Asset Market Experiments

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Laboratory evidence indicates that prices of financial assets such as stocks and bonds respond to changes in the assets' fundamental value but are also sometimes distorted by investors' cognitive and other biases.

INTRODUCTION

0706.001 Any society allocates some resources to current consumption and some to investment, to building a better future. Asset markets determine the extent and form of investment in modern economies. Non-market allocation procedures such as those once used in Communist countries clearly worked less well and became less prevalent in the late twentieth century. Asset markets now have global scope and significance.

0706.002 By definition, asset markets are efficient when asset prices reflect all relevant information about investment opportunities. Theory shows that efficient asset markets lead society to choose only the most productive investment prospects, and to choose the best overall level of investment.

0706.003 Efficient asset price is called fundamental value. Actual asset prices are set by fallible human investors in imperfect markets, and thus may contain other components, called bubbles, that can lead to inefficient resource allocation and impair future wellbeing.

0706.004 Laboratory and field evidence sheds light on asset market efficiency. Asset markets sometimes compensate for investors' cognitive biases, but at other times they amplify them and produce large bubbles. Laboratory experiments help to test policies intended to improve asset market efficiency.

FUNDAMENTAL ASSET VALUE

0706.005 An asset is anything that provides its owner with a stream of benefits over time. Its economic value is the monetary equivalent of the net benefits it provides. Valuation of a real asset (such as a house, a pizza delivery car or a microprocessor production facility) involves estimating prices for the services the asset generates and for the resources required to maintain its productivity. This article will focus on financial assets, such as stocks and bonds, which are easier to value since they directly promise a monetary income stream. A stock, for example, promises annual per share dividends chosen by the company's board of directors.

0706.006 Valuing a known income stream is straightforward. One computes the discounted present value: the amount of cash that, if put on deposit now and withdrawn over time, could replicate the income stream. For example, if the asset is an annuity (a simple bond) that promises $1000 every year for 30 years, and the annual interest rate is 7percnt;, then the asset value is $(\$1000)(1.07)^{-1} + (1.07)^{-2} + \ldots + (1.07)^{-30})$ or, summing the geometric series and simplifying, $(\$1000)(1 - (1.07)^{-30})/(0.07) = \$12{,}409$.

0706.007 Valuation is more interesting when the income stream is uncertain, either because the promise is vague (as for a stock) or because the promise might not be kept (as in the case of a 'junk' bond). The economic value is defined to be the mathematical expectation of the income stream, discounted at the interest rate appropriate for the associated risk. For example, if the $1000 annual payment in the previous example had a 50% independent probability of being cancelled every year, and this requires a 2% risk premium or 9% interest rate, then the expected annual income is $500 and the asset value is $(\$500)(1 - (1.09)^{-30})/(0.09) = \$5{,}137$.

0706.008 Two questions arise. Firstly, what is the appropriate interest rate (or risk premium)? This question stimulated the development of modern finance theory in the 1950s and 1960s, but we will not pursue it here. Secondly, how can people with diverse information arrive at a common expectation of the income stream (or its discounted present value)? Some people may know a lot about the technical performance of a company's new product, others about customer demand, or competing products, or production costs, or the company's management and financing capacity. Usually nobody has all the relevant knowledge.

0706.009 'Fundamental asset value' is the present value expectation incorporating all existing information regarding future income. The definition seems to assume that people immediately share all knowledge and combine it without bias or distortion. But people may not share information; they often are cognitively biased. Cognitive biases might cause the market price to deviate from fundamental value.

COGNITIVE BIASES

0706.010 Which cognitive biases might distort people's estimates of asset value? Some of the main biases are summarized below (Camerer, 1993; Rabin, 1998; Thaler, 1992).

0706.011 Firstly, judgement biases may distort the aggregation of diverse information (Massaro and Friedman, 1990) and income stream estimates. In particular, investors may:

- neglect some pieces of information and over-weight others, as in cue competition;
- overestimate the resemblance of the future to the immediate past, as in the well-known availability and representativeness heuristics or the anchoring and inertia biases;
- over-weight new information and neglect old information, as in overreaction to news and base rate neglect;
- regard ambiguous news as reinforcing current beliefs, as in the confirmatory bias;
- overrate the precision of their own information, relative to other traders' information, as in overconfidence;
- indulge in the gambler's fallacy or magical thinking, perceiving patterns in random data;
- react incorrectly to increasing information precision, or switch biases depending on state, for example, by overreacting to news when asset prices are volatile but underreacting otherwise.

0706.012 Secondly, when moving from income estimates to asset value estimates, investors may apply hyperbolic discounting, using too high interest rates when comparing current income with near future income, and too low interest rates when comparing income received at two distant dates (Ainslie, 1992).

0706.013 Thirdly, investors may make decision errors when they buy and sell assets, such as overvaluing assets they currently hold, as in the endowment effect, or making inconsistent risky choices, as in prospect theory, regret theory, or (more generally) decision field theory (Busemeyer and Townsend, 1993).

