A Theory of Asset Price Booms and Busts and the Uncertain Return to Innovation*

BY SATYAJIT CHATTERJEE

Many observers believe that turbulence in asset prices results from bouts of optimism and pessimism among investors that have little to do with economic reality. While psychology and emotions are no doubt important motivators of human actions, an explanation for asset price booms and busts that ignores the fact that humans are also *thinking* animals does not seem entirely satisfactory or plausible. In this article, Satyajit Chatterjee presents a counterpoint to the view that "it's all psychology." He reports on a theory of asset price booms and busts that is based entirely on rational decision-making and devoid of psychological elements. The explanation suggests that asset price booms and crashes are most likely to occur when the value of the asset in question depends on an innovation whose full profit potential is initially unknown to investors.

Asset prices, such as the price of company stock, the price of houses in a particular location, or the price of a foreign currency, can often rise strongly for many periods and then crash spectacularly. Does such turbulence in asset prices result from irrational behavior on the part of market participants, or does it have a basis in rational behavior?

Many observers believe that the turbulence in asset prices results from bouts of optimism and pessimism among investors that have little to do with economic reality. More than 60 years ago, John Maynard Keynes attributed these highs and lows in the stock market to the "animal spirits" that motivate humans to collectively take on or shun financial risk. Given the recent history of booms and crashes in the industrialized world, the influence of mass psychology on asset prices has once again come to the fore. People wonder how much of the frenetic buying and selling in capital markets around the world serves any useful social purpose.

While psychology and emotions are no doubt important motivators of human actions, an explanation for asset price booms and busts that ignores the fact that humans are also *thinking* animals does not seem entirely satisfactory or plausible. Why would investors believe that an asset will rise strongly in value unless there is, at some level, a good reason for such a belief? As a counterpoint to the view that "it's all psychology," this article reports on a theory of asset price booms and busts that is based entirely on rational decision-making and devoid of psychological elements. The explanation suggests that asset price booms and crashes are most likely to occur when the value of the asset in question depends on an innovation whose full profit potential is initially unknown to investors. As investors learn over time about what that earnings potential is, the price of the asset can rise strongly for a while and then crash. As an example, think of the advent of the World Wide Web in 1990, an innovation that opened the door to the commercialization of the Internet.[1] Initially, it was not evident

Satyajit Chatterjee is a senior economic advisor and economist in the Philadelphia Fed's Research Department. This article is available free of charge at www.philadelphiafed.org/research-and-data/publications.

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[1] The concept of the World Wide Web (or simply the web) was proposed by the English computer scientist Tim Berners-Lee and the Belgian computer scientist Robert Cailliau in 1990. The originators conceived of the web as a vast information repository that anyone anywhere in the world could access via the Internet.

how to make money using the web, but many new ideas were tried and investors and entrepreneurs learned over time what worked and what did not.

PRIMER ON THE DETERMINATION OF ASSET PRICES

What theory do economists use to discuss the determination of asset prices? The most basic and simplest of such theories asserts that the price an investor will pay to buy an asset today is related to the dividend the investor expects to receive on the asset in the future and the price at which he expects to sell the asset at a future date. An example will make this clear. Suppose that a single share in the stock of company X promises to pay $5 in dividends one year from today. Also suppose that investors expect the price of this single stock to be $100 a year from today. Ignoring taxes, an investor who can put his money in the bank and earn a 5 percent interest rate will not be willing to pay more than $100 for the stock today. If he paid $100, he will earn $5 in dividends and then sell the asset for $100. Therefore, he will have $105 from his investment a year from today. He can get the same dollar amount by saving $100 in the bank and earning a 5 percent return on it. Therefore, the market price of the asset cannot exceed $100. The market price of the asset cannot fall below $100 either because, if it did, then all investors who currently have their money in the bank would be better off removing their funds from the bank and buying the asset. They would earn a higher rate of return on the stock than on their bank accounts.

