Commodity durability, trader specialization, and market performance

John Dickhaut[a,1], Shengle Lin[b], David Porter[a], and Vernon Smith[a,2]

[a]Economic Science Institute, Chapman University, Orange, CA 92866; and [b]Haas School of Business, University of California, Berkeley, CA 94720-1900

Contributed by Vernon Smith, November 29, 2011 (sent for review September 23, 2011)

The original double auction studies of supply and demand markets established their strong efficiency and equilibrium convergence behavior using economically unsophisticated and untrained subjects. The results were unexpected because all individual costs and values were private and dependent entirely on the market trading process to aggregate the dispersed information into socially desirable outcomes. The exchange environment, however, corresponded to that of perishable, and not re-traded goods in which participants were specialized as buyers or sellers. We report experiments in repeated single-period markets where tradability, and buyer-seller role specialization, is varied by imposing or relaxing a restriction on re-trade within each period. In re-trade markets scope is given to speculative motives unavailable where goods perish on purchase. We observe greatly increased trade volume and decreased efficiency but subject experience increases efficiency. Observed speculation slows convergence by impeding the process whereby individuals learn from the market whether their private circumstances lead them to specialize as buyers or sellers.

durable goods | specialization of trade | speculation and liquidity

Equilibrium between supply and demand (S&D) based on subjective marginal unit value was first articulated by Jevons (1) in 1862.* The model is here characterized by buyers whose consumption values vary for a commodity and sellers who can supply the commodity at varying costs. When a buyer buys a unit, both buyer and seller earn a private surplus. There exists a price at which quantity demanded equals quantity supplied defined as the equilibrium price and quantity. At this price, the total social surplus is maximized, and full efficiency is achieved. Jevons (3) believed that this theoretical equilibrium would not be achievable unless all participants had "perfect knowledge of the conditions of supply and demand, and the consequent ratio of exchange" or price (3).

The theory was tested in the laboratory one century later, yielding the unanticipated result of rapid convergence to efficient outcomes. Naïve subjects, learning through experience and informed only of their own marginal value (cost) information, have no prevision of the S&D equilibrium, but they discover it by sequential adjustment of their trades (4). Until experimental research established that the perfect knowledge conditions were neither necessary nor sufficient for empirical S&D equilibrium to be closely approximated by untrained subjects, Jevons' belief was widely accepted in economics [proposition 6 in the work by Smith (5)].

These experiments share characteristics common to nondurable consumer goods and services in the national economy (e.g., hamburgers and haircuts): buyers and sellers who are specialized in their roles do not retrade, have premarket knowledge of their role, and values are realized immediately on purchase or sale. As we move from services and other items that perish with their purchase to goods durable enough to be retraded, the participants may act as both buyers and sellers depending on their circumstances and decisions. For example, the design of market institutions for retradable fishing quotas and pollution permits has encountered such a role specialization discovery task. Participants in these markets are initially endowed with a certain number of allowance permits under certain regulatory cap guidance, and they have no prior experience to help them decide whether to buy or sell permits. Some studies have documented large deviations from equilibrium price and quantity, whereas others documented convergence.† Our experiments inherit the basic features of S&D but study goods capable of being retraded by nonspecialized traders within a market period.

Another characteristic of the economy not represented in these early experiments is the existence of cash (US currency) holdings traded against commodity during an exchange period. Cash endowments can be large relative to expenditures for goods acquired and relative to a good's subjective consumption value, which may influence the dynamics and compromise the discovery process documented in S&D.‡ Specifically, in multiperiod durable

Author contributions: J.D., S.L., D.P., and V.S. designed research, performed research, analyzed data, and wrote the paper.

The authors declare no conflict of interest.

Data deposition: The comma-delimited files with subject and market data from the experiment with defined data fields reported in this paper are available at http://esi2.chapman.edu/sandler/pnas/PNAS_20sessions.txt

[1]Deceased May 10, 2010.

[2]To whom correspondence should be addressed. E-mail: vsmith@chapman.edu.

This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1115742109/-/DCSupplemental.

*In September of 1862, Jevons (2) records sending the paper "Notice of a General Mathematical Theory of Political Economy" to the British Association for the Advancement of Science; the paper was read, but only a short abstract was published in the *Report of the Proceedings*. The following year, Jevons submitted a paper of the same title, a summary of which was printed in *Report of the Thirty-Second Meeting of the British Association for the Advancement of Science* (2). These papers and additional references and discussion are in ref. 2; of particular note is that Jevons' model included extensions to multiple commodities—what later came to be known as general equilibrium.