Fourthly, investors may learn by trial and error, 0706.014
some faster than others, creating additional asset price deviations from fundamental value (Kitzis *et al*., 1998; Busemeyer *et al*., 1993).

Note, however, that individual investors' biases 0706.015
do not translate directly into asset price biases. Market prices are set by subtle interactions between investors that may either attenuate (e.g., Friedman, 2001) or amplify (e.g., Akerlof and Yellin, 1985; DeLong *et al*., 1990) the individual biases and learning heterogeneities. Thus, whether (or when) asset price follows fundamental value is an empirical question in its own right.

FIELD EVIDENCE

Evidence from existing asset markets is interesting 0706.016
but inconclusive. Historians point to dramatic episodes of asset price increase and collapse, from the South Sea bubble and 'tulipmania' in the sixteenth century to Japan's 'bubble' economy of the late 1980s, various 1990s financial crises (in Western Europe, Latin America, East Asia and Russia), and the 'dot com' bubble of 2000.

Some economists argue that these episodes are 0706.017
merely unusual movements in fundamental value (Garber, 2000). Economists cannot observe the private information held by traders in the field, and therefore have no direct measure of fundamental value or bubbles. Some indirect field evidence, however, favours the bubbles interpretation. Shiller (1981) and later writers surveyed in LeRoy (1989) show that stock market indices are much more volatile than would be justified by subsequent changes in dividends. Roll (1984) argues that changes in the fundamental value of US orange juice futures come predominantly from two observables (Florida weather hazard and Brazil supply) but account for only a small portion of the actual price variability. Additionally, nonfundamental effects consistently observed, such as the day of the week or month and January effects, also suggest that stock prices are more volatile than fundamental values. Finally, in a natural field experiment, the stock prices (but arguably not the fundamental values) are far less volatile on weekends and days when the exchange is closed for upgrades. On the other hand there is also field evidence suggesting efficient information aggregation. The Iowa Electronic Market has consistently outperformed major polls in predicting election

outcomes (Forsythe *et al*., 1999) and similarly with the Hollywood Stock Exchange for box office revenues and Oscar winners (Pennock *et al*., 2001).

0706.018 Field evidence is indirect and can seem either to support or to undermine claims of market efficiency.

LABORATORY EVIDENCE

0706.019 Laboratory asset markets provide direct evidence, because the experimenter can control the information available to traders and can always compute the fundamental value. The first generation of asset market experiments in the early 1980s used oral double auction trading procedures similar to the traditional Chicago trading pits. To sharpen inferences, the laboratory markets are much simpler than field markets: for example, they often allow only 8 to 16 subjects to trade a single asset. Most of the results described below involve experienced traders who are fully adapted to the laboratory market. See (Sunder, 1993) for an excellent early survey, and Holt (1999) for an online bibliography.

Market Attenuation of Traders' Biases

0706.020 There are several distinct forces that tend to attenuate biases. Firstly, people can learn to overcome their biases when the market outcomes make them aware of their mistakes. Secondly, to the extent that biased traders earn lower profits (or make losses), they will lose market share and will have less influence on asset price. Thirdly, institutions evolve to help people overcome cognitive limitations: for example, telephone books mitigate the brain's limited digital storage capacity. Trading procedures such as the oral double auction evolved over many centuries and seem to enhance market efficiency.

0706.021 Oral double auctions allow all traders to observe other traders' attempts to buy and sell, and might enable them to infer other traders' information. Moreover, the closing price is not set by the most biased trader or even a random trader. The most optimistic traders buy (or already hold), and the most pessimistic traders sell (or never held), the asset, so the closing price reflects the moderate expectations of 'marginal' traders, the most reluctant sellers and buyers.

0706.022 These attenuating forces may explain the surprisingly rapid convergence of asset price to fundamental value in the first generation of laboratory experiments. Forsythe *et al*. (1982) obtained such convergence for assets that pay different dividends to different traders over two periods. Likewise, Plott and Sunder (1982) obtained convergence to efficient asset price for a single-period asset even when some traders have inside information. Friedman *et al*. (1984) found that simultaneous operation of spot and futures markets improved convergence to efficient asset price and allocation when assets pay different dividends to different traders over three periods and traders know only their own dividend schedule. Generally, convergence was first observed in the last dividend period, then in the middle period as traders correctly anticipated last-period prices, and finally in the first trading period as traders learned the asset's present value.