A bit more formally, the theory asserts that the current price of the asset, call it P, is simply the present discounted value of the dividend to be given out next period, call it D, plus the expected price of the asset next period, call it P^e. As we just saw, it must be the case that the amount one can earn by keeping the money in the bank, namely, P(1+r) (where r is the interest rate on the bank deposit), must equal the amount one can earn from the stock, namely, $[D+P^e]$. Therefore, P(1+r) must equal $[(D+P^e]$, so P must equal $[D+P^e]\div(1+r)$. The essence of the economic theory of asset price determination is the idea that the rate of return on different but equally risky assets should be equalized. In

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the above example, we assumed that the return from holding the stock for one year was perfectly certain so that the rate of return on the stock had to equal the interest rate on bank deposits. If the return on the stock is uncertain, the theory takes into account that investors would demand a higher rate of return on the risky asset as compensation for bearing that risk and the price of the stock will be correspondingly lower, resulting in an expected capital gain.

DIVIDEND GROWTH AND GROWTH IN ASSET PRICES

This simple theory of asset price determination, when coupled with a theory of how expectations about the next period's asset price are formed, makes predictions about the level and growth of asset prices that depend only on fundamentals, in this case the dividend flow from the asset and the interest rate on bank accounts. This connection between fundamentals and asset prices can be somewhat subtle, and we will approach it through some simple examples.

Imagine that the dividend from the stock is the same each period and the interest rate on bank deposits is constant over time. In this situation, an investor might reason that whatever the price of the asset is today, it will be the same in the next period. After all, if neither the dividend nor the interest rate changes, why should the price of the asset change? This kind of reasoning — which is at the heart of the theory of expectation formation that economists call *rational expectations* — leads to the prediction that the price of the asset will be the (constant) dividend flow D divided by the (constant) interest rate r.[2]

However, if dividends are growing over time at some constant rate and the interest rate is constant over time, the same investor might now reason that since the asset is becoming more profitable over time, its price should increase over time at the same constant rate as that of dividends. With this guess about the behavior of future asset prices, the theory predicts that the price of the asset in period t will be the dividend to be given out next period, D, divided by the difference between the interest rate, r, and the growth rate of dividends, g. That is, the current asset price will simply be D divided by (r-g). Since the dividend given out each period is growing over time at rate g, this

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[2] This formula can be obtained by solving the equation P = [D+P]/[1+r] for P (in terms of D and r). The investor's guess that if the dividend flow and the interest rate are both constant over time then the price of the asset will be constant over time is employed to replace P^e (the future price) with P (the current price). Notice that the investor's guess that the future price of the asset will be the same as it is today is indeed verified by the resulting formula for P: the formula depends only on D and r, both of which are constant over time.

formula confirms the investor's guess that the asset price will grow at the same constant rate as dividends.[3]

Thus, the simple theory of asset price determination links the growth in asset prices to the growth in dividends. But this simple theory does not come to grips with the behavior of asset prices during a boom. During a boom, asset prices seem to grow faster than the growth rate of dividends. As an example of this phenomenon, Figure 1 displays the time paths of the logarithm of the S&P 500 index and of the logarithm of earnings per share for the index for the period around the tech boom.[4] On a logarithmic scale, steeper lines imply faster growth, and we can see that between 1995 and 2001, the index grew at a faster rate, while the growth in earnings did not show any tendency to grow faster.

