Asset Pricing Experiments: Bubbles, Crashes & Expectations

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Asset Price Bubbles

- A bubble is difficult to define, but it involves seemingly irrational behavior and is manifested by a sustained departure of the price of an asset from underlying fundamentals.
- Bubbles are typically viewed as unsustainable, though examples of stationary bubbles, e.g. fiat money, have been provided (Tirole *Ecmta* 1985).
- The supposed irrationality underlying asset price bubbles has been thoroughly questioned, as it challenges the efficient markets hypothesis. This has led to theories of rational bubbles.
- However, as these rational bubble theories appear at odds with the actual volatility in asset prices, as well as with laboratory evidence showing that individuals are not invariant to the decision-frame, a new behavioral finance literature has emerged to challenge the conventional view of asset pricing.

Rational Bubbles

- Perhaps the main theory of bubbles is the rational bubble theory.
- Define the gross rate of return on an asset

$$R_{t+1} = \frac{p_{t+1} + d_{t+1}}{p_t}$$

so the net return $r_{t+1} = R_t - 1$, with p_t being the price in period t and d_t the dividend.

- Rearranging and taking expectations conditional on date t information, we have

$$p_t = \frac{E_t(p_{t+1} + d_{t+1})}{1 + E_t(r_{t+1})}$$

- Assuming rational expectations and that $E_t(r_{t+1}) = r$, the rate of time preference, we can write:

$$p_t = (1 + r)^{-1} E_t(d_{t+1} + p_{t+1}). \quad (1)$$

Rational Bubbles, Continued

- Using the law of iterated expectations, we can expand the price equation as:

$$p_t = \sum_{i=1}^{n} (1+r)^{-i} E_t(d_{t+i}) + (1+r)^{-n} E_t(p_{t+n}).$$

- Taking the limit as n goes to infinity:

$$p_t = \sum_{i=1}^{\infty} (1+r)^{-i} E_t(d_{t+i}) + \lim_{n\to\infty} (1+r)^{-n} E_t(p_{t+n}),$$

assuming the limit exists. Call the first term the fundamental component f_t and the second term the bubble component, b_t,

$$p_t = f_t + b_t \tag{2}$$

Properties of Rational Bubbles

- Substitute (2) into (1):

$$f_t + b_t = (1+r)^{-1} E_t(d_{t+1} + f_{t+1} + b_{t+1})$$

- Using the definition of f_t:

$$\sum_{i=1}^{\infty} (1+r)^{-i} E_t(d_{t+i}) + b_t = (1+r)^{-1} E_t(d_{t+1}) + \sum_{i=2}^{\infty} (1+r)^{-i} E_t(d_{t+i}) + (1+r)^{-1} E_t(b_{t+1})$$

$$\text{or} \quad b_t = (1+r)^{-1} E_t(b_{t+1})$$

  Rational bubbles grow at the same rate as fundamentals!: if $b > 0$, prices grow exponentially.
- Rational bubbles can occur only in models with an infinite horizon, otherwise by backward induction $b_T = 0$ implies $b_t = 0 \forall t$!
- If there is a constant probability that a bubble will burst it must grow at an even faster rate to compensate. (Blanchard and Watson 1982).

Bubbles in the Laboratory?: Non-rational bubbles

- Smith Suchaneck and Williams (SSW, *Ecmta* 1988) experimental design reliably generates asset price bubbles and crashes in a *finite horizon* economy, thus by construction ruling out *rational* bubble stories.
- T trading periods (typically $T = 15$) and 9-12 inexperienced subjects.
- Each subject is initially endowed with various amounts of cash and assets. Assets are long-lived (T periods). Endowments, are ex-ante identical in expected value -there is no reason for trade!
- In each trading period, agents are free to buy or sell the asset. Trade takes place via a double auction, and bids and asks must obey standard improvement rules.
- For each unit of the asset held at the end of a trading period, the asset owner earns a dividend payment which is a uniform draw from a known distribution and has mean $\overline{d}$.
- It is public knowledge that the fundamental value of an asset at the start of period t is given by: $D_t^T = \overline{d}(T - t + 1) + D_{T+1}^T$.

