# BUBBLES AND FADS IN ASSET PRICES

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**Abstract**. The article considers the possibility that asset prices might deviate from intrinsic values based on market fundamentals. Three broad categories of theory are surveyed: (a) growing bubbles (b) fads and (c) information bubbles. 'Sunspot' theories are also discussed. The paper covers both theory and evidence, and directions for future research are discussed.

**Keywords**. Bubbles; fads; information; sunspots.

## 1. Introduction

The possibility that asset prices might deviate from intrinsic values based on market fundamentals, because of 'speculative bubbles' or 'fads', has long intrigued economists. Recent theory and empirical research has helped to clarify whether bubbles and fads are rational and whether they occur. This work merits a review because it is increasingly sophisticated, voluminous, and controversial.

In this review, theories of price deviations from intrinsic value will be divided into three categories (somewhat arbitrarily) — growing bubbles, fads, and information bubbles. 'Sunspot' theories will also be described, briefly.

*Growing bubbles* are typically constant terms which arise in solutions to difference equations that govern equilibrium prices. Such bubbles can occur even when traders act rationally and have rational expectations (e.g. Hahn, 1966; Blanchard and Watson, 1982; Tirole, 1982, 1985), unless a market is known to be limited by asset life, or by the wealth or number of traders.

*Fads* are mean-reverting deviations from intrinsic value caused by social or psychological forces like those that cause fashions in political beliefs or consumption goods (Shiller, 1984), or like Keynes's 'animal spirits'. If fads are slowly mean-reverting, they are 'near-rational' since traders would have to wait a long time to exploit their knowledge that prices are in a fad.

*Information bubbles* occur when prices depart from intrinsic values based on all available information, because information is not perfectly aggregated by market prices (e.g. Friedman and Aoki, 1986), or because agents have different beliefs about how the economy works.

The purpose of these three categories is to organize a large, rapidly growing literature in ways that suggest productive avenues for further research. The review has several other purposes: to compare theory and evidence (the two are often somewhat separated); to draw out the economic intuition behind technical

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theory and subtle empirical work; and to clarify confusion about bubbles and fads.[1]

I offer the usual apology for omitting important details or entire papers. Some are no doubt neglected because of ignorance. Others are omitted because they distract the reader; this review is meant as an approximate road map for the touring economist, not a precise map for the native economist.

Theory and evidence of rational growing bubbles are discussed in Sections 2 and 3. Fads are discussed in sections 4 and 5. Section 6 describes research on information bubbles. The review is summarized in Section 7, with an emphasis on unsolved problems and future research.

## 2. Rational growing bubbles: Theory

Macro-economic theorists were the first to thoroughly formalize the possibility of growing bubbles, noting that dynamic models of the price level could have indeterminate explosive solutions even if agents have rational expectations (Samuelson, 1958; Hahn, 1966; Sargent and Wallace, 1973a,b; Brock, 1974, 1975; Black, 1974; Calvo, 1978; Wallace, 1980; Diba and Grossman, 1988a, and see Shiller, 1978, for a review). Explosive solutions are considered anomalous in models of the general price level, but they may be good positive theories of some episodes in asset pricing.

To see most simply[2] how rational growing bubbles can occur, consider an asset in fixed supply which lives forever, and pays a dividend $D_t$ in period $t$ (which can be stochastic). Ignore the possibility that trading is motivated by differences in beliefs or the desire for insurance (see Hirshleifer, 1975; Tirole, 1982). Suppose all traders are risk-neutral, have an identical discount rate of $r$ per period, and have identical information $I_t$ in period $t$. Then the first-order condition in agents' maximization of intertemporal utility (the 'Euler equation') is[3]

$$P_t = [E(D_{t+1} \mid I_t) + E(P_{t+1} \mid I_t)]/(1+r) \tag{1}$$

Intuitively, condition (1) implies that the price of the asset today is the discounted sum of the expected dividend and resale price next period. (The expectation is statistical, conditioned on the information set $I_t$, though agents' actual expectations could possibly violate the principles of rationality correct expectations should satisfy.) An arbitrary bubble in prices satisfies this equilibrium condition as long as the bubble in time $t$ (on the left-hand side) equals the expected discounted bubble in time $t+1$ (on the right-hand side). Equilibrium is therefore satisfied by bubbles $B_t$ of the form

$$B_t = E(B_{t+1})/(1+r), \tag{2}$$

or

$$B_{t+1} = (1+r)B_t + z_t \tag{2'}$$

where $z_t$ is a random term with zero mean and no autocorrelation. Note that rational bubbles of this sort must grow every period, at a rate $r$ (hence the term 'growing bubbles'), because a bubble must provide some return to sustain participation in it.

Requiring expectations to be rational creates a difference equation in expectations which has two solution components, an arbitrary bubble and the discounted expected value. Formally, rationality of expectations forces $E(P_{t+1} \mid I_{t+1})$ to be $E[E(D_{t+2} \mid I_{t+1}) + E(P_{t+2} \mid I_{t+1}) \mid \mathrm{I}_t)]/(1+r)$ (by extending equation (1) to prices in period $t+1$ and taking an expectation). The law of iterated expectations (Sargent, 1979, pp. 208, 213) reduces $E(E(P_{t+2} \mid \mathrm{I}_{t+1}) \mid I_t)$ to $E(P_{t+2} \mid I_t)$. Define a lag operator L, such that $L(X_t) = X_{t-1}$ and $L^{-1}$ $(X_t) = X_{t+1}$. Then the rational expectation condition is a difference equation,

$$E(P_{t+1}(1 - L^{-1}/1 + r) \mid I_t) = E(D_{t+2} \mid I_t)/(1 + r). \qquad (3')$$

Now we can multiply both sides by $(1 - L^{-1}/1 + r)^{-1}$, which is just $1 + L^{-1}/(1 + r) + \cdots \mathrm{L}^{-n} + \cdots$ (by the usual expansion of $(1 + x)^{-1}$), to get

$$E(P_{t+1} \mid I_t) = \sum_{i=1}^{\infty} E(D_{t+i+1} \mid I_t)/(1 + r)^i + E(B_{t+1}), \qquad (3'')$$

The bubble term arises[4] because $B_t$ times $(1 - L_1/1 + r)$ is zero if $B_t = B_{t+1}/1 + r$ (just as an arbitrary constant arises in solving a differential equation.) Putting the expected price $E(P_{t+1} \mid I_t)$ from (3″) back into (1), we get

$$P_t = \sum_{i=1}^{\infty} E(D_{t+i} \mid I_t)/(1 + r)^i + B_t \qquad (3)$$

Thus, the rational price must equal an 'intrinsic value',[5] the discounted dividend stream, and a bubble term (which can be zero, of course).

Growing bubbles are consistent with rational expectations, and hence with the hypothesis that markets are informationally efficient, because current prices reflect the discounted price of the future bubble. Traders cannot make excess profits by knowing prices will be too high next period, because the price is too high this period also. Indeed, because expected profits from the bubble are zero, risk-neutral traders have no strong incentive to participate in it. Risk-averse traders will not.

Rational bubbles must be grown at a rate $r$ (in expected terms) each period, but they need not grow exactly at that rate. For instance, the bubble could be expected to burst with probability $p$ each period, as long as the bubble in period $t+1$, conditional on *not* bursting , is $(1 + r)B_t/(1 - p)$ so that the expected growth rate is still $r$ (see Blanchard, 1979; Blanchard and Watson, 1982).[6] The probability that a stochastic bubble lives $n$ periods is $(1 - p)^n$. This probability converges to zero as $n$ grows large, so bubbles can exist even though rational traders know they will 'eventually' burst.

The possibility of rational growing bubbles does not depend on the restrictive assumptions required to derive (3). Tirole (1982) shows that heterogeneous information among traders and restrictions on short-selling do not affect the general possibility of bubbles. If discount rates differ across traders or time, appropriate generalizations of the solution (3) hold. If traders are risk-averse, bubbles can still exist but they must grow *faster* than $1 + r$ (if they are stochastic), effectively paying traders a risk premium in expected value to hold the asset (Blanchard and Watson, 1982, pp. 297–298). However, the bubble component of price may not be negative, since then a growing bubble would eventually make the asset price negative; anticipating such an occurrence will choke off negative bubbles before they start. (Of course, the bubble may grow at a negative rate in some periods, when it bursts for instance, or in all periods if the discount rate $r$ is negative.)

Tirole (1982, 1985) suggested what kind of assets that might be subject to price bubbles. Assets must be durable, because an expectation of resale value is needed to generate a bubble. Scarcity or short-run supply inelasticity is important because an asset that can be easily produced if a bubble occurs (like similar paintings by a living artist) will drive prices down and burst the bubble. Bubbles may also require an active market for assets, and a social mechanism for coordinating the common belief that a bubble exists and will continue to grow.

Blanchard and Watson (1982) pointed out that growing bubbles can have harmful real effects on the economy, by drawing out inefficient supply at high prices or making asset prices poor signals (see also Friedman, 1984). Some argue that bubbles harm welfare because they redistribute wealth, but random redistribution is only harmful if traders are risk-averse, and risk-averse traders will avoid a bubble which grows at rate $r$.

### 2.1. *Some examples of growing bubbles*

The most famous example of a growing bubble is the 'tulip mania' in Holland in the 1600's (Posthumous, 1929; Mackay, 1932/1974). Tulip bulbs began selling for high prices, for no apparent reason (except rumors of increased demand in France by women who attached them to gowns). Prices rose dramatically, trading became feverish, and prices eventually crashed. Many bulb prices can be explained by the thinness of the market for novel, exotic types of bulbs, but the trade in common bulbs in January 1637 seems to be a bubble. The hallmark of the rational growing bubble is that traders realize prices are much higher than intrinsic values, but they buy assets anyway, expecting prices to go even higher. Historical accounts of part of the tulip mania bear this hallmark (see Garber, 1986, for a thorough description).

A bubble in modern times is the price of 'yearling' thoroughbreds, year-old horses that have never raced (*Barron's* 1985; Crist, 1986). In the 1970's prices for top-quality yearlings at prestigious auctions began to rise, to a mean of nearly $500,000 (with a maximum price of $13.1 million in the mid-1980's). These prices seem quite high because half of the most well-bred yearlings never win any races and only 2% become champion money-winners (*Philadelphia Inquirer*, 1984). Very few horses earn a million dollars from racing (none of the 150 or so million-dollar yearlings ever have). The source of the apparent bubble is breeding potential, not racetrack earnings: Yearlings can make more yearlings (up to 50 times a year), earning large 'stud fees' of up to $1 million each time. The possibility of reproduction creates an equilibrium condition between the price paid for a yearling today ($Y_t$) and the expected sales of the yearling's offspring tomorrow ($E(Y_{t+1})$), much like the equilibrium condition (1) for stock prices, which allows rational bubbles to form.

Of course, rational growing bubbles tend to burst, and yearling prices have indeed fallen from their peak in 1983–4. (The price decline may have been softened when an organization of breeders, who benefit most from a bubble, began to increase purses enormously in 1984, arguably to boost intrinsic value closer to prices and prevent the bubble from bursting.[8])

Even with yearlings it is difficult to tell whether prices are in a bubble above intrinsic value because unobservable components of value, like tax advantages or prestige[9], *could* justify very high prices for unraced horses. Or the tulip and yearling bubbles might have been irrational Ponzi schemes created by speculators (cf. Kindleberger, 1978), as in modern 'pyramid' or 'aeroplane' games.[10] These competing explanations, whether plausible or not, show how hard it is to tell whether price movements are due to rational growing bubbles.

Another controversial example is the dramatic growth and crash of silver prices during 1980 (from $10 to $50 per ounce and back again). The typical account is that the Hunt brothers bought up silver contracts[11] to limit supply and 'squeeze the shorts' i.e. force sellers obligated to deliver silver to buy it at high prices (see Abolafia and Kilduff, 1988). Fama and French (1988b), noting that silver prices behaved no more strangely than other metals prices, suggest the apparent squeeze is consistent with the theory of storage underlying models of futures prices.

### 2.2. *Ruling out growing bubbles*

The short history of formal theory about growing bubbles is an intellectual struggle between attempts to rationalize the possibility of bubbles, because they may occur, and attempts to rule out bubbles because they are arbitrary.

#### 2.2.1. *Bubbles cannot occur if expectations are adaptive*

One way to rule out bubbles is to assume expectations are not rational, since the possibility of growing bubbles is directly traceable to the assumption of rational expectations. Under rational expectations, price paths are indeterminate because there are two variables to solve for each period, prices and expectations, but there is only a single condition constraining market equilibrium and rationality of expectations (Flood and Garber, 1982).

If expectations are adaptive rather than rational, bubbles can usually be ruled out. For instance, if $E(P_t|I_{t-1})$ is simply equal to $P_{t-2}$, it is easy to show that prices will converge to the discounted dividend level, for any value of the initial expectation $E(P_1/I_0)$ (see also Lucas, 1986). Burmeister (1980) made the dual argument that adaptiveness in price adjustment, instead of adaptiveness in expectation adjustment, will preclude divergent paths in macroeconomic models.