One can see the increase in the growth rate of stock prices even more clearly in the time path of the NASDAQ composite index.[5] Figure 2 plots the logarithm of the NASDAQ index for the same time period as in Figure 1. Between 1990 and 1995, the time path is more or less a straight line, which implies that the index grew at a roughly constant rate. Following 1995, however, the angle of the path tilts up, implying faster growth in asset prices. This continues until the market crash we associate with the end of the dot-com boom. Unfortunately, there is no easily available series on earnings

FIGURE 1

Earnings and Stock Prices: S&P 500

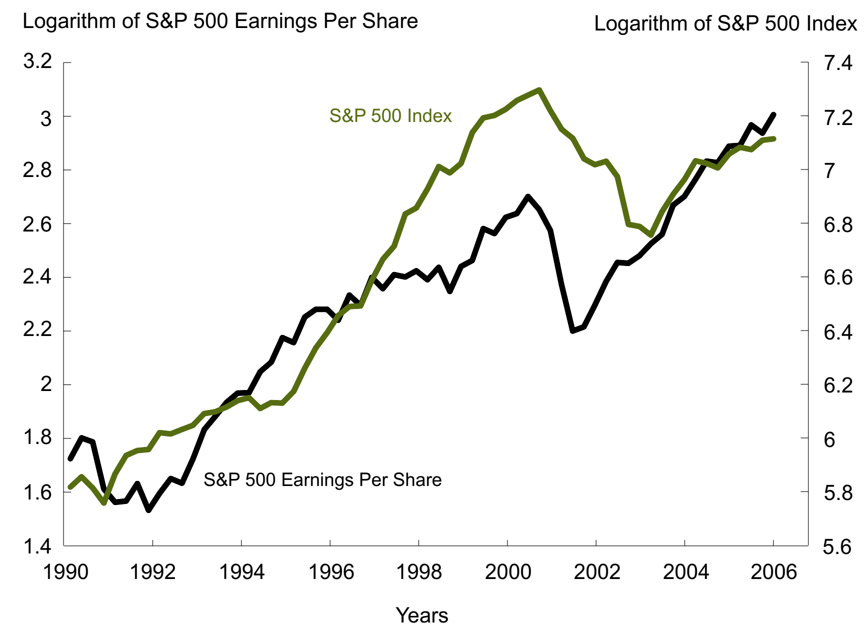
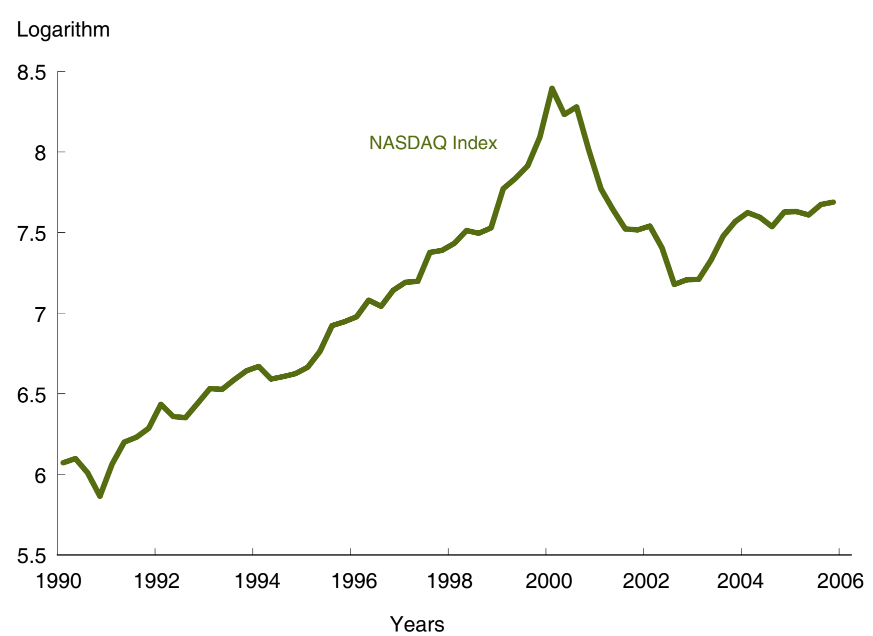


FIGURE 2

NASDAQ Index: Boom and Crash



[3] It is perhaps worth pointing out that the interest rate available on a bank account will typically depend on the dividend flow from other investments available in the economy. So, r and g will not be independent of each other. Indeed, the dependence of the interest rate on the dividend flow available in the economy is what guarantees that the interest rate, r, will always be greater than the growth rate, g. Without this ordering, the formula gives nonsensical results.