An Specific Parameterization (SSW Design #2)

Table 1. Smith et al. (1988) Experimental design 2

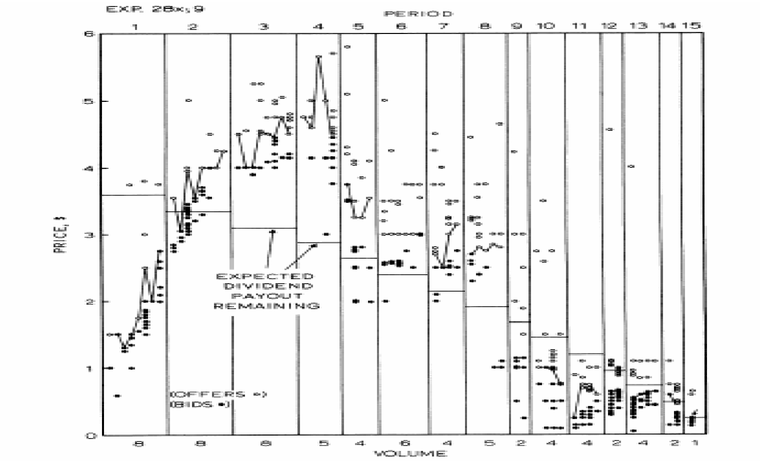
Players	Endowment (cash, quantity)	Number of players
Class I	($2.25; 3)	3
Class II	($5.85; 2)	3
Class III	($9.45; 1)	3
Dividends	$d \in \{\$0, \$0.04, \$0.14, \$0.20\}$[a]	$\overline{d} = 0.12$
Initial value of a share	$\overline{D}_1^{T}$[b] $= \$3.60$	
Buy-out value of a share	$D_{T+1}^{T} = \$1.80$	

[a] Each dividend outcome occurs with probability $\frac{1}{4}$.

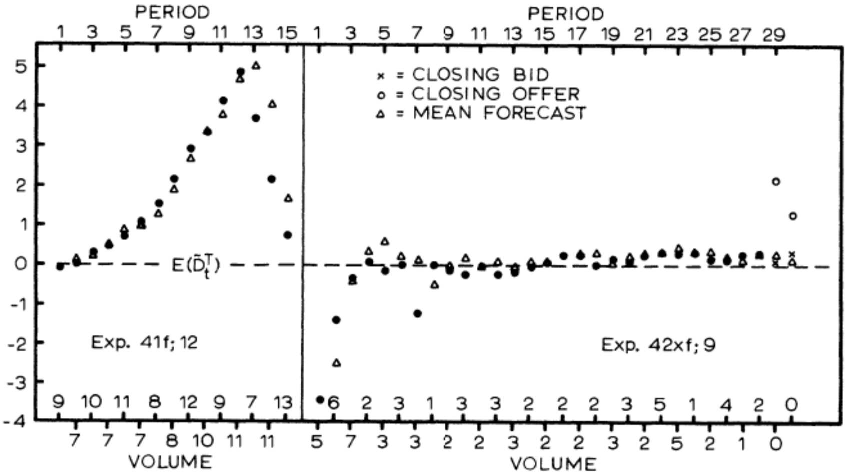
[b] Each period's expected fundamental value is denoted by $\overline{D}_t^T$ for $t = 1, ..., T+1$. These values were calculated and displayed on the screen in each trading period in the human subject experiments.

Payoff = initial endowment of money+dividends on assets held+money received from sales of shares- the money spent on purchases of shares+buyout value.

Bubbles and Crash Phenomenon Illustrated



Bubbles Often Disappear With Experienced Subjects (Two 15 Round Sessions)



Data Analysis

There is a substantial volume of bids, asks and trading volume in this type of experiment

- Smith et al. analyze a price adjustment dynamic of the form:

$$\overline{P}_t - \overline{P}_{t-1} = \alpha + \beta(B_t - O_t)$$

  where $\overline{P}_t$ is mean traded price in period t, B_t is the number of bids in period t and O_t is the number of asks in period t.
- The rational, efficient markets hypothesis is that $\alpha = -E_t d_t$ and $\beta = 0$, i.e., that subjects are trading according to fundamentals.
- Empirically, Smith et al. report that they cannot reject that hypothesis that $\alpha = -E_t d_t$ but they do find that β is significantly positive: $B_t - O_t$ captures variations in aggregate demand, which affects prices.
- Conclude that a common dividend and common knowledge of it are insufficient to generate common expectations among inexperienced subjects.