### 2.2.2. *Methodological reasons for ruling out bubbles*

Many macroeconomists have proposed methodological reasons for excluding bubble paths. McCallum (1983) suggested that indeterminate price paths be ruled out on grounds of parsimony. Gourieroux, Laffont, and Monfort (1982) discussed criteria for excluding price paths based on statistical and economic properties. Taylor (1977) noted that bubbles in the general price level are inconsistent with the collective rationality of price-variance minimization, but he proposes no way for traders to achieve collective rationality.[12]

### 2.2.3. *Economic reasons for ruling out bubbles*

Brock (1978) argued that bubbles in the general price level are ruled out by individual utility maximization, provided real money balances (M/P) times the marginal utility of real balances stays positive as M/P approaches zero. Obstfeld and Rogoff (1983) show that this requirement is economically unrealistic because it implies that the utility of zero real balances is negatively infinite, as if no amount of consumption could compensate a person for doing without money. (Gray, 1984, reviewed these arguments lucidly.) However, Obstfeld and Rogoff (1983, 1986) also showed that bubbles are ruled out if the government probabilistically guarantees a minimal redemption value for currency in units of capital[13] (see also Wallace, 1981, and Brock, 1982). Implosive bubbles (in which prices asymptote to zero) are ruled out if the utility of real balances is bounded from above (Obstfeld and Rogoff, 1986).

Farmer (1984) showed that hyperinflationary equilibria can be ruled out if units of consumption have a minimum size D. Since a hyperinflation would eventually make a fixed money stock worth less than D, and hence worthless, by backward induction no hyperinflation can be sustained. Isaac (1986) pointed out that assuming a minimum unit of consumption can preclude existence of stationary equilibria or introduce cyclical indeterminacies, but assuming trading costs rules out hyperinflations, just as minimum consumption does, without causing other complications. Diba and Grossman (1987, 1988b) noted that a rational bubble cannot begin at any arbitrary date $t^*$ in the middle of an asset's life, because rational traders must have anticipated the bubble's beginning, so a bubble must have occurred at time $t^* - 1$, etc. Rational bubbles must therefore start at the inception of an asset's life (which seems empirically implausible), unless we allow unanticipated shifts in collective expectations to trigger bubbles.

### 2.2.4. *Market limits rule out growing bubbles*

In asset markets, the most obvious reasons why growing bubbles won't exist are restrictions on the scope of a market (Tirole, 1982, 1985). For instance, if assets have a finite lifetime of $T$ periods, as bonds do, rational bubbles should not occur, by backward induction. In period $T$ no rational trader will pay more than the terminal value of the asset, so no trader with rational expectations will pay more than the discounted terminal value in period $T-1$, etc. No rational bubble can start because all traders can anticipate its ending.[14] With known wealth constraints, the bubble must stop growing at some point, and the unravelling argument again applies. (In practice wealth constraints may not be very important, since agents can borrow; see Tirole, 1982, p. 1179.).

Even if there are no limits on wealth or the life of assets, rational growing bubbles can't occur if the number of traders is finite, if traders have rational expectations *and* rational trading strategies. The argument is subtler. Along the equilibrium bubble path, traders have no *positive* (or negative) incentive to buy and sell at the bubble price. However, there is a date at which each trader will leave the market to spend gains on consumption (to do otherwise would mean postponing consumption endlessly); effectively, near retirement the incentive to buy the asset *is* negative because it has an opportunity cost.[15] Since traders will eventually depart after they have sold the asset at bubble prices, remaining traders play a negative-sum game. Anticipating this, nobody will buy initially at a bubble price.

### 2.2.5. *Removing market limits implies bubbles can occur*

Rational bubbles can occur if the number of traders is infinite (with overlapping generations of traders, for instance). Then the sum of net profits to the traders who remain after some traders depart, which is negative, is divided among an infinite number of traders so the average expected profit is zero; traders have no incentive to avoid the bubble (though they have no incentive to join it either).

Tirole (1985) showed that bubbles can occur in a model of an overlapping-generations economy like Diamond's (1965), if the long-run real interest rate is less than the rate of population growth. He concluded (p. 1093) that 'we would be best advised to believe that bubbles are not inconsistent with optimizing behavior and general equilibrium'.[16]

### 2.2.6. *Some kinds of near-rational bubbles*

Since the arguments above rule out rational bubbles under many conditions, but the empirical evidence reviewed below suggests bubbles do occur, it may be useful to speculate about 'near-rational' theories of bubbles (Tirole, 1982, p. 1180).

Even if the number of traders is finite, a rational bubble can occur if traders expect positive profit from participating in the bubble, even after the initial winning trader departs and leaves a negative-sum game. Expectations of positive profit are not rational because from the perspective of the theory, which is the perspective traders must take under rational expectations, each trader is equal, so each trader should expect an equal share of the negative-sum pie. However, people tend to be unrealistically optimistic about their relative status or ability[17] (including trading ability[18]). Optimism may be near-rational if it has psychological or biological value (Tiger, 1980; Alloy and Abramson, 1979) or if people simply prefer optimistic beliefs (Akerlof and Dickens, 1982). Optimism among a finite number of traders could cause a 'near-rational' bubble if each trader who remains after the first trader departs does not expect his or her profits to be negative (event though total profits must be negative).

Even without optimism, near-rational bubbles might occur if the limits on the scope of the market are not common knowledge (Aumann, 1976). (By analogy, in some finitely-repeated games backward induction rules out certain strategies as suboptimal if the game is commonly-known, but a lack of common knowledge can make those strategies rational. See Kreps *et al*, 1982.) For instance, suppose traders all know a bubble will eventually burst, because the asset's horizon is limited, for instance, but traders are not sure whether other traders know this. We can model this uncertainty by assuming each trader $i$ has a guess $T_i$ about how long the others think the bubble will last. (Under common knowledge, these $T_i$'s must all be zero.) It is reasonable for $i$ to hold the asset until just before $T_i$. But *some* unlucky trader, the one with the largest value of $T_i$, will be stuck with the asset when the bubble bursts. (Cf. Keynes, who called speculation 'a game of Snap, of Old Maid, or Musical Chairs', Keynes, 1936/1964, pp. 155–156.)

This simple model resembles a 'common-value auction', in which an item with a common value is auctioned to traders who have different guesses $V_i$ about what the common value is. With many bidders, the highest bidder is typically the bidder who has most overestimated the true value of the item; hence the celebrated 'winner's curse' (Wilson, 1977, Milgrom and Weber, 1982). The unlucky trader with the largest guess $T_i$ about how long the bubble will burst (call him the 'greater fool') is like the cursed winner with the largest $V_i$. Their common error is a failure to realize that their initial beliefs about $T_i$ (or $V_i$) should be conditioned on the fact that they have been allowed to hold the asset (or win the auction), and revised downward.[19] But this error seems to be difficult to unlearn: the winner's curse does not disappear with experience (Kagel and Levin, 1986). Near-rational 'greater fool bubbles', caused by the same error as the winner's curse, might therefore persist when the limits of the market (or traders' rationality, Arrow, 1982), are not commonly known.

Allen and Gorton (1988) provide an interesting example of how a lack of common knowledge about a market limit can allow rational bubbles. In their simple model, it is commonly known that there are three traders, with stochastic lifetimes, who can trade an asset with a finite lifetime. (The existence of only three traders and a finitely-lived asset should rule out bubbles, by the backward induction arguments in the last section.) However, traders cannot figure out whether there are other traders left when they contemplate buying the asset (because they don't know which traders bought the asset before them); rational bubbles can occur.

## 2.3 *Sunspots*

Arbitrary bubble paths in models of asset prices have a counterpart, called 'sunspots', in simple exchange models (see Cass and Shell, 1980; or Grandmont and Malgrange, 1986).

Consider a model in which agents are endowed with a utility function on consumption and with goods (or with labour that produces goods according to some technology). Imagine an extrinsic event, called a sunspot, which has two values ('sunspot' or 'no sunspot', for instance). Suppose sunspots do not affect agents' endowments, their utility functions, or the production technology, that is, sunspots don't affect any underlying variables in the simple economy. Several authors have shown that there are exchange equilibria in which goods prices *do* depend upon which value of the sunspot occurs, that is, sunspots *do* affect the economy. Equilibria in which sunspots matter may even be Pareto-dominated by equilibria in which sunspots are ignored, because risk-averse agents dislike the randomness introduced by sunspots.

Incompleteness in trading opportunities in markets is necessary for sunspots to matter: otherwise, agents can hedge against sunspot effects and those effects will disappear (e.g., Cass and Shell, 1983, proposition 3).

In Azariadis (1981) and Spear (1984), sunspots can matter because there are no markets for contingent claims on sunspots. (Peck, 1988, generalizes their results by allowing nonstationary fundamentals.) Even if markets are complete, sunspots can matter if agents can only trade in markets after they are born[20] (Cass and Shell, 1983). Woodford (1986) showed that even in an economy with infinitely-lived agents, sunspots can matter if agents can only finance spending from money or by borrowing against current capital, because such an economy behaves like an economy with overlapping generations of finitely-lived traders. Guesnerie (1986) extended the results of Azariadis and Guesnerie (1986) to an arbitrary finite number of commodities. Azariadis (1981, pp. 388–390) showed how likely sunspot equilibria might be.

Markets may never be complete enough to rule out sunspots because it is difficult to introduce enough contingent claims to span all the random events people might think are important (Cass, 1984; Azariadis, 1981, p. 394). Even if contingent claims markets are complete, Cass and Shell (1983) note that sunspots can matter if agents have different beliefs about the prior probability of sunspots.

Sunspot theories provide a formal basis for the Keynesian notion that business cycles might be caused by arbitrary, self-fulfilling beliefs (see Grandmont and Malgrange, 1986). Calculations in Woodford (1986, p. 135) suggest sunspot-induced business cycles are roughly the size of actual business cycles. Woodford (pp. 136–7) and Grandmont (1986) showed how government fiscal and budgetary policy can eliminate sunspots. Sunspot theories have not been directly applied to asset pricing, though the formal resemblance to rational growing bubbles is obvious (Tirole, 1985, footnote 22).

Widespread attention to money-supply figures or pronouncements of famous forecasters like Henry Kaufman (whose accuracy is suspect, see *Business Week*, 1983), could be sunspots. Traders often say they know these announcements contain no information, but they expect them to affect prices, and their beliefs are self-fulfilled. (Cass, 1984, called the overreaction of financial markets to unimportant news the 'leading example' of sunspot equilibrium.)

Even these examples may not be pure sunspots in which beliefs are entirely arbitrary. It is more likely that some traders mistakenly believed the sunspots *did* affect fundamentals and traded accordingly. Then other traders learned that sunspots affected prices; their latter belief persisted, fulfilling itself, even after the mistaken initial beliefs were corrected. (For instance, Kaufman had a remarkable record of predictions in the early 1980's; then he regressed toward the forecaster's mean and became a sunspot.)

Sunspot-type theories of goods prices should apply fairly directly to assets which yield streams of consumption (housing or art, for instance). The application might prove interesting since sunspots can exist in finite-horizon models (Cass, 1984) where growing bubbles cannot.

## 3. Rational growing bubbles: Evidence

### 3.1. *Direct estimates of growing bubbles*

In theory, one can estimate directly whether growing bubbles exist in a time series of asset prices by simply testing a specification which includes a growing bubble term. Flood and Garber (1980) were the first to do this, testing the joint hypothesis of deterministic bubbles and Cagan-type money demand (as a determinant of 'market fundamentals'), using data from the German hyperinflation of the 1920's. They accepted the no-bubble hypothesis at conventional levels.

One problem with their pioneering test is that results of asymptotic distribution theory do not apply when regressors are exponentially growing (as their hypothesized bubble was). The problem is reduced if a simultaneous bubble is estimated in data from several countries. Using data from Poland, Hungary, and Germany, Flood, Garber, and Scott (1984) rejected the no-bubble hypothesis by likelihood-ratio tests, but the results of t-tests were ambiguous (they depended on what value of the bubble coefficient was used to calculate the estimate standard error). Burmeister and Wall (1982) used Kalman filtering so that stochastic bubbles were permitted, and they strongly reject the no-bubble hypothesis.

Another problem with these tests is that money supply is assumed to be exogeneous in these tests, i.e. market fundamentals, controlled by government policy, are assumed to be independent of a bubble. Burmeister and Wall (1987) concluded that money supply growth was not exogeneous, but they still reject the no-bubble hypothesis with corrected tests.

Woo (1984), Okina (1985), and Borensztein (1987) estimated bubble terms directly in a portfolio balance model of exchange rates, using deutschemark-dollar, franc-dollar, and yen-dollar rates from the 1970's and 1980's. They found significant t-statistics on most bubble term coefficients, but their significance is somewhat overstated because starting points for bubble terms were chosen by looking at the data. (The test statistics may also be unreliable because of the growing regressor problem.)

Because of the statistical problem associated with direct estimates of explosive bubbles, West (1987) devised a robust specification test (as in Hausman, 1978).

Roughly speaking, West uses instrumental variables to estimate the discount rate $r$ in

$$P_t = (P_{t+1} + D_{t+1})/(1 + r) + u_{t+1} \tag{4}$$

where $P$ and $D$ are stock prices and dividends and $u$ is an error term. Then he estimates separately an autoregressive dividend process and a present-value relation,

$$D_t = dD_{t-t} + \varepsilon_t \tag{5}$$

$$P_t = gD_t \tag{6}$$

If prices are equal to the discounted dividend value, then some algebra on equations (5–6) implies a theoretical relationship between $g$, $d$, and $r$ (viz., $g = d/(1 + r - d)$).

If there is no bubble, then the estimates of the parameters $g$, $d$, and $r$ should satisfy the theoretical relationship (except for sampling error). If there is a bubble the first estimate of $r$ from (4) will still be 'consistent' (it approaches the true value of $r$ as the sample size gets larger), because a bubble satisfies the equilibrium condition underlying (4). But a bubble will make the estimated value of $g$ in (6) look much larger than it truly is (if the bubble is correlated with dividends), so the second estimate of $r$, calculated from the estimate of $g$, will be inconsistent. Therefore, if the two estimates of $r$ are different then there is evidence of bubbles.