[4] The S&P 500 index is proportional to the average stock price of 500 large U.S.-based corporations whose shares are traded on U.S. stock markets. The theory outlined in the text applies equally well to such averages.

[5] The NASDAQ index is the average stock price of over 3,000 corporations (not necessarily U.S. based) whose shares are traded on U.S. stock markets and that are oriented toward high-technology areas.

growth for the NASDAQ index, but all anecdotal evidence suggests that there was no corresponding speed-up in the growth rate of earnings.

The apparent disconnect between the growth rate of fundamentals (in this case, earnings) and the growth rate of asset prices makes observers think that something other than fundamentals ("animal spirits" or mass psychology) is at work. While mass psychology may well influence asset prices, it turns out that the simple theory of asset price determination outlined above can shed considerable light on the origin and mechanics of asset price booms and crashes.

The key insight is that market participants' beliefs regarding how *long* dividend growth will continue may play a crucial role in generating an asset price boom and crash.[6] When there is an innovation, such as the World Wide Web, investors may be uncertain about the full profit potential of the innovation — that is, they do not know in advance how far, or in what ways, the World Wide Web can be used for commerce. This creates uncertainty about the duration of earnings growth. As the innovation continues to diffuse through the economy and earnings continue to grow, investors revise up their estimate of the profit potential of the innovation. This upward revision may temporarily make the asset price rise faster than earnings. When earnings growth comes to a halt and investors learn the limits of the innovation, the asset price crashes. Thus, a boom can happen without a speed-up in earnings growth, while the cessation of earnings growth can result in a crash.[7] These ideas are fleshed out in the next two sections.

Cessation of Dividend Growth Can Induce an Asset Price Crash. As we have seen already, growth in dividends increases the price of the asset because the asset becomes more profitable for investors. Therefore, in order to value the asset today investors have to form beliefs about future dividend *growth*. In this situation, uncertainty about whether growth in dividends will continue or stop can have surprising consequences for the price of the asset.

Imagine that investors put a 50 percent probability on dividend growth coming to a stop next period and a 50 percent probability that dividends will continue to grow at the same rate as in the past. Then, if the growth in dividends does stop next period, the theory of asset price determination predicts that the price of the asset will *fall.* At first sight this might seem puzzling because the profitability of the asset hasn't fallen: The asset is generating the same dividend flow as it did in the previous period. However, investors yesterday had put an equal chance on dividends continuing to *grow* today and the price of the asset yesterday reflected that expectation. If dividends fail to grow today, the asset becomes less valuable to investors today compared with yesterday. Thus, the mere cessation of dividend growth will cause the asset price to fall.

Can uncertainty about the duration of dividend growth explain asset price booms and crashes? That is, can it provide an explanation for the phenomena displayed in Figures 1 and 2? To explore this question, we will work with a simple example. The interest rate available on bank accounts is taken to be 1 percent per quarter. Suppose that there is an asset whose dividend flow is currently $100. Next quarter, there is a ¾ probability that the asset's dividend flow will increase by 5 percent (i.e., rise to $105) and there is a ¼ probability that its dividend flow will stop growing and stay at $100 forever. If the dividend flow increases next quarter, the situation next quarter will be the same as in the current quarter: namely, there will be a ¾ probability that the dividend flow will increase by 5 percent again in the following quarter (to $110.25) and there will be a ¼ probability that the dividend flow will stabilize forever at $105. Thus, as long as dividends continue to grow, there is a constant probability that this growth will continue next period and a (complementary) constant probability that growth in dividends will come to a stop forever.

Figure 3 displays a snapshot of the time paths of the logarithms of

Can uncertainty about the duration of dividend growth explain asset price booms and crashes?