†Anderson (6) evaluates the effect of trading institutions on the outcome in laboratory tradable fishing allowance systems. Participants are endowed with a number of quotas, and each participant only knows their private value for the quotas in each of the use periods. The study found that market price exhibited high volatility and large deviations from equilibrium price coupled with high trading volume and poor allocation efficiency. Anderson (6) argues that "allowing trades to take place at different prices when little information is available lead to a great deal of volatility, which in turn reinforced beliefs about the prices others would be willing to pay in the future. This fuels speculation that lead subjects to bid up the price based on the beliefs about what others would pay in future periods, rather than to trade based on the marginal profit from fishing provided by the allowances" (6). By prohibiting permanent transfers in an initial lease period, Anderson (6) finds that the market for temporary lease trades can establish a price signal, which carries over to the permanent allowance market, facilitating the equilibration. Cason and Gangadharan (7) study a laboratory market for emission permits. Participants each face a type of emission abatement curve, and they can trade permits to meet a certain emission target level. They found that allowing banking of permits smoothed out price variability but made emissions significantly higher. They did not document the patterns of Anderson (6). These permit markets generally carry multiple add-on features that are not shared in the original S&D experiments.

‡Subsequent market experiments explored trading in durable assets that lived across more than one period, yielding utility services (dividends) to individuals each period. These studies all differ from our experiments in which all gains are confined to within-period exchange. A comprehensive survey is in the work by Sunder (8). Although our purpose here is to examine only single period trading behavior with static repetition, the original bubbles literature found that the most effective treatment variables were experience and the ratio of cash to share endowments—and hence, the importance of varying cash, as well as experience, in our experiments. The work by Caginalp et al. (9) finds that deviations from fundamental value increase as the ratio of endowed cash to share value increase. Smith et al. (10) find that deviations from fundamental value disappear when all dividends are deferred to the end. This finding is confirmed by Kirchler et al. (11) but much extended by showing that a key element in the creation of bubbles is the decline in fundamental value relative to a constant average inflow of cash dividends; they also examine instructions as a treatment to increase subject understanding of their declining assert value environment.

ECONOMIC SCIENCES

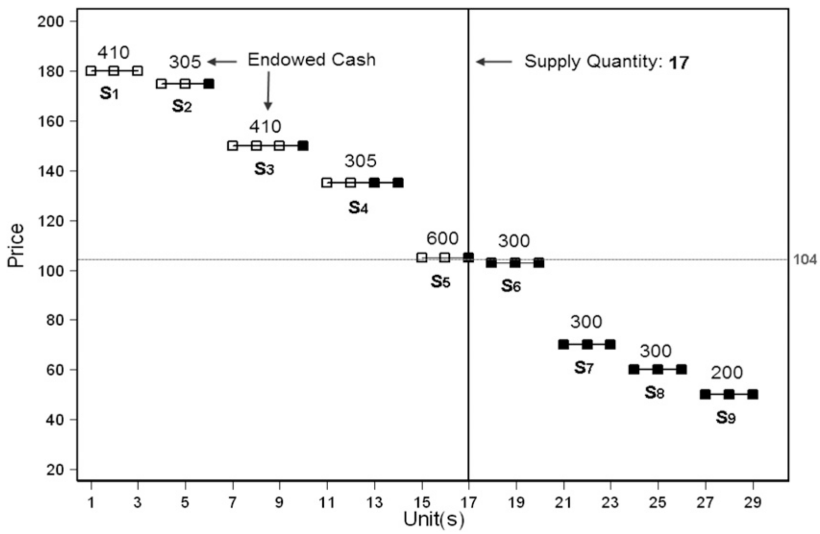

Fig. 1. Market participant parameters in P1. The chart plots the values and endowments of all participants in parameter set P1. Subjects are numbered (S_1) in decreasing order of their consumption values. At each value, a box represents a demand unit by the subject. If the box is solid, it is a unit in the subject's endowment. If the box is open, it is a net unit demand. There are 29 units in demand and 17 total units in supply. Each subject's demand units are connected by a horizontal line. Each cluster represents a subject's demand. Each subject's cash endowment is shown above the cluster. For an efficient allocation, 12 units from the endowments of subjects 6–9 (to the right of the vertical line) must be transferred to subjects 1–5 (to the left of the vertical line). At the price of 104, the number of units demanded at that price is equal to the number supplied, and every trade yields a strictly positive profit. Experiment parameters P2 and P3 are listed in Table S1.

asset markets, liquidity has been shown to effect the price path of the asset. In addition, excess cash increases asset turnover and more importantly, allows higher prices to be supported through a less restrictive budget constraint.

Consequently, our purpose is to examine systematically the treatment effect of (*i*) trader role specialization (buyer or seller) in a consumer perishable good or service market vs. nonspecialization, where the items exchanged are durable enough that they can be retraded within the current period before final value or cost is realized, (*ii*) the endowment levels of the second good (cash), and (*iii*) subject experience across repeated periods with *i* and *ii* held constant. Comparing perishable goods with one-period durable goods (retradable within a period)—(0, 1) durability—allows individual expectation formation to be confined to each repeat period.

