2.25 plus five shares.

Table 3. Characteristics of cash rich and asset rich experiments

Price, \$							
Overall mean		Mean last 8		Last value		First value	
CR	AR	CR	AR	CR	AR	CR	AR
3.43	3.03	2.89	2.77	2.95	2.74	5.91	4.99
3.73	3.32	3.19	3.25	2.92	3.11	5.05	4.03
3.97	2.55	3.50	2.55	3.60	3.30	7.64	2.88
	3.06		3.07		3.11		2.89

The following values are tabulated for the cash rich (CR) and asset rich (AR) experiments: the overall mean for each experiment, the mean for the last eight periods, the last price in each experiment, and the first price in each experiment.

In the final experiment, all traders received \$9.45 plus three shares. However, the mean price of \$3.06 for this final experiment falls between the means of \$3.32 and \$2.55 for the former two experiments, respectively. A standard t test indicates the difference between the means for the first and third is in the 95% confidence interval \$0.02 to \$0.50, while the analogous difference between the second and third is in the interval $-$\$0.73 to $-$\$0.30). Finally, grouping the first two together, one obtains a mean of \$2.94, and a confidence interval for the difference between this group and the last experiment is $-$\$0.34 to \$0.086 with a p value of 0.12 for the hypothesis that the unequal distribution results in a smaller mean than the equal distribution. The Mann–Whitney test results in medians of \$3.045 and \$3.08 for these two groups with a significance of 0.22 offering very limited support for the same conclusion.

These experiments are consistent with the observation made by Porter and Smith (ref.7, p. 117) that "Observations from four experiments with inexperienced traders show no significant effect of equal endowments on bubble characteristics."

One factor that introduces some noise into these experiments is the control of the bulk of the shares by three people so that the actions of one person are likely to influence the price greatly. Thus, to explore the issues related to distribution of shares, one needs not only a greater number of experiments, but experiments with more participants.

THEORETICAL MODELING AND CALIBRATION

Classical theories would stipulate that there would be no difference in price due to differences in initial cash/asset value because there would be no motivation for buying the asset above its rational expectation value no matter how much cash one had, and similarly for selling below rational expectation value (see, e.g., refs. 10–14).

We treat the theory of the supply/demand for a financial instrument by utilizing the conventional supply/demand cross diagram for a commodity and then deriving some quantitative relationships that can be calibrated through the experiments (see, e.g., ref. 14).

We consider the usual supply/demand graph with price, P, on the horizontal axis and quantity, Q, on the vertical for convenience of adding supply. We write the demand and (original) supply functions as

$$Q_d = A(P_e - P) + Q_e \quad [1]$$

$$Q_s = B(P - P_e) + Q_e \quad [2]$$

with P_e and Q_e as the crossing point, so that P_e is the equilibrium price and Q_e is the equilibrium quantity.

Suppose that a new supply is now introduced. In principle this function could have a different shape or slope. However, let us suppose that the motivations of the new sellers are the same, so that the new supply is simply a fraction, q, of the new supply times the old supply,

$$Q_s^n = qQ_s. \quad [3]$$

For example, if we double the supply of asset, then $q = 1$ and the aggregate supply is then

$$Q_s^a = Q_s^n + Q_s = (1 + q)[B(P - P_e) + Q_e], \quad [4]$$

and the new equilibrium point is obtained by equating

$$Q_d = Q_s^a \quad [5]$$

or,

$$A(P_e - P) + Q_e = (1 + q)B(P - P_e) + (1 + q)Q_e, \quad [6]$$

which is solved for the new equilibrium price, $P = P_e^{new}$ as

$$P_e^{new} = P = P_e - \frac{qQ_e}{(1+q)B + A}. \quad [7]$$

From the key relation **7** we can first of all determine the ratio of slopes A and B. If there is complete symmetry between the buy/sell sides, then we would obtain the ratio $A/B = 1$; otherwise the ratio would be different.

Given two experiments with different values q_1 and q_2 resulting in different changes from the equilibrium price P_e, we denote

$$\Delta P_1 = P_e^{new(1)} - P = -\frac{q_1 Q_e}{(1+q_1)B + A} \quad [8]$$

and likewise for q_2. Dividing $\Delta P_1/\Delta P_2$, one obtains

$$\frac{\Delta P_1}{\Delta P_2} = \frac{q_1}{q_2}\frac{(1+q_2)B + A}{(1+q_1)B + A} = \frac{q_1}{q_2}\frac{(1+q_2)B/A + 1}{(1+q_1)B/A + 1} \quad [9]$$

so that $R: = B/A$ is the only unknown, because we set q_1 and q_2 in the experiment and know $\Delta P_{1,2}$ from the experiments. Solving Eq. **9,** we obtain

$$R: = B/A = \frac{1 - \Delta P_1/\Delta P_2}{(\Delta P_1/\Delta P_2)q_2(1+q_1) - q_1(1+q_2)}. \quad [10]$$

Now we write **7** as

$$P = P_e - \frac{qQ_e/A}{(1+q)B/A + 1} \quad [11]$$

so that Q_e/A is the only other quantity to be determined, because we already know B/A from Eq. **10**. This can be calibrated by using additional experiments. The quantity Q_e/A is essentially a normalizing mechanism that takes time into account.