[6] This discussion draws on the 1999 article by Joseph Zeira.

[7] From the point of view of valuing an asset, the main quantity of interest is the growth rate of earnings. But to assess the validity of an earnings-growth forecast, investors will examine many sources of information. For instance, they may track the increase in the number of visitors to a website as an indicator of commercial interest. During the tech boom, investor interest in various measures of Internet use (such as the number of websites and the number of "hits" per website) was quite intense, and these measures were used to justify very optimistic earnings forecasts for Internet-related businesses. The point, however, is that such optimism could be sustained because investors were truly uncertain about the profit potential of this new way of conducting commerce.

dividends and asset prices predicted by the simple theory of asset price determination. The theory predicts that as long as dividends continue to grow, the price of the asset will grow at the same rate as the growth in dividends. In the figure, this is what happens for the periods preceding period 45: The time plot of the logarithm of asset prices and dividends rises at the same rate. At period 45, however, dividends stop growing, and the time plot of the dividend path flattens out. As displayed, the cessation of dividend growth causes a crash in the asset price. Following the crash, the time path of the asset price flattens out as well: Recall that the theory of asset price determination predicts that if dividends are constant over time, so will be the price of the asset.[8]

The crash in the asset price reflects investors' re-assessment of the profitability of the asset. Prior to the cessation of dividend growth, investors placed a three in four chance on dividend growth continuing into period 45, a nine in 16 chance of dividend growth continuing into period 46, a 27 in 64 chance of growth continuing into period 47 and so on.[9] Consequently, the price of the asset in period 44 incorporated investors' belief that dividends will continue to rise in period 45 and beyond with high probability. When these beliefs are belied by events, the price of the asset tumbles.

It appears, then, that the simple theory of asset price determination predicts sudden drops in asset prices that stem simply from a downward re-assessment of the *growth* potential of the earnings flow underlying the asset. Because the bad news that leads to the crash concerns diminished prospects for future growth, the asset price may fall even if the current dividend flow does not fall.

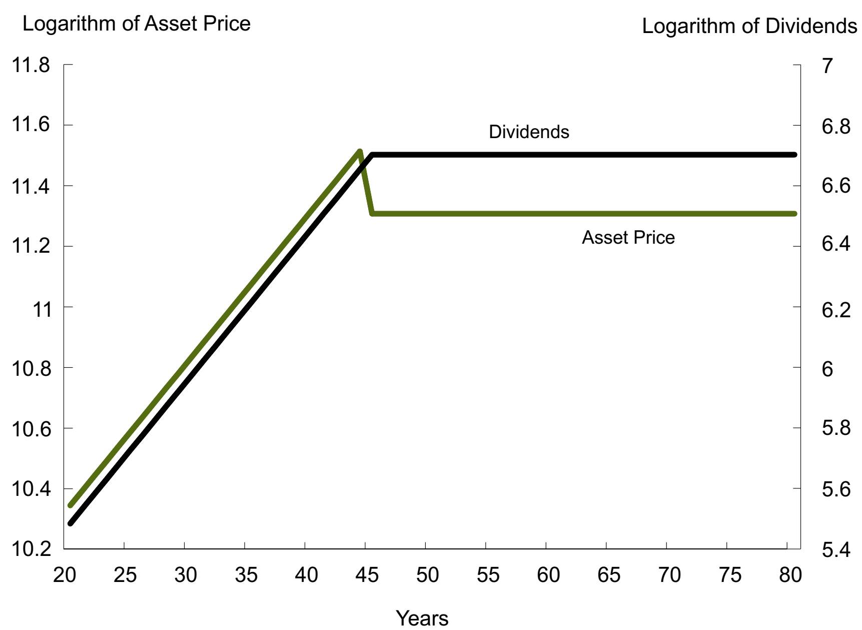
Learning About the Likely Duration of Dividend Growth Can Induce an Asset Price Boom and Crash. But how can this simple model of asset price determination account for the boom in the price of assets? As noted earlier, we cannot attempt to account for the tech boom in terms of faster dividend growth because there is no evidence of a speed-up in earnings growth during the boom phase.