Experimental Design

In the first treatment, labeled specialization (SP), the commodity is consumed when purchased and cannot be retraded; this treatment is implemented by restricting subjects' role and preknowledge of their role to either buyers or sellers in each period [the effect of buyer/seller specialization in a multiperiod asset trading horizon is reported in the work by Lei et al. (12)]. In the second treatment, labeled retrade (RT), we allow the commodity to be freely retraded without restriction within the period, and any consumer dividend surplus from units held is realized when the period ends. Participants must choose to be either a buyer or seller in any transaction based on the market information that emerges.

Nine subjects were recruited for each experimental session. Subjects are endowed with commodity units and cash (US cents). Subjects are informed only of their private dividend values and endowments. Under RT, each subject must decide in real time, based on private and observed trading information, whether to buy or sell units. In SP, role specialization strictly follows the surplus maximization equilibrium. Subjects 1–5 are buyers, and subjects 6–9 are sellers. In RT, any subject can buy and/or sell, and role specialization is endogenous (i.e., must be discovered through trial and error learning). Fig. 1 shows the parameters of our baseline trading environment,[§] labeled P1. The maximum gains from exchange occur when the highest-value net demand units are bought from the lowest-value net supply units, with a predicted exchange volume of 12 units supported by the price of 104.

An important feature of RT relative to SP is that cash can serve speculative motives to buy for resale in addition to purchases against consumption value or sales against producer opportunity cost. Any capital gains are zero sum in the aggregate and yield no social surplus, but such capital gains seeking may reduce efficiency by producing false and misleading price signals that impede the discovery of trades that increase social value. Repetition across 10 periods is the mechanism allowing disequilibrium contracts, errors, and irrational forms of individual behavior to be adjusted, corrected, or not corrected by trial and error experiential learning based on a common set of instructions across treatments.[¶]

To test for liquidity effects, we use a set of environment parameters, P2, with 45% less total cash than in P1, but each individual's endowment is more than adequate to enable the equilibrium to be achieved. If the equilibrating process is more

Table 1. Experiment design

	Environment parameters		
Treatment	P1	P2	P3
Specialization (SP)			
Number of sessions	3	3	4
Equilibrium price	104	104	NA*
Equilibrium quantity	12	12	NA†
Total cash	3,130	1,725	3,130
Retrade (RT)			
Number of sessions	3	3	4
Equilibrium price	104	104	NA*
Equilibrium quantity	12	12	NA†
Total cash	3,130	1,725	3,130

Each treatment, RT or SP, is tested with three sets of parameters: P1, P2, and P3. In each cell (2 × 3), the number of experiment sessions conducted, equilibrium price, and equilibrium quantity are listed.

*Equilibrium is not supported by a strictly profitable exchange with supply equaling demand. At a price of 105, maximum efficiency can be achieved with one of the transactions being not strictly profitable.

†Maximum efficiency in P3 is achieved at total traded units of 10.

§In our SP treatments, specialized buyers may have 1 or 2 units of commodity endowment, although they are not allowed to sell. This feature is kept only to make the RT and SP parameters identical. This slight departure from traditional paradigm should be innocuous.

¶Instructions can be found at http://esi2.chapman.edu/sandler/holdinglimit/page1.html. Instructions can also serve as a treatment variable in studying market performance, but here, only repeat experience is used to enable adjustment of behavior, as in motivating the original S&D experiments, with all treatments conducted within a uniform set of instructions. Thus, the instructions are the same in both the SP and RT treatments, except that in RT, subjects are able to buy and sell, whereas in SP, they are allowed to buy (sell) if the preassigned role is a buyer (seller).