Note that Eq. **11** provides a correction term for the classical game theoretic result that $P = P_e$. The size of the correction is of order $1/A$, or 1/(slope of demand curve). If this slope is infinite then we recover the classical result.

For example, a symmetric buy/sell ratio, $R = 1$, and a doubling of the supply—i.e., $q = 1$, means the ratio of demand to supply is 1:2 and the price differential **8** is then

$$\Delta P = \frac{-Q_e}{3}. \quad [12]$$

On the other hand, if $q = -1/2$ so that total supply is only half of the demand, then we have a 2:1 ratio, with the price differential **8** now yielding

$$\Delta P = \frac{+Q_e}{3}, \quad [13]$$

so that only the sign changes when the supply/demand roles are reversed.

In terms of the experiments, it is only the ratio of supply/demand that is really important, so we can define q according to the situation. For example, in the experiments where the asset is double the cash initially, we have $q = 1$, whereas those that have double the cash, it is $q = -1/2$.

The relationship

$$\Delta P(q) = -\text{Const.} \frac{q}{(1+q)B/A + 1} \quad [14]$$

can be tested for a range of q values. The validity of this relationship would indicate that financial instruments obey a supply/demand relation that is similar to other commodities. The elasticity for a financial instrument is then expected to lie between the perfectly elastic demand stipulated by rational markets and the relatively inelastic demand for some staple commodities.

We perform two linear regressions using the mean price versus the excess supply, q, and the term in **14,** respectively. We assume B/A is unity in **14** in the latter. Fig. 2 shows that the linear regression results in the expression

$$P(q) = 3.08 - 0.75q, \quad [15]$$

where the 0.75 coefficient has a T value of -3.22 and p value of 0.023. Similarly, the regression for expression **14** results in

$$P(q) = 3.04 - 0.927q/(2+q) \quad [16]$$

with slightly better values of -3.31 and 0.021 for T and p. Hence, the regressions are obtained with a strong statistical confirmation.

These formulae present a simple relation that can be tested with additional experiments in which q is varied continuously. For example, the prediction for $q = 0$ is that the mean price will be \$3.04, just slightly above the asset rich mean of \$2.99. Note that the concept of risk aversion does not seem to be very significant in terms of these experiments.

The influence of excess cash or asset is also inherent in the differential equations models that incorporate nonclassical behavior (15) and may be one of the factors that are responsible for the autocorrelated behavior observed in markets (16).

CONCLUSION

The analysis of the experimental data leads to the conclusion that the ratio of initial cash value to asset value is a significant predictor of initial and mean trading prices. In general, we may expect four factors to enter into each period's trading price: (*i*) the deviation from fundamental value, (*ii*) the balance of cash/asset at the previous time period, (*iii*) the previous period price, and (*iv*) the derivative of the price during the previous periods.

To understand how these factors enter into the price evolution, we consider the time history of the typical cash rich experiment (Fig. 1). As the experiment begins, there is a surplus of cash value compared with the asset (valued at the expectation value of \$3.60). This roughly 2:1 ratio leads almost linearly to a value of \$6.20, or almost double the fundamental value. Note that in the asset rich experiments, the cash/asset ratio at 0.8725 does not differ nearly as much from unity, and mean first period price is very close to fundamental value at \$3.586. Consequently, the mean prices in the first period facilitate an understanding of the first two factors in the absence of the latter two.

Once the high trading price of the first period (i.e., mean \$6.20) is established and known to the traders, there is a market price established and the perception that each share is worth that amount rather than the fundamental value of \$3.60. Because this had been the trading price, the owners of the shares feel that they can sell each share at that amount, as there is no apparent reason for any change in value. But this means that the total value of asset, by this measure, has now increased to \$6.20 × 27 = \$167.40 from the original value of \$3.60 × 27 = \$97.20, so the ratio of cash to asset has now dropped dramatically from 1.84 to 1.07. From this perspective the second period is not flush with cash as the initial period had been, precipitating a large price drop, perhaps with the influence of the expectation value that is always in the background. Of course, now, there is the influence of the first period's price as a reference point, so the price remains far above fundamental value. This interpretation is consistent with the empirical results of the autoregressive-integrated moving average

