Rational and Irrational Bubbles

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The subject of this conference is an esoteric issue in rational expectations, general equilibrium modeling. The issue arises because it is not possible to show that models of this kind converge to a unique, stationary equilibrium or dynamic equilibrium path. There are potentially multiple equilibria, and among them are some in which prices of assets or output do not converge to finite values. Prices can explode. A technical reason why a model may have bubble solutions is that there may not be an infinitely lived rational decision-maker who breaks the bubble.

We have all heard of the German, Hungarian, and other hyperinflations studied by Cagan (1956) and subsequently by many others. The price level explodes upward in his model, as it did in practice. As long as the Reichsbank, or other central banks, allowed the money stock to accelerate, the price level accelerated. Indeed, this is the point of Cagan's model, and its success in explaining hyperinflations is evidence that there was not a bubble in these cases.

The first lesson about bubbles is that all explosive movements are not bubbles. It was entirely rational for people to observe the Reichsbank's monetary acceleration and conclude that the price level would accelerate also as a systematic response to monetary acceleration.

Economists use different definitions of "bubble" in their analytic work. The common element is that asset or output prices increase at a rate that is greater than can be explained by market fundamentals. Kindleberger (1992). Or, a price is above its fundamental value today only because investors believe it will be higher tomorrow. The equilibrium of these models is a rational expectations equilibrium.

Popular use of "bubble" shares with economic usage the emphasis on anticipations. However, the Japanese stock market in the late 1980s, and the U.S. stock markets in 1929 and

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1999-2000 are usually described as driven by irrational, or non-rational, anticipations. Alan Greenspan used the term "irrational exuberance" to describe what he thought had driven stock prices. A recent Wall Street Journal article about the dollar quotes a market participant. "Another rate cut by the Fed … will help a slight recovery of the dollar, but will not reverse the view that the dollar bubble has been pricked." McCarthy (2001). Robert Shiller's (2000) much-discussed book develops this line of reasoning, as did Charles Kindleberger (1978) and many others earlier. I discuss these two meanings separately because each raises some different issues.

One problem with almost any bubble explanation of asset prices is the difference in the behavior of buyers and sellers. If buyers are rationally or irrationally exuberant, how can we characterize sellers? More on that later.

Rational bubbles

The standard model of asset prices values the asset as the present value of the stream of dividends that the owner expects to receive. Strictly speaking, the horizon must be infinite but, much of the literature discusses bubbles that collapse within a finite period. In the standard asset price model, the only systematic force driving asset prices is the expected dividend stream. If prices conform to this expectation, the rational expectations equilibria are said to be driven by fundamentals.

Many other rational expectations equilibria are possible in principle. These equilibria depend on expectations that are unrelated to the dividend stream, or other fundamentals. They are called "bubble solutions," or bubbles. To preserve a rational expectations solution, the value of the bubble expected today must equal the discounted value of next period's anticipated value and be independent of fundamentals. By iterated substitution today's value depends on all future bubble values discounted to the present. Thus the price today has two parts, the contributions of the systematic and bubble components.

At this stage in the development of economic theory, we must regard the rational bubble hypothesis as devoid of empirical content, or empty. The main reasons are that we do not observe expectations, and we cannot exclude other, entirely rational, non-bubble, alternative explanations of prices. I believe it is for these reasons that attempts to test the rational bubble hypothesis depend on expected one-period dividends plus the expected capital gain. The latter depends on expected future dividends and gains. Repeated substitution yields a formula in which today's price depends on the entire future dividend stream.

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1 Tomorrow's price depends on expected one-period dividends plus the expected capital gain. The latter depends on expected future dividends and gains. Repeated substitution yields a formula in which today's price depends on the entire future dividend stream.
hypothesis have not produced compelling evidence. Peter Garber (1990) casts doubt on some major past bubbles, including the famous tulip mania in the 18th century and the Mississippi and South Sea bubbles. After reviewing the evidence from empirical tests, Flood and Hodrick (1990, p. 99) conclude that "current empirical tests for bubbles do not successfully establish the case that bubbles exist in asset prices." And the strict version of the bubble hypothesis does not pass the eyeball test: We do not observe asset prices that become infinite. Long before an infinite value is reached, the asset value would exceed expected GDP, hardly a rational outcome. Further Paul Weller (1992, p. 272) points to another problem. The theory "provides no clue" about the conditions initiating or terminating bubbles.

One reason that a bubble hypothesis is difficult, if not impossible, to test is that expectations are measured relative to some maintained hypothesis and, with rational expectations, exploit all of the information that is relevant according to the maintained hypothesis. Bubble phenomena are what remains unexplained by the hypothesis. In this sense, bubbles are a name assigned to phenomena that may be explained by an alternative hypothesis.

