Leverage Cycle Theory of Economic Crises and Booms

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Summary

Traditionally, booms and busts have been attributed to *investors'* excessive or insufficient demand, irrational exuberance and panics, or fraud. The leverage cycle begins with the observation that much of demand is facilitated by borrowing and that crashes often occur simultaneously with the withdrawal of *lending*. Uncertainty scares lenders before investors.

Lenders are worried about default and therefore attach credit terms like collateral or minimum credit ratings to their contracts. The credit surface, depicting interest rates as a function of the credit terms, emerges in leverage cycle equilibrium. The leverage cycle is about booms when credit terms, especially collateral, are chosen to be loose, and busts when they suddenly become tight, in contrast to the traditional fixation on *the* (riskless) interest rate.

Leverage cycle crashes are triggered at the top of the cycle by scary bad news, which has three effects. The bad news reduces every agent's valuation of the asset. The increased uncertainty steepens the credit surface, causing leverage to plummet on new loans, explaining the withdrawal of credit. The high valuation leveraged investors holding the asset lose wealth when the price falls; if their debts are due, they lose liquid wealth and face margin calls. Each effect feeds back and exacerbates the others and increases the uncertainty.

The credit surface is steeper for long loans than short loans because uncertainty is higher. Investors respond by borrowing short, creating a maturity mismatch and voluntarily exposing themselves to margin calls. When uncertainty rises, the credit surface steepens more for low credit rating agents than for high rated agents, leading to more inequality..

The leverage cycle also applies to banks, leading to a theory of insolvency runs rather than panic runs. The leverage cycle policy implication for banks is that there should be transparency, which will induce depositors or regulators to hold down bank leverage before insolvency is reached. This is contrary to the view that opaqueness is a virtue of banks because it lessens panic.

Keywords: collateral, credit terms, credit surface, volatility, margin call, maturity mismatch

Subjects: Economic Development, Economic History, Economic Theory and Mathematical Models

Crashes in History

Throughout history, there have been many sudden financial crashes, of famous firms or entire economies. In November 2022, the legendary cryptocurrency trader Sam Bankman-Fried's US$32 billion Alameda–Future Exchange(FTX) empire collapsed, apparently out of the blue, as cryptocurrencies declined. In September 2022, just after the new Truss government announced a tax cut, the British pension system nearly imploded, leading the British central bank to intervene and the newly elected Truss government to fall just 6 weeks after taking office. How and why do these market crashes happen so suddenly and with so little warning?

In early 2020, the Dow Jones plunged 18% and the mortgage markets completely froze, necessitating the biggest Federal Reserve intervention in history. Of course, COVID-19 darkened the mood of investors, but no dramatic new information caused markets to suddenly seize up on March 23.

Another good example is taxi medallions in New York City, which increased in value from about US$200,000 in 2002 to over US$1 million in 2014, then crashed in value to $160,000 in 2016. During the run-up in prices, neither the number of medallions nor the population of the city changed much. The crash, of course, followed the advent of Uber. But taxi cab income only declined about 10%.

In 2007, the subprime mortgage market collapsed, and over the next 2 years, the Dow Jones plunged 45% and the Great Recession took hold. In retrospect, the only noteworthy preceding news seems to be the subprime delinquency reports, which showed delinquencies in the range of 4%–5% instead of 2%.

Other examples are the sudden crash of the famous American hedge fund Long Term Capital in 1998 on the heels of the late 1997 Asian market bond crisis, and the derivatives crisis of 1994 that led to the closing of Kidder Peabody. More famous examples include the 1980s Japan boom and crash, the 1920s' Florida land boom and crash, and the Tulip bulb craze of 1637, in which tulips reached a price of nearly US$1 million in 2023 dollars before suddenly crashing.

Of course some crashes occur because the world changes, and have nothing to do with lending, like the tech bust in 2000. Lending did play a significant role in many of the most damaging crashes, including the Great Financial Crisis that began in 2007-09.

The Usual Explanations

There are three standard explanations of the cause of the 2007–2009 crisis.[1] The first is corruption or greed, greed that overtook the banks, then the mortgage brokers, then the rating agencies, then the bondholders, and then the borrowers. One can see these forces at work in the movie *The Big Short*.

A second explanation is that a panic exploded in 2008 and 2009, causing a run on banks, money markets, and collateral. According to the second theory, the only way to stem the panic was to restore confidence, as former Fed chairman Ben Bernanke explained in his book *The Courage to Act* and Treasury Secretary Timothy Geithner argued in his book *Stress Test*.

A third explanation is irrational exuberance, as in Bob Shiller's psychological narrative explanation of markets. People talked as if housing prices could never do anything but go up. Then the narrative changed, and people thought they would go down.