It turns out that the model can account for the boom and the crash if we allow for the realistic possibility that investors' beliefs concerning the duration of dividend growth may evolve over time. Instead of imagining that investors assign a *constant* probability to dividend growth continuing (or, equivalently, a constant probability of it coming to an end), imagine that investors start off believing that dividend growth will last somewhere between eight and 15 years. That is, they believe that dividend growth will continue for sure until period 32 (since each period is a quarter, eight years amount to 32 quarters) and stop for sure by period 60. But they are uncertain about the duration of the expansion between these two dates.

Figure 4 displays the time plot of the logarithm of the asset price implied by these beliefs when dividend growth stops in period 45 (as before,

FIGURE 3

Asset Price Effects of a Cessation in Dividend Growth



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[8] It is worth pointing out that in this example, the growth rate of dividends exceeds the interest rate on bank accounts (5 percent versus 1 percent). Nevertheless, the simple theory of asset price determination applies because investors recognize that dividend growth will not continue forever. According to the theory, the growth rate of dividends can be higher than the interest rate as long as the product of the probability of growth continuing and (1+g) is less than (1+r).

[9] The nine in 16 chance comes from recognizing that the probability that dividends will grow for two consecutive periods is simply the product of ¾ and ¾, or $(3/4)^2$. Similarly, the probability that dividends will grow for three consecutive periods is $(3/4)^3$ or 27 in 64. More generally, the probability of n consecutive periods is $(3/4^{3})^{n}$.

FIGURE 4

Boom and Crash Effects of a Cessation in Dividend Growth

we assume that the interest rate is 1 percent per quarter). Notice that the time plot of the logarithm of asset price grows at more or less a constant rate until period 32. But after period 32 and until the crash in period 45, the growth rate of prices is *faster*, although there is no change in the growth rate of dividends.

This surprising outcome is the result of the evolution of investors' beliefs regarding the likelihood of the different dates at which the expansion might stop. To understand this point, notice that in period 32, an investor assigns a 1/28 chance that the expansion will continue to period 33, a 1/28 chance that it will continue to period 34, and so forth, because there are 28 possible dates (33 to 60) at which the expansion might stop and the investor is equally uncertain about at which date the expansion will stop. But once this investor learns that the expansion has, in fact, continued into period 33, he will assign a *higher* chance to the expansion's continuing to period 34 and beyond. This is because there are now only 27 possible dates left, and investors will assign each date a 1/27 chance. Thus, as the expansion continues, the investor will assign a higher and higher probability to the expansion's continuing to the fewer remaining dates.

What all this amounts to is that as the expansion continues beyond period 32, investors successively eliminate the possibility of relatively unfavorable outcomes in favor of an increase in the likelihood of relatively favorable ones. For instance, if the expansion continues on to period 35, investors know that the expansion will go on until some date that lies between periods 36 and 60. This is a more favorable assessment of the asset's earning potential than what investors believed in any earlier period. Of course, once the expansion stops, all of the remaining favorable outcomes to which investors had previously assigned a positive chance are eliminated, and that elimination results in a sharp fall in the price of the asset.[10]

There are some additional points worth making. First, the boom and crash scenario depends on the timing of the cessation of dividend growth. If the expansion in dividends continues all the way to period 60, there will be a boom but no crash: The price of the asset will simply stabilize at its peak value and stay at that level forever. At the other extreme, if the dividend expansion comes to a stop in period 33, there will be a crash but no boom. To get a boom-bust scenario, the expansion in dividends must last longer than the minimum period of expansion but less than the maximum period of expansion. Of course, in reality, investors cannot be completely certain about the minimum and maximum periods of expansion. But the explanation will work as long as the duration of the expansion falls somewhere near the "middle regions" of the set of possible outcomes.