This brings me to the second reason that we should be skeptical about rational bubbles. Suppose the euro-dollar exchange rate depreciates steadily. After a time, your hypothesis, based on fundamentals, predicts that the dollar is overvalued, so you sell the dollar short and buy the euro. The dollar appreciates. This happens repeatedly, suggesting to some that a bubble is present. Since there is both evidence and theory that nominal exchange rates overshoot their equilibrium values, others continue to bet that the fundamentals will drive down the price. Additional appreciation strengthens the expectation of a large profit when the euro-dollar exchange rate corrects.

Suppose the euro-dollar rate eventually rises. There is no way to distinguish the entirely rational expectation that the dollar was overvalued from the rational bubble explanation. The two differ only in that one predicts the devaluation from a structural hypothesis, while the bubble describes the same events as a result of a collapse of self-fulfilling expectations operating independently of the structural hypothesis. It is difficult, and perhaps impossible to distinguish between non-linear dynamics of fundamental values and a bubble.

The fact that, ex post, forecast errors appear to be serially correlated does not discriminate between the two explanations. Exchange rate theories are not sufficiently precise to predict when devaluations will occur. Random movements in relative GDP values, in
anticipated inflation, in stock prices or interest rates may delay depreciation without changing the structural model's forecast.

Several years ago Alex Cukierman and I (1982) explored a closely related model. Suppose there is a permanent change in the level or growth rate of one of the variables in the exchange rate model or in the asset-pricing model. Those who think that a permanent change occurred, and that future earnings or profits will increase, bid for assets and dollars to invest in the industries or firms that are expected to profit in the future. Those who doubt that a permanent change has occurred will regard assets as overvalued, so they sell. An econometrician using available data may find that errors are serially correlated and independent of the variables in the model. To the econometric researcher the rise in asset prices may look like a bubble; the serially correlated errors may suggest that the price rise is independent of the fundamental hypothesis. The speculator who believes that new technology has made possible a permanent increase in the profit rate will regard the rise in the stock price as the rational response to a fundamental change in expected future profits. Since profit or earnings anticipations are subjective, and not observable, it is possible to reject the true hypothesis and accept the bubble.

To use a current example suppose there has been a positive change in U.S. productivity. In the light of recent experience, it should not require much effort to convince yourself that it takes considerable time, years, to establish that a productivity change is permanent, longer still to be confident whether the change is a one-time change in level, distributed over time, or a permanent change in the productivity growth rate.

If we date the start of the current U.S. productivity increase as 1995, the earliest that we could date recognition by policy officials that a change in productivity had occurred is 1997 or 1998, when Alan Greenspan began to support that interpretation. Recall, however, that many forecasters predicted rising inflation at the time, based on models in which the NAIRU was above 5%. They did not believe that productivity or productivity growth had lowered NAIRU and the expected inflation rate. As to when we will know whether the productivity change is a change in level or growth rate, after six years, that date continues to be in the future.

It took more than three years to recognize that a change in productivity had occurred. I say more than three years because at first econometric research found little evidence of a permanent change in productivity. Research by Gordon (1998) showed very little response of economy-wide productivity to the higher productivity in the computer industry. Productivity
typically rises in economic expansions without raising trend productivity or productivity growth. Research by Oliner and Sichel (2000) was among the first to find a productivity change affecting large parts of the economy (as opposed to a single sector.) Their paper first circulated about 1999. I will generalize this set of issues after discussing a different type of bubble.

Non-Rational Bubbles

Popular discussion refers to the behavior of the Japanese economy in the late 1980s as a "bubble economy". The reference is not to the type of bubble just discussed but to a non-rational bubble, called a mania in the writings of people like Kindleberger (1978) or Minsky (1982). The rise in U.S. stock prices in 1929 and 1999 is often described in a similar way. A loose definition is a rise in the price of an asset or asset class that generates additional increases, a rapid upward price movement based on exaggerated beliefs about the potentials of a new technology or organizational structure to generate earnings, and followed by a collapse. Examples from the pricing of many technology stocks in the year 2000 are familiar. Everyone can provide an example of rising share prices for companies without earnings, and in some cases without prospect of earnings for three to five years or longer.