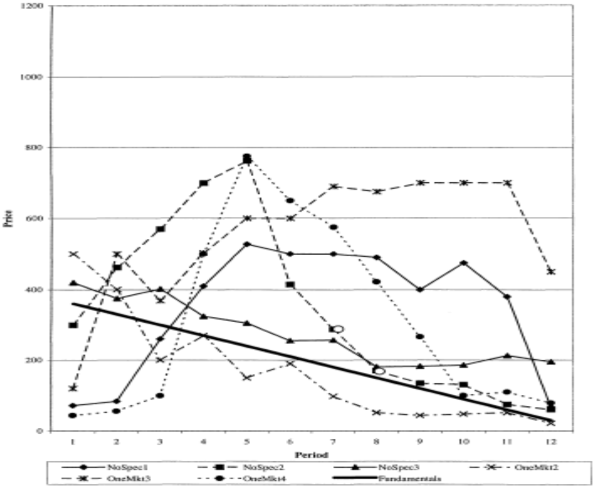
Robustness of Laboratory Bubbles?

- Smith et al. (Econ. Theory 2000) eliminate dividend payments but keep final buyout value. Still bubbles
- Noussair et al. (Exp. Econ. 2001) have a constant fundamental expected value for the asset rather than a declining value; promotes stationary pricing.
- Lei et al. (Econometrica 2001) Eliminate speculative "greater fool" behavior by restricting players to be either buyers or sellers (i.e., resale is not possible.)
- Dufwenberg et al. (AER 2005) mix in experienced traders with inexperienced traders.
- Haruvy et al. (AER 2007) eliciting long-term expectations of prices does not eliminate bubbles.
- Hussam et al. (AER 2008) find a way to re-kindle bubble among experienced subjects.
- Kirchler et al. (AER 2012) consider a constant C/A ratio and FV. Also look at contextual cues.
- Eckel and Füllbrunn (AER 2015) all female versus all male cohorts of traders.

Lei et al. (*Ecmta* 2001)

- Explore the boredom/experimenter demand hypothesis
- They consider two main treatment variables.
    - No-Spec treatment: Buyers and Sellers have distinct roles. In particular, a buyer cannot resell his asset later in a 2-minute trading period at a higher price. This tests the greater-fool hypothesis that speculation is driving the results.
    - Two-Market treatment: Two markets operate simultaneously. One is for a one-period asset Y; holders of this asset sell it to buyers in fixed roles. The other market is the standard 15-period asset of the laboratory bubble design; this asset could be traded (bought and sold) by all subjects.
- Main finding, neither treatment completely eliminates bubbles and crashes. Trading volume is much lower in the two-market treatment as compared with the standard one-market case.

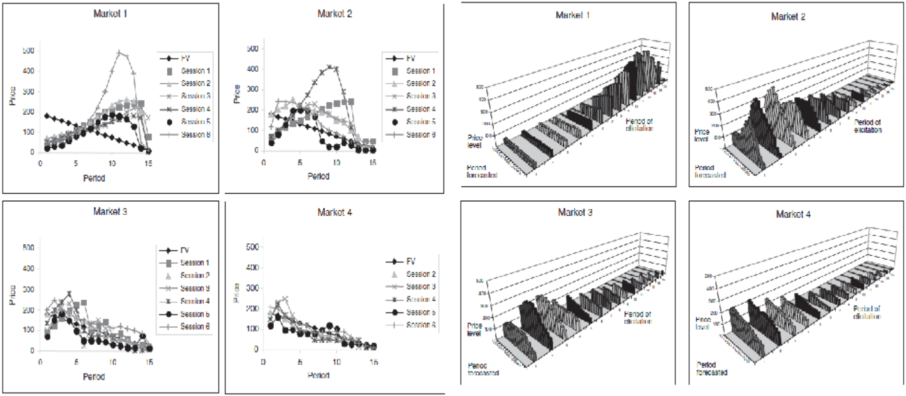
Lei et al.'s findings NoSpec/Spec illustrated



Haruvy et al. (*AER* 2007)

- Look at role of long-term expectations in the SSW design.
- At the start of each trading period, t< T=15, elicit trader's expectations of market prices in all remaining T-t+1 periods.
- Used a call-market institution, a sealed-bid version of a double auction: each trader can submit a buy or sell price and a quantity to buy/sell. Bids are ranked from highest to lowest, asks from lowest to highest and a single market price is determined.
- 9 Subjects participate together in 4, 15-period "markets" (replications).
- Subjects were paid both for trades and correct market price predictions.
- Clear evidence that inexperienced subjects have incorrect beliefs about the correspondence between prices and fundamentals.
- Price predictions are adaptive: market peaks consistently occur earlier than traders predict.

Prices and Beliefs About Prices



Repeated Bubbles and Crashes with Experienced Subjects?