Second, Figure 1 indicates that there was also a crash in operating earnings when the tech boom ended, something that is not true of the explanation given above. But this is not an important deviation between theory and fact. There was a crash in earnings because learning also affected corporate decisions. High-tech corporations discovered that they had invested "too much" in information and communications

[10] For the example shown in Figure 4, the average annual growth in asset prices prior to period 33 is 3.13 percent, the annual growth between periods 33 and 44 is 9.80 percent, and the drop in asset value at the time of the crash is 31 percent.

technology capacity because they too believed there was some chance that the expansion in profit opportunities would continue beyond 2001.[11] The write-offs related to this "excess investment" contributed to corporate bankruptcies and a drop in operating earnings. Consistent with this situation, there was also a crash in information and communication technology (ICT) investment, which, in turn, led to the brief recession of 2001-02. The recession contributed to the drop in corporate earnings as well.

Third, Figure 1 also shows that following the crash in prices and operating earnings, growth in earnings recovered quickly, which seems inconsistent with the theory outlined above. However, we have to recognize that an index as broad as the S&P 500 is affected by more than just the high-technology sector. As we are all too well aware now, the high-tech boom was followed closely by a boom in housing and construction. Although a variety of factors contributed to the housing boom and subsequent bust, at the center of the boom and crash was yet another innovation — this time in financial markets in the form of the securitized subprime mortgage.[12]

INNOVATIONS AND ASSET PRICE BOOMS AND CRASHES

The above explanation of a boom-bust scenario is special. It assumes that the uncertainty regarding dividend growth is of a particular kind (uncertainty regarding the duration of expansion) and that investors put an equal probability weight on the expansion's stopping between two fixed future time periods. However, it is also true that boom-bust scenarios do not happen all the time, which suggests that their occurrence requires a particular confluence of events. The important question to ask is: Under what circumstances are the assumptions of the theory likely to be met?

Imagine a situation in which there is a new discovery or innovation that is truly novel. For such an innovation, the past is a poor guide for judging the innovation's profit potential. Investors understand that the innovation will create new opportunities, but no one is certain about the innovation's ultimate profit potential. In this situation, the basic assumptions of the simple model outlined above seem plausible. Investors know that the innovation will generate new business opportunities over time (increasing profits or dividends) until, at some point in the future, the innovation's profit potential will stabilize and profits will stop growing (or will grow at the rate of growth of the overall economy). But no one knows when this stage of "normal" profits (or profit growth) will arrive, and past experience is of no help in making a guess. In this situation, the principle of indifference suggests that investors may well put an equal probability weight on the expansion's stopping any time between the two future dates.[13] This will be the case, for instance, if investors currently expect the expansion to last somewhere between five to 10 years.

Historically, booms in asset prices have, in fact, followed truly novel innovations or events. In describing the genesis of financial crises in Western Europe, the financial historian Charles Kindleberger summarizes the historical record thus: "The macroeconomic system receives a shock…a 'displacement'. This displacement can be monetary or real. What is significant is that it changes expectations in financial markets with respect to the profitability of some range of investments. New profit opportunities are opened up, and people move to take advantage of them."[14] Again, in another work, Kindleberger states: "The nature of the displacement varies from one speculative boom to another. It may be the outbreak or end of war, a bumper harvest or crop failure, the widespread adoption of an invention with pervasive effects — canals, railroads, the automobile — some political event or surprising financial

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[11] See Robert Gordon's article on how ICT capacity outstripped ICT demand and led to corporate bankruptcies and a slowdown in ICT investment in early 2000.

[12] See the book by Gary Gorton for a discussion of the nature of the financial innovation in mortgage markets that, in part, contributed to the housing boom and, ultimately, to the current mortgage crisis.