There is always an alternative hypothesis. For Japan in the 1980s, a rational explanation is that Japan had large annual current account surpluses early in the decade. The intergovernmental decision to fix exchange rates, made at the Louvre early in 1986, meant that, instead of appreciating the yen, the Japanese external balance would increase growth of Japan's monetary base. The proper inference was that initially nominal interest rates would fall and asset prices would rise. Speculators were not disappointed, at least not right away. With rapid base money growth, a real interest rate of about 1% and soaring earnings, land and equity prices rose rapidly. The 1990-91 recession and a more restrictive monetary policy ended the asset price boom.

Governor Hayami of the Bank of Japan agrees with part of this explanation. He has written: "Monetary easing was a necessary condition for the emergence of a bubble." Hayami (2001, p. 10) He continued:

"As a matter of fact, it is extremely difficult to identify whether it is a bubble or not when we are actually experiencing bubble expansion. One of the reasons for this difficulty is
that we can not exclude from the observed reality the impact of changes in economic structure." (ibid., p. 10)

In my words, "bubble" is a name we assign to events that we can not explain with standard hypotheses. After the event, we may rule out some explanations that appeared plausible earlier, but we are unlikely to exclude all alternatives except the bubble explanation.²

The rational story for the U.S. in 1929 starts by noting that capitalization rates for corporate earnings increased in 1926, with rising profit anticipations. The capitalization rate remained between 40 and 50 until the fall of 1929, after the recession began. The stock price increase in the first eight months of 1929 accompanied rapidly rising economic activity that suggested continued profit growth. The index of industrial production rose at a 19% annual rate in the first half of 1929. This followed nine months of double-digit annual growth. By April 1929, automobile production was 67% above the 1928 average. There are few comparable periods in U.S. history from 1919 to the present, and most of the others follow deep recessions, while 1928-29 did not.

Then, as now, there was much talk about a new economy and a new era, and there is some basis for both. In the 1920s, the new economy included automobiles and radios, adding machines, and the spread of telephones. Between 1922 and 1929, the number of registered automobiles more than doubled, from 12.2 to 26.7 million. The number of radios increased from 60 thousand to more than 12 million, and the number of telephones in service, an older technology, rose from 14 to 20 million. Historical Statistics, (1960). Changes in industrial practice contributed to belief in the new economy also. This was the era of scientific management, assembly line production, and expansion of consumer credit to purchase durable goods.

The new era supplemented and strengthened the idea of a new economy. The success of the Federal Reserve in preventing both inflation and banking panics encouraged the belief that risk had been reduced. Although there were recessions in 1923-24 and 1926-27 and many failures of country banks, the financial system avoided the major disruptions or banking panics of the pre-Federal Reserve period. Restoration of the gold standard added to the sense of stability and orderly adjustment at the end of the decade. At the time, economists, bankers, and

² Before leaving postwar Japanese experience, I note that Japan experienced two other periods in which asset prices rose rapidly, then collapsed -- the IWATO boom of 1958-61 and the Tanaka boom of 1972-73. Prolonged recessions did not follow the earlier booms in land and stock prices. See Okina and Shiratsuka (2001).
much of the public put great faith in the stabilizing properties of the gold standard. Many of
them shared the belief that Federal Reserve policy had reduced the risk of financial panic, a
frequent event from 1890 to 1910. In 1927, Congress gave the Federal Reserve a permanent
charter, a sign that the long struggle between the populists and bankers or commercial interests
had been resolved.

One can also tell a story about the 1990s relating new technology to expected future
earnings of technology stocks. As long as investors and speculators expected the new
technologies to generate ever-larger future profits, share prices could rise. Once investors or
speculators started to doubt that the new technologies would create large rents or future profits,
stock prices fell. With hindsight, it is now easier to believe that new technology has changed
productivity growth much more than it changed profit rates especially for firms that apply the
new technology, many of them called dot coms.

That said, there is reason to be skeptical about the extent to which such stories are more
qualitative than quantitative. Economists do not claim that their models explain or predict the
exact price at which the market clears. The pricing of some of the dot com stocks required
extreme beliefs about future earnings and profitability. Even for Amazon, one of the more
successful companies, it is difficult to reconcile the anticipated future growth of earnings from
the on-line sale of books and records, necessary to explain the stock price, with the historical
record of earnings and profits by large book or record chains that operate in the more
conventional way. And, if the new technology would make the historical record obsolete, what
would prevent other large chains from building warehouses and competing away the rents from
the new technology?

There are many similar examples of investor behavior in recent years that can only be
reconciled with the valuation models that economists use by invoking wildly optimistic
expectations of sustained profit growth rates. Since we do not know the model or models that
investors used and we cannot retrieve their expectations, it is unlikely that economists will find
evidence that persuades believers in non-rational bubbles to change their opinions or conversely.