Using stock prices, West (1987) found strong evidence that the estimates of $r$ were indeed different, suggesting the existence of a bubble that is correlated with dividends. Applying the same test to foreign exchange rates, Meese (1986) found evidence of bubbles in dollar-mark and dollar-pound exchange rates.

Flood, Hodrick, and Kaplan (1986b) gave a thoughtful critique of West's test. They note that a two-period version of (4) fits much more poorly than the one-period version, suggesting a slight misspecification that is compounded in longer intervals and which might account for the rejection of the no-bubble hypothesis in this test and others (see Section 5). They also found that the discount rate $r$ could be forecasted using lagged returns or dividend-price ratios (see also Keim and Stambaugh, 1986; Fama and French, 1987), suggesting West's assumption of a constant discount rate is wrong. West (1987, p. 577–578) said his assumption is adequate unless the discount rate can be forecasted using only lagged dividends. Further work on the forecastability of the discount rate is clearly needed.

### 3.2. *Indirect diagnostic tests*

While the direct tests for bubbles are ambitious and clever, one must necessarily test the joint hypothesis that a bubble exists along with some model of intrinsic value. Any apparent bubble could be evidence of a variable which affects intrinsic value but is not observed by the econometrician (Hamilton and Whiteman, 1985; Hamilton 1985).

For example, Flood and Hodrick (1986a) gave a theoretical example of price changes, in anticipation of a switch in the process generating intrinsic value, which look exactly like a growing bubble.[21] This difficult identification problem can be circumvented if bubbles have common statistical properties that do not depend on the specification of market fundamentals that underly intrinsic value.

Hamilton and Whiteman (1985) and Diba and Grossman (1982) noted that deterministic rational bubbles must grow exponentially, and no amount of differencing of an exponentially-growing time series will make the series stationary. If it takes $N$ differences to make the time series of market fundamentals stationary, then if prices contain a bubble the price series will still be non-stationary when differenced $N$ times. (However, Quah, 1985, and Meese, 1986, Table 1, showed that a stochastic bubble can look stationary so the differencing test will not detect stochastic bubbles.) Diba and Grossman (1985) found that stock prices and dividends were both stationary when differenced once, thus ruling out the possibility that a deterministic bubble existed throughout their sample. Meese (1986) found that exchange rates were less stationary than market fundamentals (relative money supplies and relative real incomes), suggesting presence of a bubble. He also tested for 'cointegration' (Granger and Engle, 1987), i.e. stationarity of a linear combination of two or more time series. If bubbles exist, the fundamentals and price series will not be cointegrated. They were not.

Simpler diagnostic tests might be used to look for bubbles. (However, their statistical power is limited: even if bubbles exist, these tests might not detect them.) For instance, bubbles will cause price changes to have fewer 'runs' than if they were random. Insufficient runs (or positive autocorrelation) were indeed observed by Huang (1981), Okina (1985), Cheung (1986), and Evans (1986) in foreign exchange rates, and Hood *et al* (1985), Lo and MacKinlay (1988) in recent stock prices; but Blanchard and Watson (1982) found the expected number of runs in gold prices.

Since bubbles will cause some extremely large positive price changes as they grow (especially during the last stages of bubble growth), and even larger negative price changes when they burst, the distribution of price changes will have negative skewness and large kurtosis if bubbles exist.[22] Large kurtosis was reported by Friedman and Vandersteel (1982) and Okina (1985) for foreign exchange rates, Dusak (1973) for commodity futures prices, Fama (1976, Chapter 1) for stock prices, and Blanchard and Watson (1982) for gold prices.

Evans (1986) defined a bubble as a nonzero median in the distribution of price changes, and he found such a bubble in dollar-pound exchange rates from the 1980's. (Okina, 1985, reported skewness in exchange rate changes too.) Evans also corrected the statistical significance of his findings for deliberate 'data mining' (the selection of a period to test for a bubble *after* observing the data); his correction could be usefully applied in many other studies.

These diagnostic tests for growing bubbles are inconclusive for a lot of reasons. Autocorrelation, kurtosis, or a non-zero median in a price series could be due to the market fundamentals having those statistical properties, rather than to a bubble (e.g., Evans, 1986). Tests of stationarity can detect deterministic bubbles but not stochastic ones. Short-lived stochastic bubbles will be missed entirely if prices are not sampled frequently. Despite their limits, diagnostic tests are easy, and they may prove useful in future work for determining whether more definitive tests are worth conducting.

### 3.3. *Experimental evidence*

Mistaking an incorrect specification of intrinsic value for a bubble can be avoided in an experiment in which intrinsic values are controlled. The benefits of control are not without cost, however, since generalizing from experiments to natural settings is always a matter of debate.

In the 28 experiments of Smith, Suchanek, and Williams (1988), subjects traded an asset which lived for 15 periods and paid a random dividend (which was identical for all traders) to whomever held the asset at the end of each of the 15 periods. Since the asset expired with a liquidation value, its intrinsic value in period $T$ of the experiment was its expected liquidation value plus the stream of $15\text{-}T$ periods of expected dividends (assuming risk-neutrality).

In most experiments prices spiraled well above the intrinsic value in temporary bubbles that crashed in the last few periods. Crashes occurred earlier and earlier when experienced subjects participated in further experiments. Since the asset had a finite horizon (and subjects knew this), these were not rational bubbles. They seem to be near-rational bubbles caused by optimism or 'greater fool' type uncertainty about other traders. In the 12 experiments of Camerer and Weigelt (1987), subjects traded an asset which paid a dividend $D$ each period, and which lived from period to period with a known probability (based on drawings with replacement from a public bingo cage). If subjects were risk-neutral the probability that the asset lives after each period, $p$, functioned like a discount rate: $P_t$ should equal $D + pE(P_{t+1})$, so rational bubbles can occur (and must grow at the rate $1/p$ on average).

Generally, prices converged slowly to the intrinsic value. In one experiment prices grew exponentially at roughly the predicted rate $1/p$, and ex-ante price forecasts gathered from subjects showed that subjects predicted the growth in prices (i.e., their expectations were rational). That experiment is as close to a rational bubble as one can imagine. After the experiment, Camerer and Weigelt discovered that the subjects had been in earlier market experiments in which the prices of a series of one-period assets rose in a steady inflation (because the experimenter shifted out demand and supply curves by a fixed percentage each period). Their beliefs about the growing bubble in prices were induced by previous experience, and were self-fulfilling.[23]

## 4. Fads: Theory

Prices might drift away from intrinsic values because social forces create fads or fashions in asset markets, as in markets for cars, food, houses, and entertainment. Theories of fads have a long oral history among practitioners and social scientists, especially non-economists. Interest in fads among economists has been rekindled by the controversial research of excessive volatility in asset prices, described below in section 5.

We can define a fad as a deviation between prices and intrinsic value, $F_t$, that slowly reverts to its mean of zero (Shiller and Perron, 1985; Summers, 1986; Lo and MacKinlay, 1988), as in

$$P_t = \sum_{i=1}^{\infty} E(D_{t+i})/(1+r)^i + F_t \tag{7}$$

with

$$F_{t+1} = CF_t + e_t$$

where $C$ is a parameter measuring the speed of convergence or decay of the fad (and $e_t$ is a zero-mean, independent error term). If $C = 0$ any fads disappear immediately. If $C = 1 + r$ the fad is a rational growing bubble as described in the last two sections. Fads are not rational because (7) does not satisfy the equilibrium condition if $C$ is less than one (since the expected return on the faddish part of the price will be less than $r$ and investors should sell assets, making the fad disappear). However, if $C$ is close to one, the fad may be so slow to decay that investors cannot easily profit by betting on it to disappear.

### 4.1. *Fads in utilities, beliefs, and returns*

Most of the debate about fads is purely empirical. In future work it may be useful to distinguish three types of fads theoretically, depending upon where faddishness is located in the discounted dividend model of stock prices.

First, prices may fluctuate because the utility people get from holding assets varies over time, as if their psychic dividends are some function $F_u(D_t)$. Collectibles are an example (artwork, for instance), since their utility seems to vary with cultural norms of taste.

Second, prices may fluctuate because of mass changes in beliefs about future intrinsic value (the fad creates a term $F_u[E(D_{t+1})]$ in the price equation) as in informal theories of 'zeitgeist' or 'market psychology'.[24] Examples of belief fads might include the South Sea (Mackay, 1932/1974; Schachter, *et al*, 1986a), or Mississippi bubbles (Thiers, 1859/1969), driven by unrealistic beliefs about the prospects of English companies given exclusive rights to do business in those regions. Modern examples are the stock of Resorts International, which boomed when Atlantic City casinos opened and crashed when profit expectations proved too optimistic (e.g., Dreman, 1982: 84–85), or prices of high-technology stocks which soar when investors mistake scientific breakthroughs for financial breakthroughs (Arrow, 1982). (Of course, calling these beliefs faddish after the fact is unfair. But extreme historical examples might be useful in suggesting theories that predict future fads.)

Third, prices might fluctuate because of fads in expected returns (as if some function $F_r(r)$ replaces the discount rate $r$). Indeed, since changes in expected returns are largely unrestricted by models of rational behavior, returns fads can be rational (or might represent fluctuations in perceptions of risk caused by cognitive errors or social forces; see De Bondt and Thaler, 1989, pp. 198–199).

In principle, empirical tests can distinguish between types of fads. Lo and MacKinlay (1988) distinguished between returns fads and fads in prices (i.e., fads in utilities of beliefs) in stock price data. Hypothesis about propensities of each type of fad in different assets, time periods, or markets can be tested.[25] Distinguishing between types of fads might also be useful in choosing a bundle of social sciences outside economics to help explain any observed fads[26], or in suggesting policy tools if fads are undesirable. (Belief fads might respond to policies that change the cost of information, while utility fads respond to taxes.)

### 4.2. *Coordination motives and rational fads*

Notice that locating faddishness in utilities or returns implies that fads are utility-maximizing, and hence rational (though belief fads are not rational). Another way to rationalize fads is suggested by a famous analogy of Keynes (1936/1964, p. 156). Investment is like a beauty contest in which the winner is the person whose choice is most like the average choice. This analogy is misleading as a model of investment because the beauty contest is clearly a game of coordination: the objective is to do what others do. Investment requires doing today what others will do tomorrow, which is not the same as coordination.

However, beauty contest-type fads may persist if there is some institutional or psychological incentive for traders to coordinate their actions. For instance, clients often judge professional investors by the returns they earn *relative* to returns of competing professionals (*Wall Street Journal*, 1986; Friedman, 1984, p. 508). Portfolio managers are often fired if their short-term performance is worse than overall market performance, which dulls the appetite for the speculation necessary to destroy fads. If risk-averse professionals seek to minimize the variance of their relative performance by trading as others do, then investment is a coordination game, the beauty contest is an apt analogy, and fads may persist because betting against them increases relative performance risk.

Note that for professionals facing performance risk, participating in a fad may be utility-maximizing. The irrationality comes from clients who are too quick to change money managers based on small samples of return data (see Denton, 1985).

Individual investors who are not professionals will also participate in a fad if they have a taste for conformity or if they care about their relative status and are averse toward status risks (cf. Easterlin, 1973; Frank, 1986).

## 5. Fads: Evidence

Much of the evidence for fads comes from tests of whether asset prices are too variable to be rational forecasts of future intrinsic values.

### 5.1. *Tests of excess volatility of asset prices*

Searches for alternative tests of the rationality of asset markets have spawned a rich and contentious literature on price variance tests. Papers with useful overviews include Leroy (1984), Shiller (1984), Kleidon (1986b), Merton (1987), and West (1988b).

Variance tests are useful because traditional tests of 'market efficiency' (can information be used to earn excess returns?) are not very powerful for detecting long-lasting departures from rationality (Summers, 1986). Increasing the amount of data, by using daily rather than monthly observations for instance, does not help because the number of years the data span is what matters when testing for fads (Shiller and Perron, 1985). Variance tests are also better than conventional regression tests when data are 'misaligned' — when the sample of available stock prices are implicitly forecasting actual dividends which are not available, for instance (Shiller, 1981b, Section V).

The basic idea of a 'variance inequality' or 'variance bounds' test is simple. Suppose today's asset price $p_t$ is an unbiased forecast of the perfect foresight price $p_t$. Then

$$p_t^* = p_t + e_t \tag{7}$$

where $e_t$ is an error term. A lack of bias implies that $E(p_t^* \mid p_t)$ is simply $p_t$, or by implication of (7), $E(e_t \mid p_t) = 0$. (That is, we expect forecast errors to be unrelated to price levels.) Thus, $p_t$ and $e_t$ should be uncorrelated. If they were positively correlated, for example, then when prices were high $e_t$ would be high, so we would know prices were higher than the perfect foresight price and we could profit by selling assets. If $p_t$ and $e_t$ are uncorrelated in (7), then by taking variances of all variables, denoted $V(x)$ (and recalling that $V(x) = V(-x)$), we see that

$$V(p_t) + V(e_t) = V(p_t^*) \tag{8}$$

Since variances must be positive, this equation implies an inequality involving variances,

$$V(p_t) < V(p_t^*) \tag{9}$$

Actual prices should vary less than the perfect foresight prices do, because a good forecast should be regressive (less volatile) compared to the variable being forecasted. If forecasts of snowfall or election results have some accuracy but vary more wildly than actual snowfall or results, then we know the forecasts overreact (or 'overpredict') the events being forecasted.

Present-value relations give rise to variance inequalities like (9) to test the discounted dividend theory of stock prices, the expectations theory of interest rate term structure (do long-term bond returns equal the geometric average of short-term returns? see Shiller, 1979; Singleton, 1980), theories relating preferred stock dividend yields and interest rates (Amsler, 1980) and foreign exchange rates and money stock differentials (Huang, 1981; Meese and Singleton, 1981), and the permanent income hypothesis (Campbell and Deaton, 1987).