[13] The "principle of indifference" asserts that if there is no knowledge indicating that any one outcome among N possible outcomes is more likely than another, each outcome should be assigned an equal chance of occurring, namely, a chance of 1/N.

[14] Kindleberger, 1993, p. 524.

success, or a debt conversion that precipitously lowers interest rates. But whatever the source of the displacement, if it is sufficiently large and pervasive, it will alter the economic outlook by changing profit opportunities in at least one important sector of the economy. Displacement brings opportunities for profit in some new or existing lines, and closes out others. As a result, business firms and individuals with savings or credit seek to take advantage of the former and retreat from the latter. If the new opportunities dominate those that lose, investment and production pick up. A boom is under way."[15]

The boom in house prices in the mid to late 2000s can, in part, be traced to a financial innovation — the securitized subprime mortgage — whose true profit potential was initially unknown. The tech boom of the 1990s was a direct consequence of the spread of ICT and the rise of the World Wide Web. The boom of the 1920s could arguably be traced to the revolutionary effects of the automobile. The boom of the 1850s (in the U.S.) could be traced to the revolutionary effects of railroads. Arguably, each of these booms ended in a crash when investors came to a more precise understanding of the innovation's profit potential.

[15] Kindleberger, 1978, p. 18.

The explanation for the boom-bust scenario described in this article is based on the fact that investors learn about the asset's profit potential over time. And what they learn can cause them to strongly revise their perception of the asset's value. The basic idea regarding the role of learning is present in other studies that go beyond the simple model discussed above. For instance, researchers have shown that the transaction costs of trading in financial markets coupled with learning about an asset's profitability over time can lead to abrupt and sharp movements in asset prices, so that asset prices may appear to be much more volatile than the flow of dividends.[16] This finding is important because the low variability of dividend flow compared with the high variability of asset prices is often taken as evidence that fundamentals (i.e., dividend flow) have little to do with asset price fluctuations.

[16] See the article by In Ho Lee for a discussion of this point. As the author explains, transaction costs can keep an investor from immediately trading on new information that becomes available to him. Thus, information relevant to the value of the asset can remain hidden until some shock (which could be relatively minor) forces all investors who had refrained from trading to trade. At that point, information that was hitherto dispersed and hidden among investors gets reflected in the price, which can cause the price to change abruptly.

SUMMARY

There is considerable circumstantial evidence supporting the notion that asset price booms and busts follow the advent of novel innovations that are expected to have pervasive effects on the economy. If this is accepted as a starting point for further analysis, the problem becomes one of understanding why and how innovation and novelty generate asset booms and busts. The simple model outlined above provides one explanation. It stresses the fact that truly novel innovations create uncertainty in the mind of investors regarding the innovation's ultimate profit potential, and the resolution of this uncertainty can first lead to a boom and then a crash.

The informational theory of booms and busts suggests that such episodes are inevitable, since they arise from deep-seated forces governing the evolution of industrial economies. It implies that there is more than a grain of truth to the notion that boom-bust scenarios are unique ("this time it's different") in that these episodes result from circumstances that are truly novel, such as the advent of railroads, the automobile, the personal computer, and the Internet.

REFERENCES

Gordon, Robert J. "Hi-Tech Innovation and Productivity Growth: Does Supply Create Its Own Demand?" NBER Working Paper 9437 (2003).

Gorton, Gary B. *Slapped by the Invisible Hand: The Panic of 2007.* Oxford: Oxford University Press, 2010.

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

Kindleberger, Charles P. *A Financial History of Western Europe*, Second Edition. Oxford: Oxford University Press, 1993.

Lee, In Ho. "Market Crashes and Informational Avalanches," *Review of Economic Studies*, 65:4 (1998), pp. 741-59.

Zeira, Joseph. "Informational Overshooting, Booms and Crashes," *Journal of Monetary Economics*, 43 (1999), pp. 237-57.