Market Amplification of Traders' Biases

Later experiments detected systematic discrepancies between price and fundamental value in more complex environments. Copeland and Friedman (1991) found that in a computerized double auction with three information events and eight states, a model of partial aggregation predicted price better than full aggregation or fundamental value. 0706.023

Several experimental teams found that insider information is incorporated into asset price less reliably and less quickly when the asset pays the same dividend stream to each trader and the number (or presence) of insiders is not publicly known. Some data suggest the following scenario. An uninformed trader *A* observes trader *B* attempting to buy (due to some slight cognitive bias, say) and mistakenly concludes that *B* has favourable inside information. Then *A* tries to buy. Now trader *C* concludes that *A* (or *B*) is an insider and tries to mimic their trades. Other traders follow, creating a price bubble. 0706.024

Such 'information mirages', or 'herding' bubbles, amplify the biases of individual traders, but they cannot be produced consistently, since incurred losses teach traders to be cautious when they suspect the presence of better-informed traders. (This lesson does not necessarily improve market efficiency, however, since excessive caution impedes the aggregation of information.) 0706.025

Smith *et al*. (1988) found large positive bubbles and crashes for long-lived assets and inexperienced traders. Their interpretation invokes the 'greater fool' theory, another bias amplification process. Traders who themselves have no cognitive bias might be willing to buy at a price above fundamental value because they expect to sell later at even higher prices to other traders dazzled by rising prices. Subsequent studies confirmed that such dazzled traders do exist, and that bubbles are more prevalent when traders are less experienced 0706.026

(individually and as a group), have larger cash endowments, and have less conclusive information.

0706.027 Other mechanisms that amplify biases in laboratory asset markets include firm managers' discretionary release of information and fund managers' rank-based incentives (James and Isaac, 2000).

Policy Studies

0706.028 We have only a tentative and fragmentary understanding of when asset markets amplify or attenuate investors' cognitive biases. The impact of proposed policy changes often cannot be predicted reliably, and must be assessed empirically by regulators, asset market makers contemplating reform, and entrepreneurs creating new asset markets. Laboratory markets offer helpful guidance at low cost. Recent relevant research includes performance assessment of:

- alternative market formats, including oral (or face-to-face) double auctions, anonymous electronic double auctions, call or uniform price periodic auctions, and fragmented opaque (or bilateral search) markets;
- trader privileges, such as price posting and access to order flow information;
- transaction taxes, price change limits and trading suspensions intended (usually ineffectively) to mitigate price bubbles and panics;
- new derivative securities such as call and put options and state-contingent claims.

Current Research

0706.029 Research continues at a rapid rate along all the lines mentioned. One promising new line of research investigates learning, and judgement and decision biases, in environments similar to asset markets. These environments clearly do attenuate some sorts of biases (Kelley and Friedman, forthcoming) and amplify others (Ganguly *et al*., 2000); eventually such work should clarify the patterns.

0706.030 Other promising new lines of research integrate agent-based simulation models (e.g., Epstein and Axtell, 1996) into asset markets that may include human traders. The simulated agents, or 'bots', incorporate specified cognitive limitations and the simulations examine the market-level influence of these (e.g., Arthur *et al*., 1997). Gode and Sunder (1993) showed that simple (non-asset) double auction markets are efficient even when populated by 'zero intelligence' agents, bots that are constrained not to take losses but are otherwise quite random. Research is beginning to show how these and more intelligent bots affect efficiency in various sorts of asset markets and how they interact with humans.

The laboratory asset market evidence is more 0706.031
direct than the field evidence, but is still mixed. The laboratory evidence clearly demonstrates that asset price bubbles exist and persist under some circumstances, but that under other circumstances asset prices closely track fundamental values. Future work promises to identify more clearly the circumstances that promote or impair market efficiency. This should lead to improved policy and a better-functioning economy.

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Glossary

Bubble A temporary deviation in asset market price from fundamental value.

Double auction A real-time market format whereby buyers announce prices (bids) at which they are willing to buy, and sellers announce prices (asks) at which they are willing to sell, a specified good or asset. When anyone accepts an existing bid or ask, there is an immediate transaction at that price. Alternative market formats include call markets, in which bids and asks are collected privately and cleared simultaneously at a specified time; and bilateral search markets, in which no prices are publicly submitted, but rather buyers and sellers seek each other and negotiate prices privately.

Financial crisis A financial market episode in which important asset prices (e.g., of the national currency, or bonds, or bank loans) fall precipitously, often leading to a widespread decline in the standard of living.

Forward market A market in which buyer and seller agree now on an asset price but the actual exchange of cash and asset is scheduled for a specified date in the future.

Fundamental value The efficient asset price, representing the expected present value of the net income stream produced by the asset. The expectation incorporates all relevant information currently available to investors.

Present value The amount of cash that, if put on deposit now and withdrawn over time, could replicate an asset's income stream.

Spot market A market in which two or more parties agree on price and execute the transaction immediately. (In reality, payments may take one to three days to clear.)

Keywords: (Check)

fundamental value; cognitive biases; bubbles; overconfidence; agent-based modelling

1. Please check coauthor details.
2. ‘Current Research’, 1st paragraph, 3rd sentence, (Kelley and Friedman, forthcoming): Please supply year if known.
3. References, (Arthur *et al.*, 1997): Please supply names of editors of book.
4. References, (Kitzis *et al.*, 1998): Issue numbers ‘2–3’ correct?
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