### 5.1.1. *Initial results*

To test the variance relation (9) for stocks, researchers compared the variance of stock prices (typically using annual data beginning in 1871) to the variance of a perfect foresight price (or ex post intrinsic value) constructed from historically realized dividends, assuming a constant discount rate. Initial studies showed that prices of stocks were vastly more variable then the perfect foresight price (see Leroy and Porter, 1981; Shiler, 1981a,b; Blanchard and Watson, 1982, pp. 13–19). The ratio of the sample standard deviations of $p_t$ and $p_t^*$ were around 5 to 1 (though (9) implies they should have been less than 1). Results with bonds and exchange rates generally showed excessive volatility too.

### 5.1.2. *Methodological problems*

Despite the quick acceptance of findings of excessive volatility by many economists (e.g., Arrow, 1982; Ackley, 1983; Tobin, 1984), many researchers felt the rejections of rationality must be due to some flaws in the tests. They found several methodological reasons why (9) might be violated even if prices were rational forecasts of the perfect foresight price:

(1) Prices should not necessarily equal the perfect foresight price if people are risk-averse (e.g., Leroy, 1982). Stock prices are also more volatile under risk-aversion than under risk-neutrality, so risk-aversion could conceivably account for the observed volatility of prices (Leroy and LaCivita, 1981; Michener, 1982; Flood, Hodrick and Kaplan, 1986b). Grossman and Shiller (1981) addressed this problem by correcting discount rates for risk-aversion, using a specific model of consumption risk (Breeden, 1979). (They effectively tested a specific model of returns fads.) After their correction, the perfect foresight price series $p_t^*$ is indeed closer to the stock price series $p_t$ until 1950, but after 1950 $p_t$ is still too volatile compared to $p_t^*$. However, Shiller (1986b, p. 502) guessed that there is still an 'element of truth' to the returns fads explanation.

Note that time-varying changes in expected returns (perhaps due to risk-aversion and variation in consumption) do not make actual prices deviate from the perfect foresight price. Instead they make the perfect foresight price calculated from a constant-return model (the $p_t^*$ above) deviate from the true perfect foresight price. If prices are equal to the *true* $p_t^*$ then they will look like they are deviating from the *calculated* $p_t^*$ intrinsic value.

(2) Flavin (1983) and Kleidon (1986a) independently noted that with small samples of data (even 100 annual observations), variance inequalities could be violated even if forecasts were rational because of small-sample bias in estimating variances.[27] However, the degree of bias seems too small to explain the large violations of the variance inequality (e.g., Shiller, 1985).

(3) If the time series of dividends or prices are non-stationary (like a random walk, for instance), then population variances simply do not exist (Kleidon, 1986b,c); the variance inequality is meaningless. Sample variances can be calculated so the inequality (9) can be tested, but it will often be violated, even

if prices are rational estimates of the perfect foresight price. (Marsh and Merton, 1986, showed that (9) is always violated for a non-stationary managerial smoothing model of dividends as in Lintner, 1956, assuming the terminal $p_t^*$ is set equal to the final price $p_t$.)

Whether dividends are stationary or not is thus a crucial empirical question, which is controversial and unresolved.[28] But even if dividends are non-stationary and prices are rational (so that (9) will be falsely violated), it may be unlikely that variance ratios would be as large as those Shiller and others observed. Simulation results showed that if a 5% discount rate is used, results as extreme as Shiller's could be obtained 40% of the time; with a 6.5% rate (as in Shiller 1981a), extreme results could occur 15% of the time (Kleidon, 1986b, p. S486; Shiller, 1986b, p. 502). Since the extremity of the findings could conceivably be accounted for by non-stationarity, whether dividends are non-stationary remains an important question.

(4) Kleidon (1986b,c) and Leroy (1984, pp. 185–6) pointed out that the most striking evidence in Shiller's tests is the choppiness of stock prices: prices lurch erratically from one year to the next, while the perfect foresight series chugs smoothly along. It seems that the *conditional* variance of prices is greater than that of intrinsic values i.e. $V(p_{t+n}/p_t)$ is greater than $V(p_{t+n}^*/p_t^*)$. They showed that even if prices are rational forecasts, so the inequality of unconditional variances in (9) holds, for small values of $n$ the conditional variances will be reversed ($V(p_{t+n}/p_t)$ *should be* greater than $V(p_{t+n}^*/p_t^*)$. Shiller (1979, 1986a, p. S504) conceded this point, but it does not change his conclusions about the results of (9).

(5) Shiller (1981b, pp. 299–300) pointed out if prices fluctuated wildly in anticipation of some extremely rare event that would change dividends drastically (e.g., world war or economic collapse), but that event didn't occur in a small sample of 100 years of data, prices might appear to be fluctuating irrationally. (This is called the 'peso problem'.) However, Shiller found that the magnitude of event probability that would be needed to explain the volatility of prices was unreasonably high.

### 5.1.3. *Recent results*

Three recent studies were designed to address most of the methodological problems above (especially the problem caused by dividend non-stationarity). I shall review them in some detail because they constitute the state of the art in this controversial literature.

Mankiw, Romer, and Shapiro (19850 began with the identity

$$p_t^* - p_t^0 = (p_t^* - p_t) + (p_t - p_t^0) \tag{10}$$

where $p_t^0$ is a price based on any naive forecast of dividends. (They used the myopic forecast $E(D_{t+1}) = D_{t-1}$.) If stock prices are rational forecasts of $p_t^*$, the error term $p_t^* - p_t$ (from the right hand side of (10)) should be uncorrelated with the naive forecast error $p_t - p_t^0$ (also on the right hand side of (10)). If the two errors were correlated, it would imply that there was information in the difference between $p_t^0$ and $p_t$ that enabled the market to forecast $p^*{}_t$ more accurately, an obvious violation of rationality. Since the two terms on the right hand side of (10) are uncorrelated, taking variances in (10) implies two variance inequalities,

$$V(p_t^* - p_t^0) > (V(p_t^* - p_t) \tag{11}$$

$$V(p_t^* - p^0{}_t) > V(p_t - p_t^0) \tag{12}$$

Note that non-stationarity of dividends is not a problem for this test, because the variances of $p_t^*$ and $p_t$ are taken around $p_t^0$ rather than around their sample means; the variances in (11) and (12) will exist even if $V(p_t)$ and $V(p_t^*)$ do not exist.

Mankiw, Romer, and Shapiro found that (11) was violated for all reasonable discount rates, but (12) was not violated for low discount rates (especially when corrected for heteroskedasticity). It appears that the naive forecast $p_t^0$ predicts the perfect foresight price $p_t^*$ better than actual stock prices $p_t$ do, suggesting that actual prices contain volatile fads or irrational estimates of future dividends.

West's (1988a) test was similar. Denote the expected discounted dividend value by $X_t$. (This is the ex ante counterpart of the ex post price $p_t^*$.) Let $I_t$ denote a set of information available to the market, and $H_t$ a subset of $I_t$. West proved that

$$E[(x_t - E(X_t \mid H_{t-1}))^2] > E[(p_t - E(p_t \mid I_{t-1}))^2] \tag{13}$$

That is, the market's forecast of future prices (on the right hand side) should be more accurate, or have lower variance, than a naive forecast of expected discounted dividend value which uses less information (on the left hand side). If the variance inequality (13) is violated, it suggests there is some unexpected change in prices (like a fad or bubble) that is unrelated to expected changes in a simple model of intrinsic value. Notice that (13) does not require construction of a perfect foresight price $p_t^*$ as earlier tests do.

Using past dividends for $H_t$, West found that (13) was badly violated (the right hand side term was much larger than the left hand side term). West (1986) also applied this test to Meese's data on foreign exchange rates (described in Section 3 above) and concluded that exchange rates were not excessively volatile, the opposite of Meese's conclusion that bubbles existed.[29]

Mattey and Meese (1986) studied the econometric properties of 24 test statistics, including those used by Mankiw *et al* and West, in excruciating detail. They find evidence of excessive volatility (compared to a constant discount rate model) and they lean toward the explanation that discount rates vary in time.

Campbell and Shiller (1987) conducted vector autoregression (VAR) tests of the discounted dividend model. VAR's are useful because they give a measure of economic significance of deviations from rationality, they yield implicit variance inequality tests, and they are robust to non-stationarity in prices or dividends. They use results from the theory of cointegration (Engle and Granger, 1987) to correct problems in the VAR when it is applied to stationary first differences in prices or dividends. Using a constant discount rate of 8.2%, they found large violations of the discounted dividend model, but violations were much smaller with a 3.2% rate. Campbell and Shiller also ran regressions of $p_t^*$ against $p_t$. If prices anticipate future dividends rationally, the regression coefficients should be 1 but they were actually close to 0 for stocks, and 0.8 for bonds (Scott, 1985, found similar results).

### 5.1.4. *Methodological problems*

There are two kinds of objections to the results of these three recent tests (and to the earlier tests as well).

(1) It is difficult to judge the statistical significance of the variance inequality violations. Merton (1987) showed for a simple case that the standard deviation of Mankiw, Romer, and Shapiro's test statistic grows faster than the test statistic does, without bound, as the sample period increases. Therefore, we cannot draw any conclusions about statistical significance of their results. Campbell and Shiller (1987) estimated the standard errors of the variances in their variance inequality test, and they were quite large. West (1988a) estimated significance by simulation. He found that results as extreme as those he observed were very unlikely if stock prices were rational, so his results appear to be significant.

(2) The observed excess volatility could be due to variation in discount rates. (This possibility looms large as an alternative explanation to all evidence of fads, and will probably be the appropriate focus of much future research.) However, to explain the degree of volatility he observed Shiller (1981a) estimated that the annual standard deviation of real interest rates would have to be about 5%; West estimated that the standard deviation of expected returns would have to be 12%. This estimates seem implausibly high (Conrad and Kaul, 1988, report expected return standard deviations around 2%) but without a theoretical model to compare them to, the issue is unresolved.

Shiller (1986b, p. 502) also noted that some changes in discount rates should affect bonds, housing, and stocks simultaneously; but the prices of those assets do not seem to move together.

### 5.1.5. *Messages in the entrails*

Two conclusions emerge from the combative debate about variance inequalities: (i) Stock prices do fluctuate more than perfect foresight prices (calculated with constant discount rates), as if prices consist of rational expectations of perfect foresight prices *and* mean-reverting fads; and (ii) prices might appear to fluctuate excessively even if they were rational, because of small-sample bias, non-stationarity of dividends, or variation in discount rates. Marsh and Merton (1986) thus concluded that the null hypothesis of rationality was not rejected (the case for irrationality was 'unproven'). Shiller (1986a) concluded that the null hypothesis of irrationality was not rejected either.[30]

The conclusion to be drawn from the data obviously depends upon the choice of null hypothesis. Believers in rationality argue that taking fads to be the null hypothesis 'has the potential to destroy much of 2 decades of knowledge of stock prices' (Kleidon, 1986b, p. S492).[31] But unpredictable fads are *consistent* with the decades of previous research. If prices are always equal to rational expectations of future dividend streams (discounted at a constant rate), then prices will only change with the arrival of new information, unpredictably (Samuelson, 1965). Rationality of prices therefore implies unpredictability of price changes; the studies of 'market efficiency' that Kleidon alluded to do provide ample evidence of unpredictability (e.g., Fama, 1970, 1976).

However, unpredictability does not necessarily imply rationality. Prices could be unpredictable if all information is incorporated in prices *and* prices are affected by an unpredictable fad component (e.g., Friedman, 1984). By analogy, imagine a baseball crowd that cheers every hit, and unpredictably bursts into fads of random cheering or silence. We can accept the hypothesis that hits cause cheers even though some cheers are not caused by hits.

In the same way, we can accept the hypothesis that information is efficiently incorporated into prices while also believing that prices are sometimes driven by fads (provided the fads are unpredictable).

Even if fads are somewhat predictable, the degree of market inefficiency they produce, as measured by annual excess returns from betting on the fad to end for instance, may be no larger than other apparent violations of inefficiency, like the tendency of small firms to earn excess returns early in January (Keim, 1983), or the tendency of firms that have lost market value to 'bounce back' early in January (deBondt and Thaler, 1989). Shiller (1986a, p. S502) lamented that economists who mention fads 'are viewed as if they were bringing up astrology or extrasensory perception'. His plea is simply for fads to be discussed, scientifically. It is certainly too early to reject the null hypothesis of rationality, but it may not be too early to take faddish irrationality as a null hypothesis and design tests to reject it.

### 5.2. *Beliefs fads in overreactions to individual stocks*

Evidence that stock prices overreact in belief fads comes from studies with individual stocks, by de Bondt and Thaler (1985, 1987). They found that stocks with the largest price declines ('losers') bounced back and earned positive excess returns, and stocks with the largest price increase ('winners') earned negative returns. Their basic results have been replicated with American and foreign data (see De Bondt, forthcoming, and De Bondt and Thaler, 1989, for reviews).

Some of the losers are firms that have lost value so they are small in market value, and most of their excess return occurs in January. Therefore, the performance of loser firms is related to the general finding that small firms earn bigger returns than larger firms in January (Keim, 1983), though the loser effect is not entirely explained by the small-firm effect (De Bondt and Thaler, 1987; cf. Zarowin, 1988). It is also possible that apparent excess returns of losers are caused by underestimates of their risk (Chan, 1988).

The small-firm and changing-risk explanations aside, De Bondt and Thaler conclude that investors act as if surprisingly low or high earnings are permanent, but extreme earnings actually tend to regress to the mean (Brooks and

Buckmaster, 1976). The human tendency to overreact to data that are statistically imperfect, or to be surprised by regression, has been documented in many other settings by psychologists (see Kahneman, Slovic, and Tversky, 1982). (Indeed, the psychologists' evidence was the basis on which De Bondt and Thaler predicted the anomaly they found.)