Explaining asset market outcomes as the result of euphoric anticipations creates a
problem. Who are the sellers, and what do they think and do? In rising markets, there are
always Cassandras predicting collapse, but they must have sold out earlier. Perhaps they now
sell short. Short sales are too small to explain the volume of purchases in asset markets like the
foreign exchange market for dollars, and the NASDAQ or the Tokyo stock exchanges during their meteoric rise.

I do not doubt that a clever economist can invent a consistent story about buyers and sellers. I am less optimistic about the story's truth content and its ability to explain the data. Perhaps there are degrees of euphoria, so that less euphoric increasingly sell to the more euphoric. But this would suggest that holdings become more concentrated as the bubble expands. Evidence does not support this implication.

An alternative model

There are other ways of modeling expectations that remain consistent with rational expectations and full use of available information but do not involve bubbles. Suppose that the process governing asset prices or other variables is

$$x_t = A_t e^{\alpha_t t} u_t.$$  \hspace{1cm} (1)

where $t$ is time, $A$, $\alpha$ and $u$ are random walks with zero mean and constant variance.

Instead of a single random shock with zero mean and constant variance, let's assume that asset prices (or other variables) are subject to three types of shocks, each with zero mean. First, there are transitory, random deviations around a fixed trend or stationary value ($u_t$). This is the familiar random walk. Second are permanent changes in level, $\Delta A_t$, and third are permanent changes in growth rates, $\Delta \alpha_t$. Investors cannot observe the errors directly, and cannot separate them initially and for some time after. They can only infer from a series of observations whether the level has changed permanently, thereby temporarily altering the measured growth path. A single observation does not permit the investor to know whether a current change is a temporary deviation that will revert to the prior mean, a persistent change that permanently changes the mean level but not the growth rate, or a permanent change in the growth rate. Frank Knight (1921) used a model similar to this to explain economic profits as a reward for bearing uncertainty. For Knight, uncertainty differed from risk. Risk referred to drawings from a known distribution. Uncertainty did not.

If the variance of the transitory component is relatively large, several observations are required to be modestly confident that a change in the mean is permanent. And additional observations may be needed to decide whether the mean will continue to change, i.e., that the
observed change is a change in growth rate not a permanent change in level. Series like profits, stock prices and productivity are examples of relatively noisy series. After five years of productivity growth above the average or trend of the previous twenty years, we can only guess whether there has been a permanent change in trend productivity growth and profits, in one but not the other, or in neither. The length of time needed to gain confidence about the permanence of the change depends on relative variances of transitory and permanent shocks.

As a model of asset prices, this model, differs from the bubble model. It views the investor as using incomplete and noisy information to infer the future path of profits and asset prices. Investors or speculators do not trade mainly on noise. They try to infer future patterns or trends and they pay for the services of professional letter writers and advisers, or the services of professional investors, who use different types of models and procedures to reduce not just risk but uncertainty. They hire economists to forecast the future because, despite the mediocre record of such forecasts, they are the best forecasts available.

Knight (1921) distinguished between uncertainty and risk on the basis of the probability distribution governing outcomes. Risk refers to uncertain events, where the distribution of outcomes is known. We know the distribution of outcomes when we throw the dice or flip a coin. Uncertainty refers to events for which the distribution of outcomes is unknown and the basis for classification is tenuous. What is the probability that some of the technologies in which we invest today will be obsolete tomorrow? How can we know whether someone, somewhere is working on a better solution or product? When making decisions, we act as if the probability distributions are well behaved, when they are not.\textsuperscript{4}

Forecasting changes in productivity growth is not risky in Knight's sense. It is uncertain. We do not know, and cannot know, how many new innovations will be built on existing knowledge. How many will be successfully introduced? How many will be initiated, with economic rents competed away, raising productivity growth but not economic profits?

Unlike the rational bubble model, in this model expectations are based on imperfect knowledge of future fundamentals such as profits. Unlike the irrational exuberance model, systematic changes in fundamentals are critical. Investors and speculators may grossly overestimate (or underestimate) future profits and dividends, but they rely on their imprecise

\textsuperscript{3} A more complete exposition of the model in this section is Meltzer (1982).
\textsuperscript{4} John Maynard Keynes held a similar interpretation of risk and uncertainty to Knight's.
knowledge of the future and correct, perhaps over-correct, when new information becomes available.

Policy implications

Let me turn now to some policy implications. I have sketched the alternative model because its policy implications are very different from the implications of the bubble explanation of asset prices. I will compare the two.