- Hussam et al. *AER* 2008 argue that repeated bubbles among experienced subjects requires a change in the asset environment as might arise e.g., from a technological revolution.
- They first run 5 cohorts of 9-12 subjects through a standard SSW experimental design.
- In a new “rekindle” treatment, they take once-experienced subjects and: 1) randomly divide them into 3 new groups (so group composition is altered). They also 2) increase the mean and variance of the dividend process – the support changes from {0, 8, 28, 60} to {0,1,28,98} and finally 3) they cut initial share endowments in half and double the initial cash positions of the three player types.
- This rekindle treatment is compared with a standard "twice-repeated" treatment with no change in the subject population, dividend process or initial conditions.

Shocking the system leads to bubbles among experienced subjects

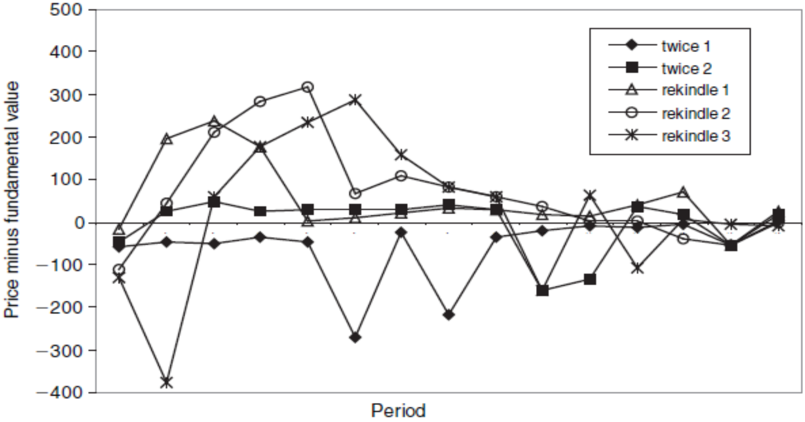


FIGURE 4. TIME SERIES PRICE DEVIATION FROM FUNDAMENTAL VALUE FOR THE REKINDLE AND TWICE-EXPERIENCED BASELINE REPLICATION

Kirchler et al. 2012

- Explore two explanations for bubbles in the SSW design
  - Increasing cash/asset ratio; subjects' dividend earnings add to their cash on hand balances and this could be a cause of asset price inflation.
  - Confusion: Declining fundamental value is a foreign experience to subjects. Combination of declining FV and increasing C/A ratio is the problem

- 2×2 Design, treatment variables are (1) FV, declining ($d = 0$ or 10 with equal pr.) or constant (d=-5 or 5 with equal pr) + buyout value in both cases and 2 C/A ratio, increasing or constant, the latter by putting dividend payments in a separate account not available for trading.
- Also explore the role of context - "assets are stocks of a depletable gold mine" framing for the declining FV treatment:
  "The stocks are of a depletable gold mine in which gold is mined for 10 periods. In each period the probability of finding (not finding) gold is 50 percent. If gold is found in period *p* a dividend of 10 Taler for each unit of the stock will be paid. If no gold is found, the dividend will be zero. After 10 periods the gold mine is depleted and the value of the stock is 0."
- This framing also works to eliminate bubbles.

Kirchler et al. 2012, cont'd

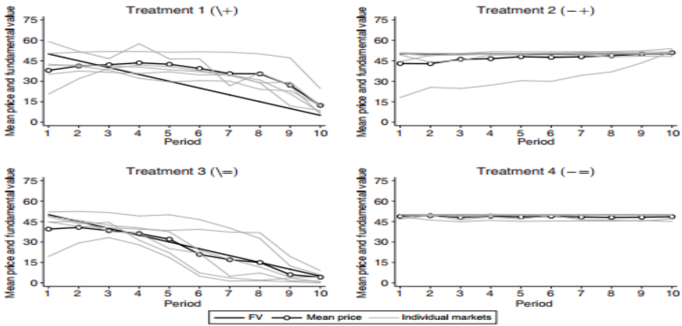


FIGURE 1

Notes: Fundamental Value (*FV, bold line*), Mean Treatment Prices (*bold line with circles*), and Volume-Weighted Mean Prices of Individual Markets (*gray lines*) as a Function of Period. Left panels: Treatments T1(\+) and T3(\=) featuring declining FVs. Right panels: Treatments T2(—+) and T4(—=) with constant FVs.