There is lots of other evidence of short-term reversals (i.e., negative autocorrelation) in returns (e.g., Lehmann, 1988). These reversals are important because it is unlikely that risk changes enough in a day or a week to explain the reversals. See De Bondt and Thaler's (1989) review for more details.

### 5.3. *Tests of stationarity in asset prices*

If stock prices are rational forecasts, price changes should have a constant conditional mean (which implies independence), and prices should follow a martingale (of which a non-stationary random walk is a special kind). If prices changes are not independent, prices are driven by fads (or by variation in expected returns).

Early studies tested whether prices were non-stationary by conducting runs tests or examining autocorrelation of price changes. These tests concluded that changes were independent (so prices are a random walk), but the early tests were not powerful for detecting small degrees of dependence. Recent tests, using the ratios of price variances over long and short holding periods, are more powerful.

If changes are independent, then the variance of changes over an $N$-month period will equal $N$ times the one-month variance. However, if there is a slight degree of negative (or positive) autocorrelation in changes, then the $N$-month variance will be less (or more) than $N$ times the one-month variance. These tests deliberately use coarsely-sampled data, taking four-month changes, for instance, even though daily data are available, because if a time series departs slightly from a random walk, that departure is better detected by sampling changes between points far apart in time than by sampling points which are close together.

From variance ratios and autocorrelations, Fama and French (1988a) and Lo and MacKinlay (1988) conclude that there is slight positive autocorrelation in short-term U.S. stock price changes, and slight negative autocorrelation in long-term changes. Poterba and Summers (1988) replicated these results with data from the U.S. and 17 other countries. Stock prices do not follow a random walk.

As with excess volatility tests, these results could be explained by changes in expected returns. Indeed, Lo and MacKinley (1988) conclude that their data are distinct evidence of fads in returns rather than fads in prices.[32] Keim and Stambaugh (1986) also found that stock and bond returns could be partially predicted by observable variables, suggesting predictable variation that might be the basis of returns fads.

### 5.4. *Distinguishing between fads and bubbles*

In the theory section 2 and 4, a distinction was drawn between rational growing bubbles and irrational fads. *Both* could exist: simply add the bubble term in (3) to the fad model (7): but they are distinct phenomena which are often confused or deliberately combined.[33] Part of the confusion is empirical: if stochastic bubbles do not live long enough to grow large they look a lot like fads (Meese, 1986, gives simulated examples in his Table 1). Direct estimation and diagnostic tests for bubbles are probably not very powerful at distinguishing between bubbles and fads (called 'near bubbles' by West, 1986).

Since growing bubbles are rational and fads are not, it is natural to wonder whether the apparent excess volatility in stock prices could be due to rational bubbles (e.g., Fishcer, 1984; Kleidon, 1986b, pp. S493–494; Merton, 1987; Stambaugh, 1986). However, bubbles seem an unlikely explanation for several reasons. Mankiw, Romer, and Shapiro (1985, p. 681) and Flood and Hodrick (1986) pointed out that most variance inequality results use the actual stock price in the last year of the sample as a proxy for the perfect foresight price (since future dividends are not known, so an ex post perfect foresight price cannot be calculated). A price bubble at the end of the sample will therefore affect both the actual price and the (assumed) perfect foresight price, so a bubble will not make actual prices appear more volatile than the perfect foresight price. (However, bubbles will cause excessive volatility if they exist early in the sample and burst before the end.)

Shiller (1981b, p. 294) also noted that the dividend-to-price ratio 'shows no particular trend' in his data, while the bubble model predicts this ratio will fall as prices grow exponentially away from dividends. Shiller (1979) also found excessive volatility in bond returns; but bonds are finitely-lived assets which cannot exhibit rational bubbles, by backward induction. Campbell and Shiller's (1987) test explicitly ruled out bubbles because differences of stock prices and dividends are assumed to be stationary (and they will not be stationary if bubbles exist). Finally, rational bubbles cannot be negative, while casual evidence from asset markets (and graphs of $p_t$ against $p_t^*$) suggests fads of asset underpricing do occur.

So fads, not rational bubbles, probably account for any excess volatility in stock prices. Nonetheless, further efforts to distinguish bubbles and fads empirically could be useful because the causes underlying them are different.

## 6. Information bubbles: Theory and evidence

When traders have different information or different models of their economic world, it is possible for prices to deviate from intrinsic value (based on their pooled information) in what we might call "information bubbles". Of course, such deviations can be perfectly rational[34] but they may not be.

### 6.1. *Agents have different information: Theory*

Since the intrinsic value of an asset is its value conditioned on information available to *all* traders, if prices do not reveal all information then prices deviate from intrinsic value and an information bubble exists.

The earliest work on whether prices aggregate information showed that prices could completely aggregate (or 'fully reveal') information, in theory (Kihlstrom and Mirman, 1975; Grossman, 1976; Grossman and Stiglitz, 1980). Prices reveal information because uninformed traders can learn what insiders know, if they know the relationship between information and prices, by observing prices and using Bayes' rule to infer what information caused those prices.

Unfortunately, prices that perfectly aggregate information are paradoxical, because if prices reveal all information then traders have no incentive to invest in information-gathering. There are several ways to resolve this paradox, and most of these ways suggest that prices will depart from intrinsic value, in information bubbles (which are typically temporary, and possibly small in size).

One resolution of the paradox is to suppose that some source of noise, like liquidity-motivated trading, muddies the waters of the market so that information and prices are not perfectly linked and prices do not reveal information perfectly (see Hellwig, 1980; and Diamond and Verrechia, 1981).

Another resolution of the paradox comes from modelling the process by which prices reveal information. In the fully-revealing models price-setting is Walrasian, so traders are allowed to observe *hypothetical* prices and infer information from those prices without actually trading. In a more realistic model, early trades which reveal information are actually consummated (Dubey, Geanakoplos, Shubik, 1987; Kyle, 1985). Traders have an incentive to gather information because early trades are profitable. Since early trades do not reflect the aggregation of information, they contain information bubbles. In a similar model, Friedman and Aoki (1986) show that noise and sluggishness in the process of changing beliefs can cause prices to depart from true value temporarily. Their 'overshooting bubbles' have momentum: an increase in the bubble is more likely to be followed by another increase than by a decrease: but departures are self-limiting because the probability of a reversal increases as the departure grows larger.

A specific kind of information bubble might arise when no trader has any information, but traders do not know that nobody has any information. Noisy trades may spark erroneous inferences of information from prices, which lead to further disequilibrium trading by traders who think they have learned something from prices, which leads to more erroneous inferences, and so on. Traders may end up thinking they have inferred inside information, even if there is no information to infer! Camerer and Weigelt (1988) call these information bubbles 'mirages', because people think they see information which is not there.

### 6.2. *Agents have different information: Evidence*

#### 6.2.1. *Asset price responses to inflation news*

Information bubbles are difficult to detect in natural data because researchers usually do not know what information traders had at any point in time, so it is difficult to know whether prices incorporate all information or not. In one clever test, Schwert (1981) and Huberman and Schwert (1985) tested whether bond and stock prices responded to public announcements of the Consumer Price Index (CPI). It is well known that stock and bond prices are affected by unexpected inflation (e.g., Fama, 1981). Since all the price observations used to construct the CPI 'market basket' are publicly observable before the announcement of the CPI, in theory prices could aggregate the information in the CPI before the announcement is made. They found that prices were somewhat affected by the announcement, so information was not completely aggregated (though most of the information was anticipated).

### 6.2.2. *Excess trading-hour volatility*

Oldfield and Rogalski (1980), French and Roll (1986), and others have found that asset prices are much more volatile during trading hours than during non-trading hours, suggesting the existence of information bubbles. The ratio of per-hour trading-hour volatility to per-hour weekend volatility, for instance, is about 70 to 1. Of course, more news is announced during trading hours than during non-trading hours, but the difference between trading-hour and non-trading hour volatilities seems too large to be explained purely by the difference in the amount of news. Trading-hour volatility is also high in the orange juice futures market, which is highly dependent on weather that is 'announced' at night when the market is closed.

Perhaps the most convincing data are from weeks in 1968 when the exchanges were closed on Wednesdays due to a paperwork backlog. Assuming the same amount of news was generated on these closed Wednesdays as on Wednesdays when the market was open, the weekly variances of price changes should be about the same in closed-Wednesday weeks and open-Wednesday weeks. But closed-Wednesday weeks actually have about 83% as much variance as open-Wednesday weeks, suggesting the number of days the exchange is open is the most important determinant of volatility. One bit of evidence for the theory that news generates volatility comes from dollar-yen exchange rates in American markets, where the ratio of trading-hour to non-trading-hour volatility is only 3 to 1 (Meese, 1986, p. 347). That low ratio suggests a lot of volatility occurs during non-trading-hours because of Japanese news that is announced when American markets are closed. French and Roll (1984) suggest trading-hour volatility might be high because trading is 'self-generating': observed trades lead to further trades, creating 'mini-speculative bubbles'. The fact that these mini-bubbles seem to occur disproportionality during hours when traders can observe each other suggests they are information bubbles (mirages, perhaps, or the overshooting bubbles of Friedman and Aoki (1986)) or short-lived fads, rather than rational growing bubbles. The fact that price movements of individual stocks are only weakly related to market movements, *even on days when idiosyncratic news events are excluded* (Roll, 1988), is consistent with this view.

### 6.2.3. *Experiments on information aggregation*

Asset market reactions to CPI news and evidence of excessive trading-hour volatility are only indirect evidence of information bubbles, since we are never quite certain what information is available to whom in natural markets. Therefore, experiments are a fruitful source of evidence about information bubbles because the information that traders have can be controlled. In most experiments prices aggregate information well: after several trading periods of experience, there are usually no information bubbles (or they vanish quickly, in a minute or less after information is released). See Plott and Sunder (1982), Friedman, Harrison, and Salmon (1984). Banks (1985), Copeland and Friedman (1986).

Plott and Sunder (1988) found many information bubbles in markets with three states (call them *X*, *Y*, and *Z*) in which some traders got information of the form '*X* or *Y*' and others learned '*Y* or *Z*'. Since the traders' information is individually imperfect but collectively perfect, prices should fully reveal the state, but did not. However, Forsythe and Lundholm (1986) found that information bubbles disappeared in the Plott-Sunder setting when there were more traders and more trading periods. Camerer and Chernew (1988) found that information bubbles disappeared if some traders were told '*X* or *Y*' in the beginning of a trading period and others were told '*Y* or *Z*' in the middle of a trading period.

In experiments designed to test for information mirages, Sunder (1988) found several mirages, Camerer and Weigelt (1988) found a few mirages (though their incidence diminished quickly with trader experience), and Ang and Schwarz (1985) found no mirages. In experiments by Friedman and von Borries (1988), there was only one informed trader (and everyone knew that); mirages were common, presumably because there was no competition among informed traders causing information to leak out.

Camerer and Chernew (1988) conducted experiments in which the amount of time the market was open varied, but the amount of news was held constant. They found little evidence that self-generating trading caused information bubbles.

## 6.3. *Agents have different models*

In theories in which agents have fundamentally different models, the interaction between classes of agents can produce information bubbles. For instance, Campbell and Kyle (1986) test a variant of Kyle (1985) (cf. Shiller, 1984), in which there are noise traders and 'smart money' traders with rational expectations. They estimate that about a quarter of the variance of price changes is due to noisy trading which pushes prices away from intrinsic value. (That finding is roughly comparable to French and Roll's 1986, estimate that between 4 and 12% of stock price volatility is due to self-generating trading.)

De Long *et al* (1987) have a similar model of noise trading. Some agents trade on the basis of 'noise' (worthless information); others know better. Smart traders do not necessarily correct pricing errors caused by noise traders, because the noise traders create a special kind of risk smart traders do not want to bear. They give some examples of empirical anomalies which can be explained by the existence of noise traders (including excess volatility of prices, the extraordinary excess return of equities over bonds, discounts to closed-end mutual funds and premia to privately-held firms, and effects of dividend and capital structure policy).

In Levine's (1982) catastrophe-theoretical model (cf. Zeeman, 1974), there are classes of traders who use decision rules which are reasonable but suboptimal: chartists forecast price changes based on past changes, etc. This model can account for some features of stock market activity around the Great Depression: Large price changes are more likely to be decreases than increases; prices rise more often than usual after 4–8 point rises following a decline; and price rises are more likely after two or three previous price rises. However, these empirical findings are only marginally significant, and could be accounted for by many of the bubble and fad models described earlier.

Frankel and Froot (1985) have a model of foreign exchange in which there are 'fundamentalist' and 'chartist' traders who use simple decision rules, and there is a class of portfolio managers who simply weight the opinions of the fundamentalists and chartists based on their past success in forecasting. For plausible parameter values, their model can account for the apparently unreasonable strength of the dollar in the 1980's.

Models in which different groups of agents interact are quite appealing, but they have drawbacks. Since there are usually many free parameters in these models, they are difficult to test squarely against competing theories. And research on judgment error suggests *most* people, both dumb and smart, are prone to make systematic errors depending on the context they are in; the world is not neatly divided into noise traders and smart traders. There have been too few attempts to integrate results of judgment research directly into noise trader models (see Shefrin and Statman, 1988). More theory and empirical work along these lines should therefore prove useful.

## 7. Conclusion

The idea that asset prices might deviate from intrinsic values has intrigued economists for a long time. I have distinguished three reasons why prices might deviate: Rational growing bubbles, fads, and information bubbles.