If the bubble model is correct, much of the rise in stock market valuations in the past few years was unrelated to economic fundamentals. Since asset prices affect decisions to merge, invest, and consume, these decisions, basic to any rational allocation, were distorted. It makes sense, indeed it would be desirable, for the government or the Federal Reserve to prevent the rise in asset prices caused by the bubble, or, failing that, to break the bubble.

This line of reasoning presupposes that our models, or the government's, can identify the bubble component with enough accuracy to improve on the market's decisions. Or, failing that, policymakers can tell the public that they regard the rise in asset prices as independent of fundamentals.

In 1996, at an American Enterprise Institute dinner, the Federal Reserve, in the person of Alan Greenspan, did exactly that. He suggested to the public that the rise in the prices of shares traded on U.S. exchanges was due, in considerable part, to irrational exuberance. His statement circulated widely but had no lasting impact.

I had spent part of the previous summer and fall in the library of the Board of Governors' building. Several staff members questioned me about whether I thought there was a bubble in stock prices. I suspect that their models suggested an affirmative answer to that question. I cannot be certain, but I can attest that several of the staff worried about a repeat of the 1929 stock market break.

Some market participants explain that the Federal Reserve's failure to raise interest rates after the chairman's speech is the reason that the market's response to Chairman Greenspan's 1996 statement was short-lived. This explanation suggests that the initial decline occurred because investors and speculators anticipated an increase in interest rates. When the increase did not come, market prices resumed their increase. Notice that this explanation suggests that the change in interest rates, a systematic force or its absence, not just expectations, was one of the
driving forces for stock prices. The other was the expectation of a continued high rate of earnings growth. When estimates of earnings growth collapsed for firms using the new technology, such as dot coms, so did their share prices.

The alternative explanation emphasizes uncertainty about the future and the incomplete information that characterizes estimates of future earnings and asset prices. Policymakers do not typically have superior information, so they have no basis for intervening in asset markets. I believe the emphasis this model places on uncertainty, in the Keynes-Knight sense, corresponds well to behavior on asset markets. The model emphasizes the difficulty of separating purely random changes from the systematic forces governing earnings and asset prices. It recognizes that investors may misread signals and, as a result, misallocate capital. But it recognizes also that these errors are found only ex post and cannot be prevented. It is only after the fact that we clearly see the upper and lower turning points and can be reasonably certain that a given change was a transitory, random movement around a fixed mean rather than a permanent change in the mean or its growth rate.

A very different line of reasoning suggests that asset prices contain information about future inflation. This is certainly an implication of the models I worked on for many years with Karl Brunner. See, e.g., Brunner and Meltzer (1989). In those models, asset prices respond to monetary and fiscal policy actions but also to changes in the expected return to real capital and the size of the capital stock. These general equilibrium models of money, bonds and capital give no support to recent proposals urging policymakers to respond to asset price changes. These models can be consistent with the "fat tails" found in most asset price distributions.

It is true in these models, as I believe it is in fact, that asset prices reflect anticipations of inflation and that the response of asset prices with low transaction costs typically occurs before there is an increase in the prices of many goods and most services. But asset prices also rise for reasons unrelated to inflation. There is no reason to presume that policymakers are more capable of extracting the response of asset prices to monetary expansion or identifying inflationary and non-inflationary components as they arise. One can imagine, and perhaps hope, that, in the future, economists will develop techniques that reliably separate the determinants of asset prices. When a reliable rule of this kind can be written, the information in asset prices can be used to increase the accuracy of inflation forecasts.
We are not there. We are not even close to having a useful model of asset prices that separates the various sources of change. Bubble explanations do not offer a consistent explanation of buyers and sellers. The absence of serious discussion of alternatives to rational bubbles, or irrational bubbles, may suggest how far we have to go. I have sketched such an alternative. Doubtless there are others. Testing those alternative hypotheses could do more to advance our discipline than continued work on empty propositions about rational bubbles or irrational behavior.

One policy lesson has been reinforced by recent experience. Asset price declines, even large declines, need not be followed by output or consumption price deflation or by deep, and lasting recessions. The stock market decline in 1987 and the Nasdaq decline in 2000 were not the prelude to major recessions or deflations, as in the 1930s or Japan in the 1990s. The difference is explained mainly by the difference in policy action. Expansive policies, especially monetary policy, prevented a recession in 1987 or 1988 and possibly in 2001.

The decline in the Nasdaq index after March 2000 is of similar order to the decline in the Nikkei beginning in 1990. The policy response was very different. This comparison, and the 1987 experience, suggest that expansive economic policies can compensate for any deflationary impulse on output prices coming from asset prices.
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