Gender Differences Eckel and Füllbrunn (2015)

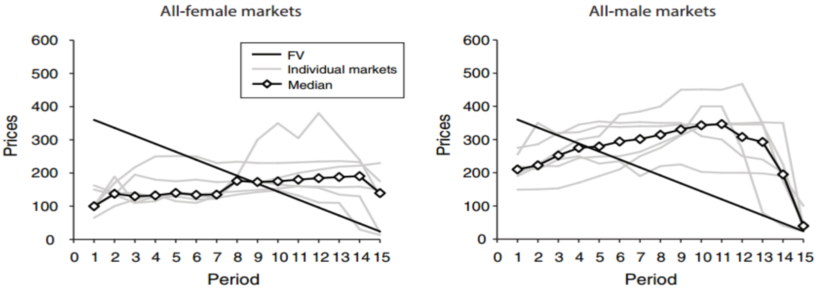


FIGURE 1. TIME SERIES OF MEDIAN TRANSACTION PRICES

Note: Median prices of individual markets (gray lines), fundamental value (FV, bold line), and average of median session prices (black line with diamonds) for each period.

- Bubbles in all-female markets are smaller than in all-male markets.

A Learning to Forecast Approach to Asset Pricing (Hommes et al. 2005)

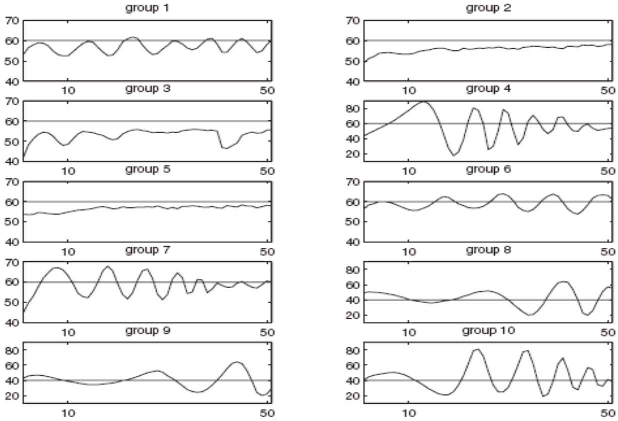
- 6 subjects seek only to forecast the price of an asset. They can condition on past prices (except for the first period).
- The dividend per unit of an asset is a known constant $\bar{d}$ (alternatively, it can be stochastic with a known distribution).
- Given the 6 forecasts, actual prices are determined by a computer program using the arbitrage pricing relation (1) which is unknown to subjects.

$$p_t = \frac{1}{1+r}\left(\frac{1}{6}\sum_{i=1}^{6} p^e_{i,t+1} + \bar{d} + \epsilon_t\right).$$

  where ϵ_t is a mean zero stochastic process.
- Payoffs are according to forecast accuracy alone.
- Rational expectation prediction is $p_t = \bar{d}/r + \epsilon_t/r$. (ignoring the rational bubble term b_t).

Findings

- Monotonic and Oscillatory Convergence/Divergence are all observed.
- Often there is excess volatility relative to ϵ which is very small.



Summary

- Participants who succeed in predicting average opinion well perform well in this experiment.
- This feature may be similar to real asset markets and is support for Keynes' famous beauty contest analogy.
- Subjects are rather successful in anticipating what "average opinion expects average opinion to be."
- They also consider a variant where some fraction of traders are programmed to predict the fundamental price in every period; this further helps convergence to some degree.
- But restriction of prices to (0,100), though this range includes the fundamental price, rules out rational bubbles.

A Consumption-Smoothing GE Asset Pricing Approach (Crockett and Duffy 2014)

- Assets are potentially long-lived and pay a common dividend (in terms of francs)
- Francs (consumption) converted into dollars each period and then disappear.
- Infinite horizon, implemented as a constant probability of continuation of a sequence of trading periods.
- We induce a utility function on subjects (the franc-to-dollar exchange rate) that is either concave or linear.
- If concave, there is an induced (smoothing) incentive for trade in the asset; If linear, there is no induced incentive for trade in the asset.
- We find asset under-pricing (relative to the expected value) in the concave utility treatment, and asset bubbles in the linear utility treatment.

Model

- The representative agent of type i seeks to maximize:

$$\max_{\{c_t^i\}_{t=1}^{\infty}} E_1 \sum_{t=1}^{\infty} \beta^{t-1} u^i(c_t^i),$$

subject to

$$c_t^i = y_t^i + d_t s_t^i - p_t \left(s_{t+1}^i - s_t^i \right),$$
$$y_t^i + d_t s_t^i - p_t (s_{t+1}^i - s_t^i) \geq 0,$$
$$s_t^i \geq 0.$$

- The first order condition for each time $t \geq 1$, suppressing agent superscripts for notational convenience, is:

$$p_t = \beta E_t \left[\frac{u'(c_{t+1})}{u'(c_t)} (p_{t+1} + \bar{d}) \right].$$

- Steady state equilibrium price: $p^* = \frac{\beta}{1-\beta} \bar{d}$. Same for both the concave and linear treatments.