In the past two decades theorists have shown that under many conditions prices can exhibit growing bubbles, which are self-fulfilling and hence rational. The theory of rational bubbles is fairly conclusive (especially about the conditions under which rational bubbles cannot occur) but empirical tests for bubbles are not so conclusive. Tests often suggest bubbles do occur, but a bubble is necessarily defined relative to some specification of intrinsic value; an apparent bubble could be a specification error. Some tests also suffer from problems caused by doing regression on growing bubbles terms, and all tests appear to have little power to distinguish between growing rational bubbles and long-lived irrational fads. Data from experiments in which intrinsic value is controlled show that rational bubbles can occur, and near-rational bubbles are common when subjects are inexperienced.

Prices may also deviate from intrinsic values because of fads, caused by socially-determined swings in utility from owning assets or in beliefs about true intrinsic values. Fads are not well understood theoretically, but there have been many empirical studies of them. Tests of the volatility of stock prices, and indirect tests for autocorrelation in price changes, generally show that stock prices are not rational forecasts of perfect foresight prices (constructed ex post, assuming constant discount rates). (These tests are controversial and subtle; the curious reader is encouraged to read the papers cited in section 5.) These apparent deviations from rational forecasts could be due to fads, or to changes in discount rates. There are good cases for both hypotheses, and a clear need for more research. If fads do exist, they beg for theoretical explanation.

A third kind of deviation occurs when all information is not incorporated into prices. Such "information bubbles" might account for the small temporary price swings that are evidenced by the large volatility of prices during trading hours on organized exchanges (relative to the implicit volatility during non-trading hours). These data suggest that trading is at least partly 'self-generating' i.e. information bubbles are caused by traders overreacting or making imperfect inferences from observed trading of others. Simple experiments show little evidence of information bubbles, but richer settings with more complicated features of natural markets will prove more conclusive.

Most of the research described in this review is quite recent. As good research tends to do, it collectively raises more questions than it answers. My personal views, shared by some,[35] are that several new directions will prove useful: theories of near-rational fads or bubbles (which are sensible but not fully rational); data from assets other than stocks and bonds (on housing see Case and Shiller, 1988, in press); more study of non-price data, especially trading volume; and more data from experiments in which intrinsic values and discount rates are controlled.

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## Notes

1. For example, Tirole (1982), Evans (1986), and Aoki and Friedman (1985) all use the term 'bubble' to describe what we shall call growing bubbles, fads, and information bubbles, respectively. Each of these reseachers defines the term 'bubble' carefully, but confusion may result when their work get discussed and their precise usages are forgotten.
2. More formal derivations are given by Blanchard and Watson (1982), Diba and Grossman (1982), and Tirole (1982).
3. Since we are assuming risk-neutrality, equation (1) omits the marginal utility of consumption terms from prices and dividends. See Flood, Hodrick, and Kaplan (1986) for a more careful treatment.
4. Bubbles are ruled out by the 'transversality condition', the limit of $E(P_{t+i} \mid I_t)/(1+r)^{t+i}$ as $i$ becomes infinite is zero, but there is typically no a priori reason to impose this condition.
5. Intrinsic value is more slippery than it might appear. In (3), it depends on both the information set $I_t$ and the discount rate (or expected return) $r$. When agents have different information sets (or form different beliefs based on the same information, see Harrison and Kreps, 1978), and when discount rates vary over time or agents, intrinsic value is an amalgam of discounted dividend streams determined by exchange. In practice, it may be difficult to disentangle observed prices from unobserved intrinsic value, but it can still be useful to speculate about deviations from intrinsic value.
6. Stochastic bubbles of this form have an expected life of $1/p$ periods, so they constitute a probabilistic answer to a question posed by Samuelson (1957): 'Of course, history tells us that all tulip manias have ended in finite time... Every bubble is some day pricked. But I have long been struck by the fact, and puzzled by it too, that in all the arsenal of economic theory we have absolutely no way of predicting how long such a "Stage (i)" (bubble) will last.'
7. Harrison and Kreps (1978) point out that if traders have heterogeneous opinions, based on the same information, then the intrinsic value is poorly-defined because each trader will have a different perceived intrinsic value. Trading opportunities permit speculation — buying in anticipation of selling to something with a higher perceived intrinsic value — and make market prices higher than the prices that would result if people could not resell. When I speak of *the* intrinsic value, this market price (absent bubbles) is what I have in mind.
8. Their 'Breeder's Cup' programme sponsors single day of racing for $10 million in purses, and adds about the same amount to various races throughout the year. The prestigious Kentucky Derby, by contrast, is worth about $500,000 to the winner.
9. Some of the yearling bubble can be accounted for by rich oil sheikhs eager to buy Kentucky Derby winners. At the height of the bubble, one group of four brothers flew to the Lexington summer sales in their 747 and spent $60 million in cash for yearlings.
10. In a pyramid game, players pay money for the right to collect several times as much money when several others are persuaded to join the pyramid and contribute. Such a scheme is a bubble with *no* dividend, equation (3) with $P_t = B_t$. Pyramids break down because they require a rate of growth of new players that is impossible to sustain. Such schemes are generally illegal and highly popular.
11. In January 1980, accounts controlled by the Hunts held claims on 50% of the deliverable silver inventory at the Comex and 70% at the Chicago Board of Trade (Abolafia and Kilduff, 1988).
12. Taylor imagines 'some dominant group (the government?) pointing the way toward those self-fulfilling expectations which have the highest expected utility'. This hope, Shiller (1978) remarked, 'clearly gives more credit to the government than it could possibly deserve.'

13. Price bubbles are ruled out because prices should never exceed the price level at which it pays to 'cash in' currency for capital. By backward induction, bubbles should never begin.
14. Note that the stochastic bubbles mentioned above, which might burst with probability $p$ each period, do not necessarily end so the unravelling argument doesn't apply.
15. For instance, suppose traders have a probability of dying each period (which they know) which increases each period. 'Old' traders with high probabilities of death have discount rates which are higher than the market discount rates which determine the bubble's growth rate, so buying the bubble has negative discounted expected value for them. They'll quit and retire.
16. Tirole also pointed out (pp. 1090–1093) that an asset's intrinsic value depends upon how it is used, so a speculative bubble can therefore affect intrinsic value (if gold is held in a safe, for instance). This is akin to the problem of non-exhaustion of a non-renewable resource.
17. For instance, Roll (1986) suggested managerial 'hubris' explains why firms earn no gains from takeovers. And a majority of automobile drivers say they are better than average, even those interviewed in hospitals after accidents (Svenson, 1981).
18. In economics experiments where subjects were paid several dollars if they predicted their rank in trading profits correctly, 90% guessed they were in the top 50% in earnings (Camerer, 1987).
19. Holding the asset or winning the auction informs traders that they have higher values of $T_i$ (or $V_i$) than other people, and they should revise their estimates downward to account for the information about the estimates of others that is implicitly conveyed by holding (or winning).
20. Trading before one is born is not so absurd as it seems. If members of families have dependent utility functions, a mother gets utility from her daughter's consumption for instance, parents might rationally trade on behalf of their children before they are born.
21. An example might be the Hong Kong stock market, which rose 10 times in value between 1970 and 1973, then dropped 75% in a year. These enormous price swings might indicate a bubble or fad, or they could be rational swings based on changing beliefs about what will happen when Hong Kong reverts to China after the British lease expires in 1997.
22. Excessive kurtosis is induced because the distributions of returns or price changes will have changing variance over the bubble 'life cycle'. Mixing low and high-variance observations by sampling across the life cycle will create more large observations (from the high-variance periods) than in a normal distribution.
23. The bubble is not quite rational, because subjects' initial bubble belief stemmed from their misconception that the long-lived asset market should necessarily behave like the one-period asset market. (Their belief is not rational in Muth's sense of being consistent with the correct economic model.) But their beliefs, regardless of origin, were self-fulfilling.
24. For example, Shiller (1984) argued that 'perceptions of return themselves represent changing fashions.' See also Schachter *et al* (1985b) on the social psychology of the stock market.
25. For instance, if utility fads occur because people get utility from discussing their asset holdings with others, then well-known stocks will be more faddish than unknown stocks. Belief fads may be more common when there is more uncertainty about intrinsic value: in new issues of common stock, for instance. Other hypotheses of this sort are not hard to imagine.
26. Sociology and anthropology might be useful for understanding utility fads (e.g., Douglas and Isherwood, 1978); social and cognitive psychology for belief fads (e.g., Schachter *et al*, 1985b); and the psychology of time preference for returns fads (e.g., Loewenstein, 1987).

27. Recall from basic statistics that sample variances always underestimate true population variances, hence the familiar need to divide by $n - 1$ rather than $n$ (when data are independent). When data are serially correlated, the degree of underestimation bias is much worse. If $p_t^*$ is smoother than $p_t$, the degree of underestimation will be greater for $p_t^*$ than for $p_t$, so $p_t^*$ may appear to vary less than $p_t$ purely because of bias in estimating their variances.
28. Shiller said his dividend series is stationary, since a regression of log dividends against lagged log dividends and a time variable yielded a coefficient estimate of 0.807 (see also Blanchard and Watson, 1982, and West, 1988). But Kleidon (1986c) accepted the hypothesis of non-stationarity, using only data from 1926 on because of concerns about errors in older data, and Marsh and Merton (1987) concluded that a non-stationary Lintner-type model fit better than stationary autoregressive models. LeRoy and Parke (1987) concluded that dividends follow a geometric random walk rather than a stationary process with a time trend, but their simulations indicate the two processes are difficult to distinguish statistically. (The variance-bound is *not* violated in their test when a geometric random walk is assumed.)
29. West (1986) speculated that the difference in his 1986 test and Meese's test (which used West, 1987) is that the volatility test (13) is more robust to within-sample changes in market fundamentals, and therefore more conclusive.
30. Shiller (1986a, pp. S504–505): 'Intuitively, it is hard to see how a model that makes $p_t^*$ roughly a trend with $p$ bounced around this trend by fashions or fads could ever be rejected by these data in favour of a model that says price movements anticipate dividends.'
31. Kleidon reports that graduate students and courts may not use stock prices as measures of firm value if they think prices contain fads. But most 'faddists' contend that prices react to information *and* to fads; prices are not *perfect* indicators of true value but they should be used. Should faddists whisper about fads models just to prevent students and lawyers from hearing and misinterpreting them?
32. Fads in prices will create negative autocorrelations, while fads in returns create positive autocorrelations. Lo and MacKinlay suspect that the negative autocorrelations Fama and French (1988) observed in long-term returns might be less statistically reliable than the positive autocorrelations in short-term returns, because long-term returns are fewer in number and appear more sensitive to choice of sampling period.
33. For example, in a discussion of Shiller (1984), Fischer (1984) says new statistical tests 'will also in all likelihood be more closely related to the speculative bubble literature than to the fads literature — if indeed those approaches are ultimately different'.
34. For instance, stock market insiders may know the true intrinsic value (based on pooled information) is different from the market price, and I may know that they know, but none of us can do any better than we are by knowing there is such a bubble.
35. E.g., Tirole (1982, p. 1180), Shiller (1984), Black (1986), and Merton (1987).

## References

Abolafia, Mitchel Y. and Martin Kilduff. (1988) Enacting market crisis: The social construction of a speculative bubble. *Administrative Science Quarterly* 33, 177–193.

Ackley, Gardner. Commodities and capital: Prices and quantities. (1983) *American Economic Review*, 73, 1–16.

Akerlof, George A. and William T. Dickens. (1982) The economic consequences of cognitive dissonance. *American Economic Review* 72, 307–319.

Allen, Franklin and Gary Gorton. (1988) Rational finite bubbles. Wharton School Department of Finance working paper, July.

Alloy, Lauren B. and Leslie Y. Abramson. (1979) Judgment of contingency in depressed and non-depressed students: Sadder but wiser? *Journal of Experimental Psychology: General* 108, 441–485.

Amsler, Christine. (1980) The term-structure of interest rates in an expanded market model. Unpublished Ph.D. dissertation, University of Pennsylvania.

Ang, James S. and Thomas Schwarz. (1985) Risk aversion and information structure: An experimental study of price variability in the securities markets. *Journal of Finance*, July 40, 825–844.

Arrow, Kenneth. (1982) Risk perception in psychology and economics. *Economic Inquiry* 20, 1–9.

Aumann, Robert. (1976) Agreeing to disagree. *The Annals of Statistics* 4, 1236–1239.

Azariadis, Costas. (1981) Self-fulfilling prophecies. *Journal of Economic Theory* 25, 380–396.

Azariadis, Costas and Roger Guesnerie. (1986) Sunspots and cycles. *Review of Economic Studies.*

Banks, Jeffrey S. (1985) Price-conveyed information versus observed insider behavior: A note on rational expectations convergence. *Journal of Political Economy* 93, 807–815.

*Barron's.* (1985) Mare's nest: The market in thoroughbreds is a mess. July 15, p. 14+.

Black, Fischer. (1986) Noise. *Journal of Finance*, July 41, 529–543.

Black, Fischer. (1974) Uniqueness of the price level in monetary growth models with rational expectations. *Journal of Economic Theory* 7, 53–65.

Blanchard, Olivier J. (1979) Speculative bubbles, crashes and rational expectations. *Economic Letters* 3, 387–389.

Blanchard, Olivier J., and Mark W. Watson. (1982) Bubbles, rational expectations, and financial markets. In P. Wachtel (Ed.), *Crises in the Economic and Financial Structure*. Lexington, Mass.: Lexington Books.

Borensztein, Eduardo R. (1987) Alternative hypotheses about the excess return on dollar assets, 1980–84. *International Monetary Fund Staff Papers*, March 34, 29–59.