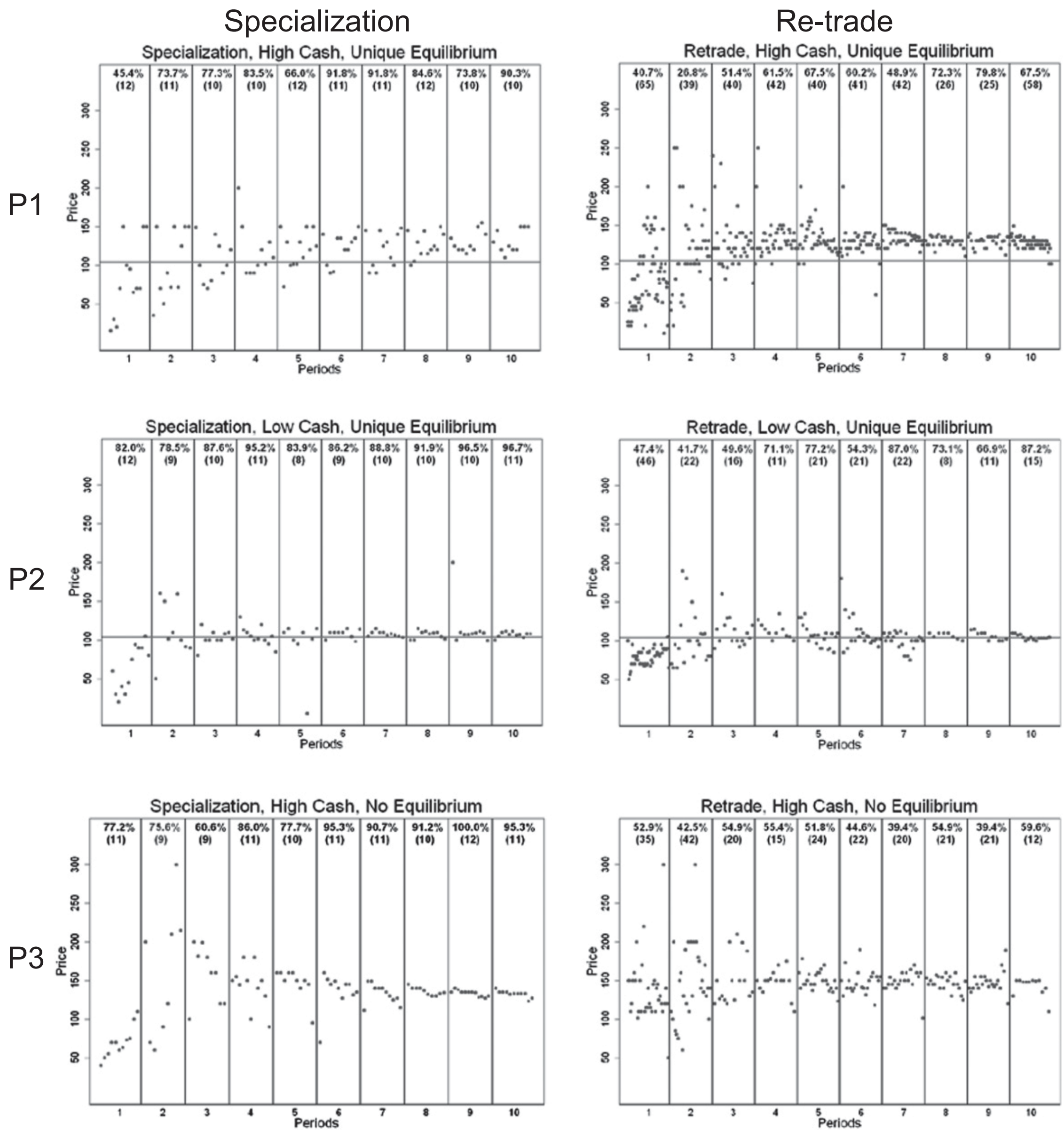

Fig. 2. Transactions, efficiency, and volume. Each of the six charts represents an example session from one of the six design cells: tradability (specialization or retrade) and parameter (P1, P2, or P3). In each plot, the session with the average efficiency nearest to the average efficiency of all sessions in the cell is chosen for display. A session lasts for 10 repeat periods. Periods are separated by vertical lines. The small solid circles denote the price of each transaction in sequence. The percentages above each period denote the efficiency for that period. Each number in parentheses denotes the volume count of transactions in the period. The P1 and P2 cells have the unique equilibrium price of 104, indicated by the horizontal lines.

challenging in RT relative to SP because of speculative motives, we can test the hypothesis that a less cash-rich endowment will reduce subject capacity to implement speculative purchases and improve performance.

Table 2. Average market performance: Retrade vs. specialization

	Environment parameters						Aggregate	
	P1		P2		P3			
	SP	RT	SP	RT	SP	RT	SP	RT
Efficiency	0.805 (0.115)	0.568 (0.119)	0.889 (0.091)	0.675 (0.234)	0.886 (0.105)	0.542 (0.209)	0.863 (0.110)	0.590 (0.202)
Volume	9.4 (1.8)	36.5 (15.1)	10.2 (1.2)	24.6 (14.6)	11.1 (0.9)	31.0 (13.1)	10.3 (1.5)	30.7 (14.8)
Mean price	113.8 (22.9)	113.5 (46.5)	95.9 (13.6)	95.6 (18.9)	120.5 (19.7)	132.9 (13.8)	111.1 (21.6)	115.9 (32.5)
Price deviation	19.6 (15.0)	43.0 (18.6)	12.2 (10.0)	14.6 (14.5)	18.3 (17.1)	28.0 (13.6)	16.8 (14.8)	28.5 (18.9)

This table reports on efficiency, volume, price level, and price deviation across six design cells: two treatments (RT and SP) × three environments (P1, P2, and P3). Each period provides one observation. The averages of these variables in each cell, together with their period to period SDs (in parentheses), are listed.

Table 3. Regression analysis: Summary statistics on dependent variables

	Count	Mean	Minimum	p25	Median	p75	Maximum	Skewness	Kurtosis
Efficiency$^{(\lambda)}$	200	−0.195	−0.407	−0.311	−0.194	−0.085	0.000	0.000	1.829
Volume$^{(\lambda)}$	200	0.966	0.859	0.932	0.951	1.004	1.034	0.000	1.937
$\Delta P^{(\lambda)}$	200	7.217	−1.342	3.220	7.837	10.841	17.871	0.000	2.158

This table provides the summary statistics for the dependent variables.