Within-period Sequencing

The timing of activity is summarized below:

- Begin period t.
- Income and dividends paid.
- Assets traded (3-minute double auction)
- Random draw against β determined by die roll.
- Begin period $t + 1$, if applicable.

The set of periods that comprise the "life" of a given asset is called a *sequence*. We run several sequences per session.

Endowments and Treatments

Endowments

Type	No. Subjects	s_1^i	$\{y_t^i\} =$	$u^i(c) =$
1	6	1	110 if t is odd, 44 if t is even	$\delta^1 + \alpha^1 c^{\phi^1}$
2	6	4	24 if t is odd, 90 if t is even	$\delta^2 + \alpha^2 c^{\phi^2}$

2×2 Treatment Design

	$\bar{d} = 2$	$\bar{d} = 3$
Concave $\phi^i < 1$ and $\alpha^i \phi^i > 0$	**C2** 5 sessions	**C3** 5 sessions
Linear $\phi^i = 1$	**L2** 5 sessions	**L3** 5 sessions

Steady State Competitive Equilibrium Benchmarks

- $\bar{d} = 2$
  - $p^* = 10$
  - Type 1 shares cycle between 1 (4) in odd (even) periods
  - Type 2 shares cycle between 4 (1) in odd (even) periods
- $\bar{d} = 3$
  - $p^* = 15$
  - Type 1 shares cycle between 1 (3) in odd (even) periods
  - Type 2 shares cycle between 4 (2) in odd (even) periods

Holt-Laury Paired Choice Lottery

Beginning with session 7, subjects faced Holt-Laury (2002) paired-lottery task after the asset market experiment.

- Ten choices between two lotteries, A and B.
- A paid \$6 or \$4.80, B paid \$11.55 or \$0.30.
- In choice $n \in 1, 2, ...10$, the probability of receiving the high payoff was $0.1 * n$
- One choice was chosen for payment at random.
- Risk-neutral subject would choose B six times.
- 16% of subjects chose B at least six times, 30% chose B at least five times, mean number of B choices was 3.9 (a common frequency in the literature) which implies a Coeff of RRA 0.41<r<0.68 (moderate risk aversion).

Price Results

Finding 1: In the concave utility treatment ($\phi^i < 1$), observed transaction prices at the end of the session are generally less than or equal to $p^* = \frac{\beta}{(1-\beta)}\bar{d}$.

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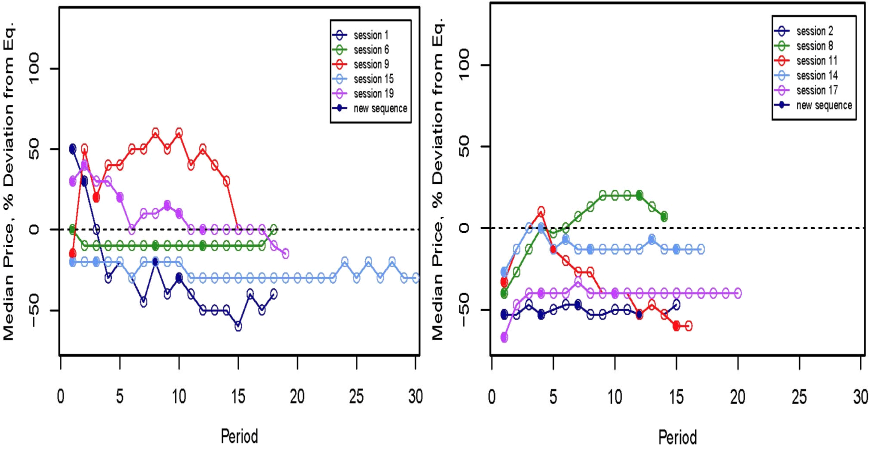
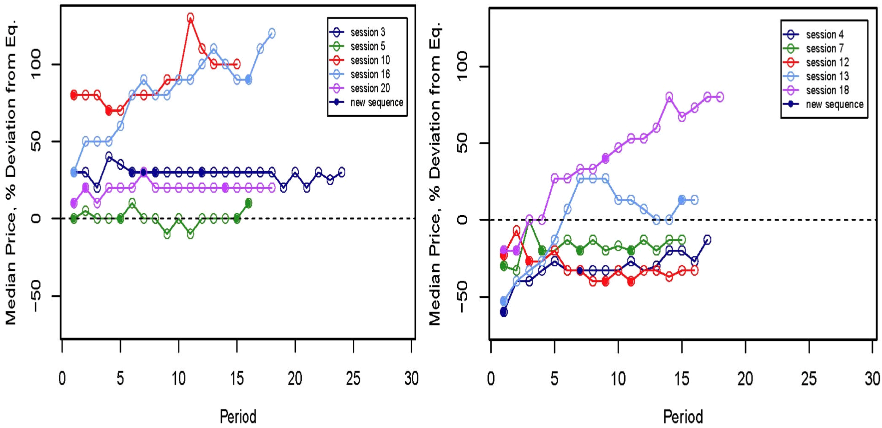
Finding 2: In the linear induced utility sessions ($\phi^i = 1$) trade in the asset does occur, at volumes similar to the concave sessions. Observed transaction prices are significantly higher in the linear sessions.