Breeden, Douglas. (1979) An intertemporal asset pricing model with stochastic consumption and investment opportunities. *Journal of Financial Economics*, September 7, 265–296.

Brock, William A. (1974) Money and growth: The case of long run perfect foresight. *International Economic Review* 15, 750–777.

Brock, William A. (1975) A simple perfect foresight monetary model. *Journal of Monetary Economics* 1, 133–150.

Brock, William A. (1978) A note on hyper-inflationary equilibria in long run perfect foresight monetary models: A correction. University of Chicago working paper.

Brock, William A. (1982) Speculative hyperinflations in maximizing models: Corrigendum and clarification. University of Wisconsin, Madison working paper.

Brooks, LeRoy D. and Dale A. Buckmaster. (1976) Further evidence of the time series properties of accounting income. *Journal of Finance*, December 1359–1373.

Burmeister, Edwin. (1980) On some conceptual issues in rational expectations modeling. *Journal of Money, Credit, and Banking*. November 12, 800–816.

Burmeister, Edwin and Kent D. Wall. (1982) Kalman filtering estimation of unobserved rational expectations with an application to the German hyperinflation. *Journal of Econometrics* 20, 255–284.

Burmeister, Edwin, and Kent D. Wall. (1987) Unobserved rational expectations and the German hyperinflation with endogeneous money supply. *International Economic Review*, February 28, 15–32.

*Business Week*. (1983) Behind Henry Kaufman's mystique. February 28, 86–87.

Calvo, Guillermo. (1978) On the indeterminacy of interest rates and wages with perfect foresight. *Journal of Economic Theory* 19, 321–337.

Camerer, Colin F. (1987) Do biases in probability judgment matter in markets? Experimental evidence. *American Economic Review*, December 77, 981–997.

Camerer, Colin F., and Michael Chernew. (1988) Is trading self-generating? Experimental evidence. University of Pennsylvania Department of Decision Sciences working paper.

Camerer, Colin F. and Keith Weigelt. (1987) Tests for rational bubbles in experimental markets for infinitely-lived assets. University of Pennsylvania Department of Decision Sciences working paper, March.

Camerer, Colin F., and Keith Weigelt. (1988) Information 'mirages' in experimental asset markets. University of Pennsylvania Department of Decision Sciences working paper, October.

Campbell, John Y. and Angus Deaton. (1987) Is consumption too smooth? Princeton University, Woodrow Wilson School Economics Discussion Paper #122, January.

Campbell, John Y. and Albert S. Kyle. (1986) Smart money, noise trading and stock price behavior. Princeton University working paper.

Campbell, John Y. and Robert J. Shiller. (1987) Cointegration and tests of present value models. *Journal of Political Economy* 95, 1062–1088.

Case, Karl E., and Robert J. Shiller. (1988) The behavior of home buyers in boom and post-boom markets. Cowles Foundation working paper #890.

Case, Karl E. and Robert J. Shiller. (in press) The efficiency of the market for single family homes. *American Economic Review*.

Cass, David. (1984) Sunspots and financial markets: The leading example. CARESS working paper #84-06R, University of Pennsylvania, December.

Cass, David, and Karl Shell. (1980) In defense of a basic approach. In J. Kareken and N. Wallace (Eds.), *Models of Monetary Economies*. Minneapolis: Federal Reserve Bank of Minneapolis.

Cass, David, and Karl Shell. (1983) Do sunspots matter? *Journal of Political Economy* 91, 193–227.

Chan, K. C. (1988) On the contrarian investment strategy. *Journal of Business* 61, 147–163.

Cheung, Yin-Wong (1986) The spot exchange rates: Random walks or bubbles? University of Pennsylvania Department of Economics working paper.

Conrad, Jennifer and Gautam Kaul. (1988) Time-variation in expected returns. *Journal of Business*, October 61, 409–426.

Copeland, Thomas, and Daniel Friedman. (1987) The effect of sequential information arrival on prices: An experimental study. *Journal of Finance*, July 42, 763–797.

Crist, Steven. (1986) *The Horse Traders*. New York: W. W. Norton.

De Bondt, Werner F. M. (forthcoming) Stock price reversals and overreaction to news events: A survey of theory and evidence. In Taylor, S. J., B. G. Kingsman and R. M. C. Guimaraes (eds), *A Reappraisal of the Efficiency of Financial Markets*. Heidelberg, West Germany: Springer-Verlag.

De Bondt, Werner F. M. and Richard Thaler. (1985) Does the stock market overreact? *Journal of Finance*, July 40, 793–805.

De Bondt, Werner F. M. and Richard Thaler. (1987) New evidence on investor overreaction and stock market seasonality. *Journal of Finance*, July 42, 557–581.

De Bondt, Werner F. M. and Richard Thaler. (1989) A mean-reverting walk down Wall Street. *Journal of Economic Perspectives*, Winter, 189–202.

De Long, J. Bradford, Shleifer, Andrei, Summers, Lawrence H. and Robert J. Waldmann. (1987) The economic consequences of noise traders. Harvard Institute of Economic Research Discussion Paper 1348, November.

Diamond, Douglas W. and Robert E. Verrecchia. (1981) Information aggregation in a noisy rational expectations economy. *Journal of Financial Economics*, September 9, 221–235.

Diamond, Peter. (1965) National debt in a neoclassical growth model. *American Economic Review* 55, 1126–1150.

Diba, Behzad T. and Herschel I. Grossman. (1987) On the inception of rational bubbles. *Quarterly Journal of Economics*, August 102, 697–700.

Diba, Behzad T. and Herschel I. Grossman. (1988a) Rational inflationary bubbles. *Journal of Monetary Economics*, January 21, 35–46.

Diba, Behzad T. and Herschel I. Grossman. (1988b) The theory of rational bubbles in stock prices. *Economic Journal*, September 98, 746–754.

Diba, Behzad T. and Herschel I. Grossman. (1985) Rational bubbles in stock prices? Brown University Department of Economics working paper #85–38.

Douglas, Mary and Baron Isherwood. (1978) *The World of Goods*. New York: Basic Books.

Dreman, David. (1982) *The new contrarian investment strategy*. New York: Random House.

Dubey, Pradeep; Geanakoplos, John and Shubik, Martin. (1987) The revelation of information in strategic market games: A critique of rational expectations equilibrium. *Journal of Mathematical Economics* 16, 105–137.

Dusak, Katherine. (1973) Futures trading and investor returns: An investigation of commodity market risk premiums. *Journal of Political Economy* 71, 1387–1406.

Easterlin, Richard. (1973) Does economic growth improve the human lot? Some empirical evidence. In P. David and M. Reder (Eds), *Nations and households in economic growth: Essays in honor of Moses Abramovitz*. Palo Alto, Calif.: Stanford University Press.

Engle, Robert F. and Clive W. J. Granger. (1987) Cointegration and error-correction: Representation, estimation, and testing. *Econometrica* 55, 251–276.

Evans, George E. (1986) A test for speculative bubbles in the sterling-dollar exchange rate: 1981–84. *American Economic Review* 76, 621–636.

Fama, Eugene F. (1970) Efficient capital markets: A review of theory and empirical work. *Journal of Finance* 35, 383–417.

Fama, Eugene F. (1976) *Foundations of finance*. New York: Basic Books.

Fama, Eugene F. (1981) Stock returns, real activity, inflation, and money. *American Economic Review*, September 71, 545–565.

Fama, Eugene F. and Kenneth R. French. (1987) Dividend yields and expected stock returns. University of Chicago Graduate School of Business working paper, July.

Fama, Eugene F. and Kenneth R. French. (1988a) Permanent and temporary components of stock prices. *Journal of Political Economy* 96, 246–273.

Fama, Eugene F. and Kenneth R. French. (1988b) Business cycles and the behavior of metals prices. *Journal of Finance*, December 43, 1075–1093.

Farmer, Roger. (1984) Bursting bubbles: On the rationality of hyperinflations in optimizing models. *Journal of Monetary Economics* 14, 29–35.

Fischer, Stanley. (1984) Stock prices and social dynamics: Comments and discussion. *Brooking Papers on Economic Activity* 2, 499–504.

Flavin, Marjorie. (1983) Excess volatility in the financial markets: A reassessment of the empirical evidence. *Journal of Political Economy* 91, 929–956.

Flood, Robert P. and Peter M. Garber. (1980) Market fundamentals versus price-level bubbles: The first tests. *Journal of Political Economy* 88, 745–770.

Flood, Robert P., and Peter M. Garber. (1982) Bubbles, runs, and gold monetization. In P. Wachtel (ed.), *Crises in the Economic and Financial Structure*. Lexington, Mass.: Lexington Books.

Flood, Robert P., Garber, Peter M. and Louis O. Scott. (1984) Multi-country tests for price level bubbles. *Journal of Economic Dynamics and Control* 8, 329–340.

Flood, Robert P. and Robert J. Hodrick. (1986a) Asset price volatility, bubbles and process switching. *Journal of Finance*, September 41, 831–842.

Flood, Robert P., Hodrick, Robert J. and Paul Kaplan. (1986b) An evaluation of recent evidence on stock market bubbles. National Bureau of Economic Rsearch working paper no. 1971, July.

Forsythe, Robert and Russell J. Lundholm. (1986) Information aggregation in an

experimental market. University of Iowa Department of Economics Working Paper No. 86–40, December.
Frank, Robert. (1986) *Choosing the Right Pond: The Quest for Status.* Cambridge: Cambridge University Press.
Frankel, Jeffrey A. and Kenneth A. Froot. (1986) The dollar as a speculative bubble: a tale of fundamentalists and chartists. NBER Working Paper No. 1854, March.
French, Kenneth R. and Richard Roll. (1984) Is trading self-generating? University of Chicago Center for Research in Security Prices Working Paper no. 121, February.
French, Kenneth R. and Richard Roll. (1986) Stock return variances: The arrival of information and the reaction of traders. *Journal of Financial Economics* 17, 5–26.
Friedman, Benjamin. (1984) Stock prices and social dynamics: Comments and discussion. *Brooking Papers on Economic Activity* 2, 504–508.
Friedman, Daniel and Masanao Aoki. (1986) Asset price bubbles from poorly aggregated information: A parametric example. *Economics Letters* 21, 49–52.
Friedman, Daniel, Harrison, Glenn and Jon Salmon. (1984) The informational efficiency of experimental markets. *Journal of Political Economy*, June 92, 349–408.
Friedman, Daniel and Stoddard Vandersteel. (1982) Short-run fluctuations in foreign exchange rates: Evidence from the data, 1973–79. *Journal of International Economics*, August 13, 171–186.
Friedman, Daniel and Alexander von Borries. (1988) Monopolist insiders in computerized asset markets: A note on some experimental results. Organized Research Activity in Applied Economics working paper #178, University of California, Santa Cruz.
Garber, Peter M. (1986) The tulip mania legend. Brown University Department of Economics working paper no. 86–13, July.
Gourieroux, C., Laffont, J. J. and A. Monfort. (1982) Rational expectations in dynamic linear models: Analysis of the solutions. *Econometrica*, March 50, 409–425.
Grandmont, Jean-Michel. (1986) Stabilizing competitive business cycles. *Journal of Economic Theory*, October 40, 57–76.
Grandmont, Jean-Michel, and Pierre Malgrange. (1986) Nonlinear economic dynamics: Introduction. *Journal of Economic Theory*, October 40, 3–12.
Gray, Jo Anna. (1984) Dynamic instability in rational expectations models: An attempt to clarify. *International Economic Review*, February 25, 93–122.
Grossman, Sanford J. (1976) On the efficiency of competitive stock markets where traders have diverse information. *Journal of Finance* 31, 573–585.
Grossman, Sanford J. and Robert J. Shiller. (1981) The determinants of the variability of stock market prices. *American Economic Review* 71, 222–227.
Grossman, Sanford J. and Joseph E. Stiglitz. (1980) On the impossibility of informationally efficient markets. *American Economic Review* 70, 393–408.
Guesnerie, Roger. (1986) Stationary sunspot equilibria in an *n* commodity world. *Journal of Economic Theory*, October 40, 103–127.
Hahn, Frank H. (1966) Equilibrium dynamics with heterogeneous capital goods. *Quarterly Journal of Economics* 80, 633–646.
Hamilton, James D. (1986) On testing for self-fulfilling speculative price bubbles. *International Economic Review*, October 27, 545–552.
Hamilton, James D. and Charles H. Whiteman. (1985) The observable implications of self-fulfilling expectations. *Journal of Monetary Economics* 16, 353–373.
Harrison, J. Michael and David M. Kreps. (1978) Speculative investor behavior in a stock market with heterogeneous expectations. *Quarterly Journal of Economics*, May 92, 323–336.
Hausman, Jerry A. (1978) Specification tests in econometrics. *Econometrica* 46, 1251–1271.
Hellwig, Martin. (1980) On the aggregation of information in capital markets. *Journal of Economic Theory* 22, 477–498.

Hirshleifer, Jack. (1975) Speculation and equilibrium: Information, risks and markets. *Quarterly Journal of Economics* 89, 519–542.

Hood, Donald C., Andreassen, Paul and Stanley Schachter. (1985) II. Random and non-random walks on the New York Stock Exchange. *Journal of Economic Behavior and Organization* 6, 331–338.

Huang, Roger D. (1981) The monetary approach to exchange rate in an efficient foreign market: Tests based on volatility: *Journal of Finance* 36, 31–41.

Huberman, Gur and G. William Schwert. (1985) Information aggregation, inflation, and the pricing of indexed bonds. *Journal of Political Economy* 93, 92–114.

Isaac, Alan G. (1986) Bursting bubbles: Further results. *Journal of Monetary Economics* 17, 425–431.