Last, we examine the adjustment process in a set of potentially more challenging environment parameters, P3, with no unique price at which the number of strictly profitable units supplied are equal to the number of strictly profitable units demanded. P3 has the same cash endowments as P1. In Fig. 1, P3 is achieved by decreasing subject 5's demand from 3 to 2 units and reducing his goods endowment from one to zero, reducing total supply to 16. Subject 6's demand value is increased from 103 to 105. Observe that, at a price of 105, the market clears with 12 units demanded and 12 units supplied but only if subject 6 sells 3 units and subject 5 buys 2 units, each earning a zero profit. Market theory formally treats this case as one of equilibrium, but we will here distinguish it from the baseline environment shown in Fig. 1, allowing for the two cases to yield behavioral differences [Plott and Smith (13) found that exchange volume was materially affected by the existence of equilibrium units that were not strictly profitable]. Maximum gains from exchange are well-defined when 10 units are sold by subjects 6–9 with lowest demand value to subjects 1–4 with the highest demand value (the 10 highest open boxes in Fig. 1). Without a unique profitable equilibrium price, environment P3 is conjectured to exhibit more deviant prices than P2, and this could impede efficiency.[‖] (The specifications of P1, P2, and P3 can be found in Table S1.)

Thus, we use the 2 × 3 design (Table 1). Each cell contains at least three independent experiment sessions. Each session is repeated for 10 periods. All endowment and value parameters are reinitialized each period, corresponding to a steady state environment. Repetition allows us to examine the effect of experience on individual and market performance under the various treatments.

Performance: Results and Analysis

Fig. 2 provides the complete contract time series and period summary data for one example of a market session drawn from each of our 2 × 3 treatment cells (transaction plots for the other sessions can be found in Fig. S1). Efficiency is defined as the ratio of realized net gains from exchange to the maximum net gains from exchange; 100% efficiency is achieved if and only if all individual gains from exchange have been exhausted (i.e., 12 units are transferred from subjects 6–9 to subjects 1–5 in P1 and P2, whereas 10 units are transferred from subjects 6–9 to subjects 1–4 in P3). Volume is the number of units transacted in a period. The data of Fig. 2 show a pronounced contrast between the much larger volumes in retrading markets relative to specialization markets. Efficiency, however, is higher for low-volume specialization markets. All markets exhibit some levels of price variability as well as deviations from the equilibrium prices. Over repeated experience, efficiency tends to grow, and volume tends to drop.

These impressions from the charted examples are also supported by the average efficiency and average volume across all periods of experience for each of the 2 × 3 treatments listed in Table 2. We first obtain the mean efficiency in each session across 10 periods and then, the average of these session-specific means in each treatment. The pooled average efficiency is 86.3% for SP and 59.0% for RT (mean difference = 27.3%, n = 20, two-sample Wilcoxon rank sum test, P = 0.001). The pooled average volume is 10.3 for SP and 30.7 for RT (mean difference = 20.4, n = 20, two-sample Wilcoxon rank sum test, P = 0.000; although the volume in SP has an upper bound, it is still possible that the volume in RT can be equal to or smaller than the volume in SP). On average, RT sessions generated volumes about three times the equilibrium quantity, whereas SP sessions have volume that is about 1 unit less than the predicted volume.

In addition to efficiency and trading volume, we obtained measures of price levels and price deviation from equilibrium price. The first measure is simply the mean price in a period. The price deviation in session i and period t ($\Delta P_{i,t}$) is measured as the mean absolute deviation from equilibrium price, defined as (k = *1, 2, . . .*, K is the sequence of transactions in the period) (Eq. **1**)

$$\Delta P_{i,t} = \sum_{k=1}^{K} \left| price_k - equilibrium\ price_{i,t} \right| / K. \qquad [1]$$

The term captures the extent to which prices converge to the equilibrium price. Table 2 shows that prices are higher in high-cash environments P1 and P3 than in the low-cash environment P2, indicating that the level of liquidity is an important factor affecting the level of prices. Price deviations from equilibrium prices are also higher in P1 and P3 than in P2.[**]

Table 2 indicates four points.

i) Average efficiency across all sessions within each environment is much larger and average volume is much smaller in SP than RT. The efficiency levels are lower in SP than standard S&D experiments.[††]

ii) In the high-cash RT environments P1 and P3, the efficiency is lower and the volume is higher than in the low-cash RT treatment P2.

iii) Comparing the two high-cash RT environments P1 and P3, however, we find only slightly higher efficiency and volume in P1 with a unique equilibrium. Hence, environment P3 does not constitute a greater efficiency challenge than P1. However, P3 exhibits persistently higher prices as measured in row 3, especially in RT, although price deviations are higher in P1 than P3.

[‖]Actually, environment P3 was the first environment that we investigated in the laboratory. After we found the high volume and slow increase in efficiency, we created the P1 and P2 environments to see if our results were parameter-dependent.