Median Equilibrium-Normalized Prices Concave Treatment



Median Equilibrium-Normalized Prices Linear Treatment



Prices Across Treatments

	Median	First Pd	Final Half	Final 5 Pds	Final Pd	τ	p-value	
C2-Mean	**9.6**	**10.9**	**9.4**	**9.0**	**8.3**			
S1	7	15	6	5	6	-0.67	0.0002	
S6	9	10	9	9	10	0	1	
S9	14	8.5	15	14	10	0.02	0.9592	
S15	7	8	7	7	7	-0.39	0.0132	
S19	11	13	10	10	8.5	-0.80	< 0.0001	
L2-Mean	**14.2**	**13.0**	**15.0**	**15.0**	**15.6**			
S3	13	13	13	13	13	-0.32	0.0609	
S5	10	10	10	10	11	-0.06	0.8248	
S10	18	18	20	20	20	0.63	0.0027	
S16	18	13	20	20	22	0.81	< 0.0001	
S20	12	11	12	12	12	0.27	0.1946	
C3-Mean	**10.8**	**8.4**	**10.8**	**10.6**	**10.4**			
S2	7	7	7	7	8	0.15	0.5174	
S8	15	9	17	17	16	0.70	0.0010	
S11	10	10	8	7	6	-0.78	< 0.0001	
S14	13	11	13	13	13	-0.13	0.5698	
S17	9	5	9	9	9	0.28	0.1551	
L3-Mean	**13.8**	**9.4**	**15.0**	**15.4**	**16.0**			
S4	10	6	11	12	13	0.72	0.0002	
S7	13	10.5	13	13	13	0.33	0.1282	
S12	10	11.5	10	10	10	-0.46	0.0228	
S13	16	7	17	16	17	0.41	0.0356	
S18	20	12	24	26	27	0.95	< 0.0001	

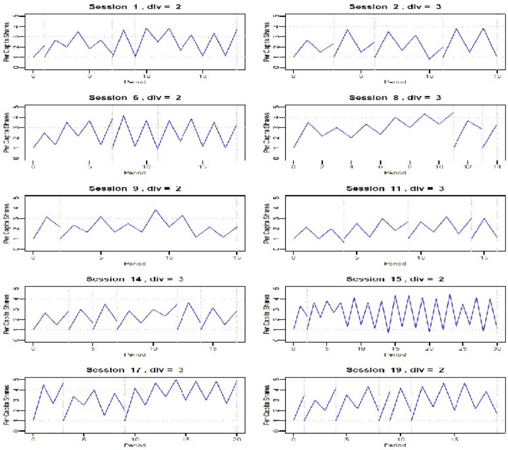
Analysis of Final Price Differences

- Why? Rather complicated environment with potential for substantial learning. Final prices best reflect learning and long-term trends.
- Pooling by linear vs. concave, linear sessions finished 32% above fundamental price on average, concave sessions 24% below (test of null of no difference has a p-value 0.006).
- In treatment-to-treatment comparisons, the difference in the distribution of final period prices is significantly different between L2 and C2 (p-value is 0.012) but not between L3 and C3 (p-value is 0.139).