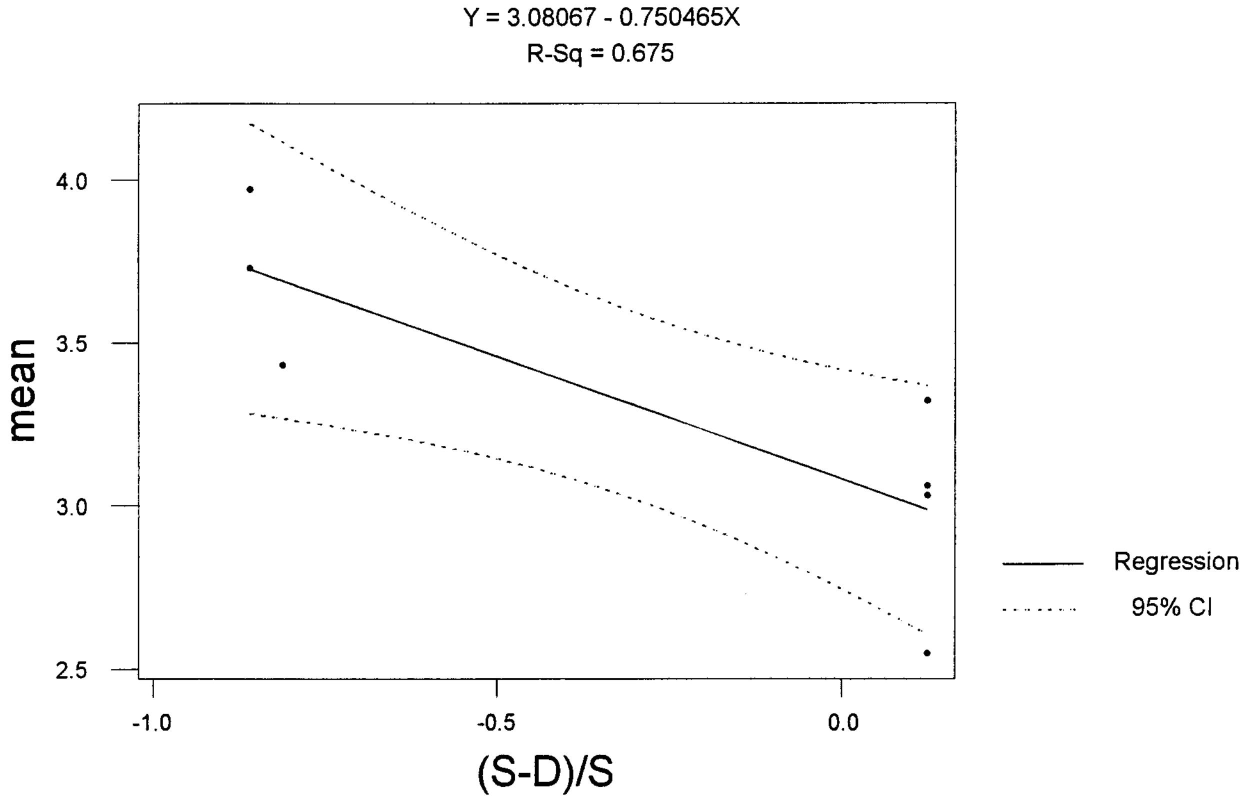

FIG. 2. Regression: Mean price versus excess supply. The mean of each experiment is computed and plotted with dots against the value of the initial excess supply. The dots at left represent the cash rich experiments that are associated with higher prices, while those at the right are endowed with an excess of asset. A linear regression is displayed by the solid line, with 95% confidence intervals shown by the broken lines.

(ARIMA) model (16) which suggested that prices are described by the midpoint attained from the average of the most recent price and discrete derivative. A more qualitative explanation can be based on the reluctance of traders to offer the asset at a much lower price than they could have sold it for a few minutes ago. At the end of the second period, the ratio of cash to asset value has now gone up, as a consequence of the price having fallen. However, the price does not move up, because the final factor, momentum, is now also in play. The traders are aware that each period seems to bring a lower price, and are unwilling to bid high prices even with the surplus of cash. And so the price keeps falling through the fundamental value, at which time the cash/asset value ratio is even more favorable to rising prices. But even the combination of fundamental value and high liquidity can only produce a stalemate when confronted with factors *iii* and *iv*: recent price and a steadily declining price history. The price then approaches an equilibrium that is below the fundamental value.

Note that the factors *i–iv* are incorporated into a differential equations model (15) that predicted that an initial overvaluation would lead to a lower equilibrium value, and that the equilibrium value is a function of initial cash/asset value and the initial price. In each of the experiments the initial price was above fundamental value. It would be interesting to see whether the terminal price would be higher if price controls forced an initial price below expectation value with the same initial cash/asset distribution value. Such an experiment would establish a distinctly different momentum history, with a positive bias in the earlier periods that should lead to higher terminal prices.

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