[**]High-cash environments P1 and P3 have significantly higher prices than the low-cash environment (n = 20, Wilcoxon rank sum test, P = 0.01). Price levels are not significantly different between SP and RT. Because P2 (low cash) is known to have lower prices, we compare price levels between P1 (with equilibrium) and P3 (no equilibrium). P3 has higher prices than P1 (n = 14, Wilcoxon rank sum test, P = 0.01). For deviations from equilibrium price, we use 104 as equilibrium price for P1 and P2 and 105 for P3 as an approximation. High-cash environments have significantly higher deviations than the low-cash environment (n = 20, Wilcox rank sum test, P = 0.00). RT has significantly higher deviations than SP (n = 20, Wilcoxon rank sum test, P = 0.00). Because P2 (low cash) is known to have lower price deviations, we compare price deviations between P1 (with equilibrium) and P3 (no equilibrium). The price deviations are higher in P1 than P3 (n = 14, Wilcoxon rank sum test, P = 0.05).

[††]The low efficiency of SP with P1 comes from the fact that trading volume is lower. The average volumes are 9.43, 10.17, and 11.08 for P1, P2, and P3, respectively. We note that efficiencies increase with time, and therefore, for the last five periods of the treatments, the efficiencies are 84% for P1 and 92% for P2 and P3. This finding is still somewhat below what is typically found in standard S&D environments. Our SP is slightly more complex than traditional S&D, because (*i*) a second commodity (cash) is included, (*ii*) earnings are realized at the end of a period rather than immediately after the transaction, and (*iii*) buyers may have 1 or 2 units of endowed commodity. These features are kept to match RT. Our SP is an interim treatment between traditional S&D and RT. It should reasonably be expected that efficiencies in SP would be slightly different from traditional S&D.

Table 4. Regression analysis: Random effect generalized least square regressions with clustered SEs

Dependent variable	Independent variable						
	RT	High cash	Equilibrium	Experience	RT × experience	High cash × experience	Equilibrium × experience
Efficiency$^{(\lambda)}$							
Coefficient	−0.162	−0.023	−0.025	0.017	0.001	−0.009	−0.002
Clustered SE	0.035	0.042	0.037	0.006	0.004	0.004	0.005
z Statistics	−4.69*	−0.55	−0.69	2.77*	0.18	−2.07†	−0.30
Volume$^{(\lambda)}$							
Coefficient	0.084	0.000	−0.010	−0.001	−0.003	0.001	0.000
Clustered SE	0.005	0.008	0.007	0.001	0.001	0.001	0.001
z Statistics	15.63*	0.04	−1.32	−1.15	−5.61*	0.89	0.37
$\Delta P^{(\lambda)}$							
Coefficient	3.360	0.231	0.159	−0.856	−0.074	0.751	0.325
Clustered SE	1.525	1.698	1.895	0.318	0.236	0.285	0.346
z Statistics	2.20†	0.14	0.08	−2.69*	−0.32	2.64*	0.94

This table evaluates three measures of market performance in response to treatment factors. The dependent variables are the Box and Cox (14) power transformations of efficiency, volume, and price deviation. The treatment factors include RT (specialization, 0; retrade, 1), high cash (low P2 environment, 0; high P1 and P3 environment, 1), equilibrium (not existing P3, 0; existing P1 and P2, 1), and experience (t = 1, 2, . . ., 10 periods). We also include the first three treatment variables interacted with experience to see if these variables influence the learning process. We run random effect panel regressions with SEs clustered on each session. This table reports the regression coefficients, clustered SEs, and *z* statistics.
$^{*}P < 0.01$.
$^{\dagger}P < 0.05$.

iv) Cash availability is a key variable driving the level of prices and price deviations. Low-cash environment P2 has lower prices, and the price deviations exhibit much improved convergence to equilibrium.

To test for the marginal statistical significance of the treatment variables, including the effects of increasing experience, we run three regressions to evaluate treatment factors' effect on efficiency, volume, and price deviation. The regression model adopts random effect with SEs clustered on each session (Eq. **2**):

$$\begin{aligned} Efficiency_{i,t}^{(\lambda)} &= \alpha + \beta_1 RT_{i,t} + \beta_2 Highcash_{i,t} + \beta_3 Equilibrium_{i,t} \\ &+ \beta_4 Experience_{i,t} + \beta_4 RT_{i,t} \bullet Experience_{i,t} \\ &+ \beta_5 Highcash_{i,t} \bullet Experience_{i,t} \\ &+ \beta_5 Equilibrium_{i,t} \bullet Experience_{i,t} + u_i + \varepsilon_{i,t}. \end{aligned} \quad [2]$$