Kagel, John H. and Dan Levin. (1986) The winner's curse and public information in common-value auctions. *American Economic Review* 76, 894–920.

Kaheman, Daniel, Slovic, Paul and Amos Tversky. (1982) *Judgment under Uncertainty: Heuristics and Biases.* Cambridge: Cambridge University Press.

Keim, Donald B. (1983) Size related anomalies and stock return seasonality. *Journal of Financial Economics,* June 14, 13–32.

Keim, Donald and Robert Stambaugh. (1986) Predicting returns in stock and bond markets. *Journal of Financial Economics* 17, 357–390.

Keynes, John Maynard. (1964) *The General Theory of Employment Interest, and Money.* London: Harcourt Brace (originally published 1936).

Kihlstrom, Richard E. and Leonard J. Mirman. (1975) Information and market equilibrium. *Journal of Economic Theory* 20, 357–376.

Kindleberger, Charles P. (1978) *Manias, Panics and Crashes.* New York: Basic Books.

Kleidon, Allan W. (1986a) Bias in small sample tests of stock price rationality. *Journal of Business* 59, 237–261.

Kleidon, Allan W. (1986b) Anomalies in financial economics: Blueprint for change? *Journal of Business,* October 59, S469–S499.

Kleidon, Allan W. (1986c) Variance bounds tests and stock price valuation models. *Journal of Political Economy,* October 94, 953–1001.

Kreps, David M., Milgrom, Paul, Roberts, John, and Wilson, Robert. (1982) Rational cooperation in the finitely repeated prisoners' dilemma. *Journal of Economic Theory,* August 27, 245–252.

Kreps, David M., and Wilson, Robert (1982) Sequential equilibria. *Journal of Economic Theory,* August 27, 253–279.

Kyle, Albert F. (1985) Continuous auctions with insider trading. *Econometrica,* November 53, 1315–1333.

Lehmann, Bruce N. (1988) Fads, martingales, and market efficiency. Hoover Institution working paper E-88-5, January.

Leroy, Stephen F. (1982) Expectations models of asset prices: A survey of theory. *Journal of Finance,* March 37, 185–217.

Leroy, Stephen F. (1984) Efficiency and the variability of asset prices. *American Economic Review* 74, 183–187.

Leroy, Stephen F. and C. J. LaCivita. (1981) Risk-aversion and the dispersion of asset prices. *Journal of Business* 54, 535–547.

Leroy, Stephen F. and William R. Parke. (1987) Stock price volatility: A test based on the geometric random walk. University of California, Santa Barbara Department of Economics working paper, August.

Leroy, Stephen F., and R. D. Porter. (1981) the present-value relation: Tests based on implied-variance bounds. *Econometrica* 49, 555–574.

Levine, David. (1982) Theory of price bubbles. UCLA Department of Economics working paper.

Lintner, John (1956) Distribution of incomes of corporations among dividends, retained earnings, and taxes. *American Economic Review,* May 66, 97–113.

Lo, Andrew W. and A. Craig MacKinlay. (1988) Stock market prices do not follow random walks: Evidence from a simple specification test. *Review of Financial Studies* 1, 41–66.

Loewenstein, George. (1987) Anticipation and the valuation of delayed consumption. *Economic Journal* 97, 666–684.

Lucas, Robert E., Jr. (1986) Adaptive behavior and economic theory. *Journal of Business*, October 59, S401–S426.

Mackay, Charles. (1974) *Extraordinary Popular Delusions and the Madness of Crowds.* New York: Noonday Press (originally published 1932).

Mankiw, N. Gregory, Romer, David and Matthew D. Shapiro. (1985) An unbiased reexamination of stock market volatility. *Journal of Finance*, July 40, 677–687.

Marsh, Terry A. and Robert C. Merton. (1986) Dividend variability and variance bounds test for rationality of stock market prices. *American Economic Review*, June 76, 483–498.

Marsh, Terry A. and Robert C. Merton. (1987) Dividend behavior for the aggregate stock market. *Journal of Business* 60, 1–40.

McCallum, Bennett T. (1983) On non-uniqueness in rational expectations models. *Journal of Monetary Economics*, 11, 139–168.

Mattey, Joe and Richard Meese. (1986) Empirical assessment of present value relations [including discussion]. *Econometric Reviews* 5, 171–234.

Meese, Richard A. (1986) Testing for bubbles in exchange markets: A case of sparkling rates? *Journal of Political Economy* 94, 345–373.

Meese, Richard A. and Kenneth J. Singleton. (1980) Rational expectations, risk premia and the market for spot and forward exchange. Federal Reserve Board working paper.

Merton, Robert C. (1987) On the current state of the stock market rationality hypothesis. In S. Fischer *et al* (Eds), *Macroeconomics and Finance: Essays in Honor of Franco Modigliani.* Cambridge: MIT Press.

Michener, Ronald W. (1982) Variance bounds in a simple model of asset pricing. *Journal of Political Economy* 90, 166–175.

Milgrom, Paul and John Roberts. (1982) Predation, reputation, and entry deterrence. *Journal of Economic Theory*, August 27, 280–312.

Milgrom, Paul and Robert J. Weber. (1982) A theory of auctions and competitive bidding. *Econometrica* 50, 1089–1122.

Muth, John F. (1961) Rational expectations and the theory of price movements. *Econometrica* 29, 315–335.

Obstfeld, Maurice and Kenneth Rogoff. (1983) Speculative hyperinflations in maximizing models: Can we rule them out? *Journal of Political Economy* 91, 675–687.

Obstfeld, Maurice, and Kenneth Rogoff. (1986) Ruling out divergent speculative bubbles. *Journal of Monetary Economics*, May 17, 349–362.

Okina, Kunio. (1985) Empirical tests of 'bubbles' in the foreign exchange market. *Bank of Japan Monetary and Economic Studies* 3, 1–45.

Oldfield, George S. and Richard J. Rogalski. (1980) A theory of common stock returns over trading and non-trading periods. *Journal of Finance*, June 35, 729–751.

Peck, James. (1988) On the existence of sunspot equilibria in an overlapping generations model. *Journal of Economic Theory* 44, 19–42.

*Philadelphia Inquirer.* (1984) Slew's foals falling short of expectations. June 24.

Plott, Charles R. and Shyam Sunder. (1982) Efficiency of experimental security markets with insider information: An application of rational expectational expectations models. *Journal of Political Economy* 90, 663–698.

Plott, Charles R. and Shyam Sunder. (1988) Rational expectations and aggregation of diverse information in laboratory security markets. *Econometrica*, September 56, 1085–1118.

Posthumus, N. W. (1929) The tulip mania in Holland in the years 1636 and 1637. *Journal of Economic and Business History* 1, 434–455.

Poterba, James M. and Lawrence H. Summers. (1988) Mean reversion in stock prices: Evidences and implications. *Journal of Financial Economics* 22, 27–59.

Quah, D. (1985) Estimation of a nonfundamentals model for stock price and dividend dynamics. Massachusetts Institute of Technology working paper, September.

Roll, Richard. (1986) The hubris hypothesis of corporate takeovers. *Journal of Business* 59, 197–216.

Roll, Richard. (1988) $R^2$. *Journal of Finance*, July 43, 541–566.

Samuelson, Paul. (1958) An exact consumption loan model of interest, with or without the social contrivance of money. *Journal of Political Economy* 66, 467–482.

Samuelson, Paul A. (1957) Intertemporal price equilibrium: A prologue to the theory of speculation. *Weltwirtschaftliches Archiv* 79, 181–219. Reprinted in *The Collected Papers of Paul A. Samuelson, Volume 2*, J. E. Stiglitz (ed.), Cambridge, Mass.: MIT Press, 1972.

Samuelson, Paul A. (1965) Proof that properly anticipated prices fluctuate randomly. *Industrial Management Review*, Spring 6, 41–49.

Sargent, Thomas J. (1979) *Macroeconomic Theory*. New York: Academic Press.

Sargent, Thomas J. and N. Wallace. (1973a) Rational expectations and the dynamics of hyperinflation. *International Economic Review* 14, 328–350.

Sargent, Thomas J. and N. Wallace. (1973b) The stability of models of money and growth with perfect foresight. *Econometrica* 41, 1043–1048.

Schachter, Stanley, Gerin, William, Hood, Donald C., Andreassen, Paul. (1985a) I. Was the South Sea bubble a random walk? *Journal of Economic Behavior and Organization* 6, 323–329.

Schachter, Stanley, Hood, Donald C., Gerin, William, Andreassen, Paul, and Rennert, Michael. (1985b) III. Some causes and consequences of dependence and independence in the stock market. *Journal of Economic Behavior and Organization* 6, 339–357.

Schwert, G. William. (1981) The adjustment of stock prices to new information about inflation. *Journal of Finance* 36, 15–30.

Scott, Louis O. (1985) The present value of model of stock prices: Regression tests and Monte Carlo results. *Review of Economics and Statistics*, November 57, 599–605.

Shefrin, Hersh and Meir Statman. (1988) Noise trading and efficiency in behavioral finance. Leavy School of Business, University of Santa Clara working paper, August.

Shiller, Robert J. (1978) Rational expectations and the dynamic structure of macroeconomic models: A critical review. *Journal of Monetary Economics* 4, 1–44.

Shiller, Robert J. (1979) The volatility of long-term interest rates and expectations models of the term structure. *Journal of Political Economy* 87, 1190–1219.

Shiller, Robert J. (1981a) Do stock prices move too much to be justified by subsequent changes in dividends? *American Economic Review* 71, 421–436.

Shiller, Robert J. (1981b) The use of volatility measures in assessing market efficiency. *Journal of Finance* 36, 291–304.

Shiller, Robert J. (1984) Stock prices and social dynamics. *Brooking Papers on Economic Activity* 2, 457–498.

Shiller, Robert J. (1985) Discussion [of Mankiw, Romer, and Shapiro (1985)]. *Journal of Finance*, July 40, 688–689.

Shiller, Robert J. (1986a) Comments on Miller and on Kleidon. *Journal of Business*, October 59, S501–S505.

Shiller, Robert J. (1986b) The Marsh-Merton model of managers' smoothing of dividends. *American Economic Review*, June 76, 499–503.

Shiller, Robert J. and Pierre Perron. (1985) Testing the random walk hypothesis: Power versus frequency of observation. *Economics Letters* 18, 381–386.

Singleton, Kenneth. (1980) Expectations models of the term structure and implied variance bounds. *Journal of Political Economy*, December 88, 1159–1176.

Smith, Vernon L., Suchanek, Gerry L., and Arlington W. Williams. (1988) Bubbles, crashes, and endogeneous expectations in experiment spot asset markets. *Econometrica*, September 56, 1119–1151.

Spear, Stephen E. (1984) Sufficient conditions for the existence of sunspot equilibria. *Journal of Economic Theory* 34, 360–370.

Stambaugh, Robert F. (1986) Discussion [of Summers, 1986]. *Journal of Finance*, July 41, 601–602.

Summers, Lawrence H. (1986) Does the stock market rationally reflect fundamental values? *Journal of Finance*, July 41, 591–601.

Sunder, Shyam. (1988) Market for information: Experimental evidence. Carnegie-Mellon Graduate School of Industrial Administration working paper, January.

Svenson, Ola. (1981) Are we all less risky and more skillful than our fellow drivers are? *Acta Psychologica* 47, 143–148.

Taylor, John B. (1977) Conditions for unique solutions in stochastic macroeconomic models with rational expectations. *Econometrica* 45, 1377–1386.

Thiers, Adolphe. (1969) *The Mississippi Bubble: A Memoir of John Law*. New York: Greenwood Press (originally published 1859).

Tiger, Lionel. (1980) *Optimism: the Sociobiology of Hope*. New York: Simon and Schuster.

Tirole, Jean. (1982) On the possibility of speculation under rational expectations. *Econometrica* 50, 1163–1181.

Tirole, Jean. (1985) Asset bubbles and overlapping generations. *Econometrica* 53, 1071–1100. (Reprinted with corrections in *Econometrica*, 1985, 53, 1499–1528.)

Tobin, James. (1984) On the efficiency of the financial system. Hirsch Memorial Lecture, New York, May 15.

Van Horne, James C. (1985) Of financial innovations and excesses. *Journal of Finance*, July 40, 621–631.

Wallace, Neil. (1980) The overlapping generations model of fiat money. In J. Karaken and N. Wallace (eds), *Models of Monetary Economies*. Minneapolis: Federal Reserve Bank of Minneapolis.

Wallace, Neil. (1981) A hybrid fiat-commodity monetary system. *Journal of Economic Theory*, December 25, 421–430.

*Wall Street Journal*. (1986) Fee changes roil money managers. May 19, p. 23.

West, Kenneth D. (1986) A standard monetary model and the variability of the deutschemark-dollar exchange rate. National Bureau of Economic Research working paper no. 2102, December.

West, Kenneth D. (1987) A specification test for speculative bubbles. *Quarterly Journal of Economics*, August 102, 553–580.

West, Kenneth D. (1988a) Dividend innovations and stock price volatility. *Econometrica*, January 56, 37–61.

West, Kenneth D. (1988b) Bubbles, fads and stock price volatility: a partial evaluation. *Journal of Finance*, July 43, 639–656.

Wilson, Robert B. (1977) A bidding model of perfect competition. *Review of Economic Studies* 44, 511–518.

Woo, Wing T. (1984) Speculative bubbles in the foreign exchange markets. Brookings Discussion Paper in International Economics #13.

Woodford, Michael. (1986) Stationary sunspot equilibria in a finance constrained economy. *Journal of Economic Theory*, October 40, 128–137.

Zeeman, Edward C. (1974) On the unstable behavior of stock exchanges. *Journal of Mathematical Economics* 1, 39–49.