Consumption-Smoothing

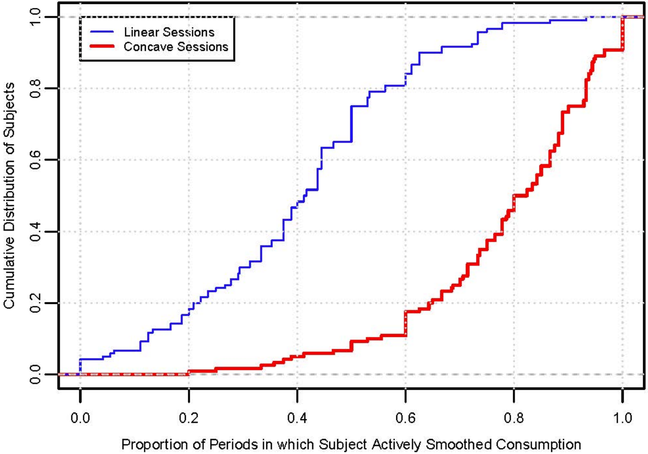
Finding 3: In the concave utility treatments there is strong evidence that subjects are using the asset to intertemporally smooth their consumption.

Concave sessions, per capita shares held by Type 1



Consumption-smoothing behavior

Proportion of periods Type 1 players buy (sell) shares if the period is odd (even) and Type 2 players buy (sell) shares if the period is even (odd).

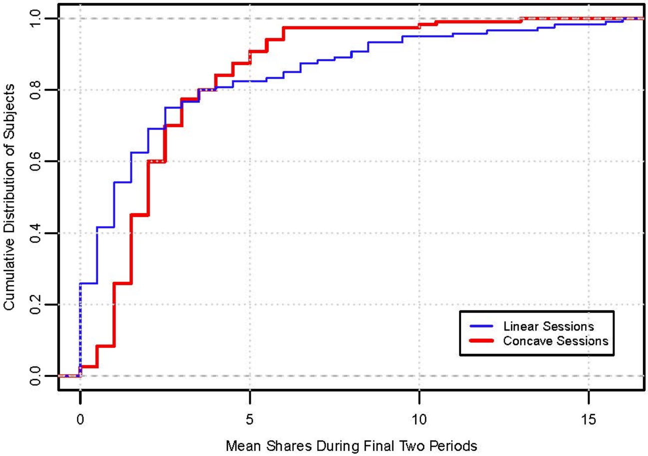


Assets are Hoarded in Linear Sessions

Finding 4: In the linear utility treatment, the asset is hoarded by just a few subjects.

- Mean Gini coefficient for shareholdings in final two periods of a session is 0.37 in all concave treatments (compared with 0.3 or lower in equilibrium).
- Mean Gini coefficient is 0.63 in all linear treatments (difference between concave and linear p-value $=0.0008$).

Distribution of Mean Shares During Final Two Periods



Risk Tolerance and Shareholdings

Finding 5: The more risk-tolerant subjects (according to the HL instrument) tend to accumulate assets in linear sessions, but not in the concave sessions.

- Random effects regression of shares held during the final two periods on HL scores ($\#B$ (risky) choices).
- Coefficient on $\#B$ choices is 0.46 in linear sessions (p-value 0.033) Interpretation - Every two additional B choices leads to nearly one extra share held on average during the final two periods (per capita share endowment is only 2.5).
- Coefficient on B choices is -0.10 in the concave sessions (p-value$=$ 0.407)

Results - Summary

- Relative to fundamental price / expected value, prices tend to be low when consumption-smoothing is induced and high when it is not in otherwise identical economies.
  - Under-pricing of asset in concave treatment relative to fundamentals can be viewed as a kind of endogenous premium for holding the risky asset.
  - Over-pricing of asset in linear treatment is similar to what is observed in bubbles experiment literature.
- Most subjects smooth consumption in the concave sessions and rarely accumulate a large number of shares.
- High prices in linear sessions are driven by a high asset share concentration among the most risk-tolerant subjects.

Some Further Extensions:

- Unpack the shock components of Hussam et al. 2008 to figure out what is necessary to rekindle a bubble among experienced subjects.
- Asset price bubbles with increasing fundamental prices?
- Add an initial public offering (IPO) of shares (rather than giving these away to subjects) at an initial price that is below the first period fundamental value: do subjects buying shares in an IPO think harder about the asset's fundamental value over a T-period horizon?
- Fund management model (are $n > 1$ heads better than 1 / team behavior): One person forecasts price. Given this forecast, the other person makes an asset purchase decision (or some other consensus process).
- Test the capital-asset pricing model (CAPM) where assets are priced according to their sensitivity to non-diversifiable risk β, e.g., under the assumption of mean-variance preferences.