The subscripts (i, t) index, respectively, the session and experience level (trading period where t = 1, 2, . . ., 10). Efficiency$^{(\lambda)}$ = (efficiency$^{\lambda}$ − 1)/λ is the Box and Cox (14) power transformation of the dependent variable efficiency. The power λ is determined such that the skewness in the distribution of the transformed variable is minimized.[‡‡] RT is a {0, 1} indicator variable for the retrade (1) vs. specialization (0) treatments. High cash is a {0, 1} indicator variable for high (1) vs. low (0) cash environments; P1 and P3 have high (1), whereas P2 has low (0) cash endowments. Equilibrium is a {0, 1} indicator variable for sessions with no strictly profitable equilibrium clearing price (0) vs. sessions with a strictly profitable equilibrium clearing price (1). Experience is the repetition number (period) in a session and thus, the control variable for subject experience. Because each of the basic treatments may interact with experience under repetition, these interaction terms are specified as multiplicative additive independent variables; u_i is the random residual for the independent subject sample in each session, and $\varepsilon_{i,t}$ is the random residual for session i period t. In light of the potential correlation between observations within a session, the regression adopts clustered SEs on each session to control for within-group correlation (the coefficient estimates and the basic findings are similar when using the bootstrapping method with 500 replications). The same transformation is done for two other dependent variables: volume$^{(\lambda)}$ = (volume$^{\lambda}$ − 1)/λ and $\Delta P^{(\lambda)} = (\Delta P^{\lambda} - 1)/\lambda$.

Tables 3 and 4 provide summary statistics for the dependent variables and regression results. They suggest that the treatment factor RT significantly reduces efficiencies, increases volume, and increases price deviations from equilibrium. RT also interacts with experience to reduce trading volume at a significantly faster pace in RT treatment. Experience increases efficiencies and dampens price deviation, suggesting that the learning effect helps improve market performance. High cash does not have direct effects on market outcomes, but it interacts with experience to impede market performance improvement over time. The interaction term high cash × experience has a negative effect on efficiencies and a positive effect on price deviation, indicating that the learning effect is significantly smaller in high-cash environments than in the low-cash environment. Our expectation that equilibrium would be an effective treatment is not confirmed. Neither the variable itself nor its interaction with experience is significant, although the environment without equilibrium experienced higher levels of prices as documented in Table 2.

Table 5 is included to help explicate the poorer performances in the RT treatment, characterized by lowered efficiency, higher volume, and higher price deviations. We investigate the nature of the trades by looking at three types of transactions.

i) The percentage of trades that are consistent with equilibrium-predicted specialization (buyers are from S1 to S5 and sellers are from S6 to S9).
ii) The percentage of trades that improves efficiency (buyer value exceeds seller value; even where specialization is violated, the trade creates positive surplus).
iii) The percentage of speculative trades as characterized by a buy (or a sell) action that is immediately followed by a limit or market offer to sell at a higher price (or a limit or market offer to buy at a lower price) before or in one's next transaction.

[‡‡]The dependent variables examined are not normally or even symmetrically distributed; as a result, the estimation residual errors are not normally distributed. We use the common Box and Cox (14) power transformation to address this concern. The transformation preserves the ordering of the original observations, while at the same time, makes the variables more normally distributed. The power ratios λ are chosen such that the skewness in the distributions of the transformed variables is minimized. The power ratios λ are 2.439, −0.953, and 0.542 for efficiency, volume, and deviation, respectively.

ECONOMIC SCIENCES

Table 5. Trade summaries by liquidity and experience in RT treatment

Types of trades	Aggregate	Liquidity	First five periods	Second five periods
Percent specialized trades* (buyers are from S1 to S5, and sellers are from S6 to S9)	0.40	Low cash	0.41	0.59
		High cash	0.35	0.41
Percent efficiency improving trades (buyer value > seller value)	0.62	Low cash	0.63	0.73
		High cash	0.59	0.63
Percent speculative trade [buys (sells) followed immediately by an attempt to sell higher (buy lower)]	0.66	Low cash	0.69	0.58
		High cash	0.65	0.67

Three types of trades are reported across liquidity (high and low) and experience levels (first five periods and second five periods). The percentage of specialized trades and the percentage of efficiency improving trades describe the equilibrating activeness, whereas the percentage of speculative trades describes the magnitude of disequilibrating speculations.
*In P3, S5 is counted as a predicted buyer, and S6 is counted as a predicted seller for simplicity.

The three types of activities are generally impossible or always fully realized in SP,[§§] and thus, they provide insight into the underperformance in the RT treatment. To investigate the effect of liquidity and experience, each type of activity is tabulated on 2×2 format: [low cash, high cash] $\times$ [first five periods, second five periods].

i) The trades that are consistent with equilibrium specialization predictions are 40% in total. In low cash, 41% are consistent in the first five-period block, increasing to 59% in the second block. In high cash, only 35% are consistent in the first block, and 41% are consistent in the second block.

ii) Sixty-two percent of trades in aggregate are efficiency-improving. Percentage of efficiency-improving trades is always higher than percentage of specialized trades, because the former also includes transactions among equilibrium buyers or among equilibrium sellers. The former is, thus, a broader measure of equilibrating activity. In low cash, 63% of trades are efficiency improving in the first block, and it increases to 73% in the second block. In high cash, 59% improves efficiency in the first block, rising to 63% in the second block.

iii) A majority of 66% of trades are speculative. With low cash, speculation falls from 69% in the first block to 58% in the second block, whereas in high cash, speculation hardly changes (65% vs. 67%; we examined profitability and the number of trades made by a participant, and we find that these measures are slightly inversely related).

iv) From *i* to *iii*, liquidity slows down the process of specialization and hence, the realization of more efficient outcomes. Our results resemble the results by Anderson (6) with regard to realized trading volume, efficiencies, and price deviations from the equilibrium. The clear intention on the part of subjects to seek short run capital gains confirms the conclusion by Anderson (6) that subjects were actively speculating.

Concluding Remarks

Our experiments investigate the effect of retrading on market performance as measured in efficiency, volume, and price convergence. In contrast with markets for services and perishables where buyers and sellers are role-specialized (as in the original S&D experiments), goods durable enough for within-period retrading deliver lowered allocation efficiencies, much higher trading volumes, and poorer price convergence.[¶¶] Experience plays an important role in improving market performances, but its effect is retarded by the infusion of more liquidity.

A detailed analysis of the bilateral exchanges in retrade shows that retrade's relatively poorer performance is because of persistent speculative motives to profit from capital gains that, in turn, detract from learning to efficiently specialize by trial and error experience. Hence, compared with the original S&D experiments, retrade opens up an activity space for nonequilibrating behaviors based on false price signals. Participants engage intensively in repurchasing or reselling commodities, with clear intentions to profit from speculation.

The level of liquidity correlates with the frequency of speculative trades and effects market outcomes. Money is not neutral. It increases price levels, exacerbates price divergence from equilibrium, and impedes learning.

The experimental literature shows that such poor performance can be improved with more intense subject instructional training, but our purpose here is to study the effect of experience in replication within a set of instructions common to all of the treatments, which does not asymmetrically target particular problematic conditions.

Finally, comparing two equilibrium environments—one with and one without all trades strictly profitable—we find no significant differences in accordance with standard equilibrium theory.

[§§]In SP, the percentage of specialized trades is 100%, and the percentage of speculative trades is 0%. The percentage of efficiency improving trades is 98%, because 2% occurs, in environment P3 where trades occur between the two subjects with the same values.

[¶¶]These results are broadly consistent with the much greater stability of consumer services and nondurables relative to durables and investment in the national income accounts (15).

1. Jevons WS (1886) Notice of a general mathematical theory of political economy. *Letters and Journal of W. Stanley Jevons*, ed Jevons HA (Macmillan, New York), pp 160–170.
2. Howey RS (1989) *The Rise of the Marginal Utility School* (Columbia University Press, New York), pp 16–18.
3. Jevons WS (1888) *The Theory of Political Economy* (Macmillan, New York), 3rd Ed, p 87.
4. Smith V (1962) An experimental study of competitive market behavior. *J Polit Econ* 70: 111–137.
5. Smith V (1982) Microeconomic systems as an experimental science. *Am Econ Rev* 72: 923–955.
6. Anderson CM (2004) How institutions affect outcomes in laboratory tradable fishing allowance systems. *Agric Resour Econ Rev* 33:193–208.
7. Cason TN, Gangadharan L (2006) Emissions variability in tradable permit markets with imperfect enforcement and banking. *J Econ Behav Organ* 61:199–216.
8. Sunder S (1995) Experimental asset markets: A survey. *The Handbook of Experimental Economics*, eds Kagel JH, Roth AE (Princeton University Press, Princeton), pp 445–500.
9. Caginalp G, Porter D, Smith V (1998) Initial cash/asset ratio and asset prices: An experimental study. *Proc Natl Acad Sci USA* 95:756–761.
10. Smith V, van Boening M, Wellford C (2000) Dividend timing and behavior in laboratory asset markets. *Econ Theory* 16:567–583.
11. Kirchler M, Huber J, Stockl T (2011) Thar she bursts: Reducing confusion reduces bubbles. *Am Econ Rev*, in press.
12. Lei V, Noussair C, Plott C (2001) Nonspeculative bubbles in experimental asset markets: lack of common knowledge of rationality vs. actual irrationality. *Econometrica* 69: 831–859.
13. Plott C, Smith V (1978) An experimental examination of two exchange institutions. *Rev Econ Stud* 45:133–153.
14. Box GEP, Cox DR (1964) An analysis of transformations. *J R Stat Soc Series B Stat Methodol* 26:211–252.
15. Bauer PW, Shenk M (2008) *Trends in the Components of Real GDP, Federal Reserve Bank of Cleveland*. Available at http://www.clevelandfed.org/research/trends/2008/1108/03ecoact.cfm. Accessed January 4, 2012.