Similar stories are told about all the booms and busts mentioned earlier. Bankman-Fried allegedly was a crook and a fraud, and then when word got out that there was trouble, the depositors panicked. The taxi medallion crash, which left thousands of New York cab drivers penniless, was said to be the result of a great conspiracy to defraud them. The Japanese and Florida land booms, as well as the Tulip craze, are all attributed to irrational frenzies by investors.

There is surely some truth to all these explanations. However, neither greed nor panic nor irrationality can be legislated away, or prevented, by macroprudential policy.[2] There is also another underlying mechanism that is common to all these booms and busts. In every one of them, investors were able to spend so much money buying assets because they borrowed most of the money, using the assets themselves as collateral. Nobody paid a million dollars in cash for a tulip or a taxi medallion. The crashes always occurred simultaneously with the lenders withdrawing their loans.

Traditional macroeconomists since Keynes have attributed economic booms and busts to excessive or insufficient demand, somewhat reminiscent of the third explanation for market booms and crashes. The very language economists and journalists use to describe these episodes invariably refers to investors' animal spirits, irrational exuberance, risk appetite, or precautionary savings. According to the traditional theory, these ups and downs can be smoothed over by raising the interest rate when demand is too high and lowering the interest rate when demand is too low.

The trouble with this demand-centric and riskless interest rate-centric view of macroeconomics is that it leaves unanswered what we mean by tight credit, if not just a high interest rate. When business people talk about tight credit, they do not mean that the riskless interest rate set by the Fed is too high. Default, and especially lenders' fear of default, is what is missing in the traditional macroeconomics theory. During a crisis, investors do not stop demanding loans at the riskless interest rate. If anything, they want more. They cannot get a loan of the size they want at the riskless rate, or anything close to it, because lenders are afraid they might default.

The Leverage Cycle

At the World Econometric Society Congress of 2000, long before the crisis of 2007–2009, Geanakoplos proposed another theory of booms and crashes: the leverage cycle, caused by a buildup of too much leverage and then a faster de-leveraging.[3] Rising leverage leads to rising asset prices, making the economy progressively more vulnerable so that eventually a little bit of "scary bad news" can trigger a great crash. If the asset prices end up far enough below the debts, then a failure to partially forgive underwater debtors can create more losses.[4]

Between 2000 and the 2007–2009 crisis, leverage did indeed rise in the banks and in households, and so did housing and mortgage-backed securities prices. Then leverage and asset prices collapsed. Eventually, leverage and asset prices recovered. The failure to forgive a nonnegligible amount of mortgage debt did, in some people's opinion, delay the recovery and stirred resentment that lingers today. Unlike greed and panic, the leverage cycle crash can be prevented by wise public policy.

The leverage cycle begins with the observation that much of demand is facilitated by lending. Just as Shakespeare's *Merchant of Venice* is superficially about the merchant-investor Antonio but is also about the lender Shylock, so booms and busts are also about changes in lending terms.

Once default is recognized as a possibility, lenders should be expected to require additional terms for a loan, like a maximum debt to income (DTI), or a minimum credit score (which for individuals is usually set by FICO- Fair Isaacs Corporation). The most important requirement is usually collateral, and the focus is on collateral here. According to the leverage cycle theory, fluctuations in lending standards are the defining feature and perhaps the primary cause of many cycles.

Busts, and especially crashes, are typically accompanied by increased uncertainty. When uncertainty rises, investors see not only more downside risk but also more upside potential. Lenders, by comparison, do not share in the upside; they see bigger downside losses. Lenders therefore have a bigger incentive than investors to change their behavior. They ask for more collateral, or equivalently, they withdraw funds. In the leverage cycle, the bust does not come from the panic of investors but the margin calls of lenders.

If an $80 loan requires collateral of $100, then we say that the collateral rate is 125%, the loan to value (LTV) is 80%, the margin or downpayment is 20%, and the asset leverage is 5, since $20 cash can allow for the purchase of an asset worth $100. All of these amount to the same thing. It has been known for centuries that more leverage leads to more risk. If the collateral falls in value to $99, and the $80 loan is paid off, the borrower is left with $19 out of his original $20. A 1% fall in the collateral price leads to a 5% fall in investor capital, which is in the same ratio as the leverage.

Investor debt/equity leverage is the ratio of debt owed by an investor to net worth. It is closely related to asset leverage, but distinct. One difference is that scary bad news about assets will typically lower net worth and thus *raise* investor leverage, while at the same time *lowering* the leverage available on *new* purchases of assets. For this reason we shall always mean asset leverage when we refer to leverage.

The Elements of the Leverage Cycle

Twenty-two elements of the leverage cycle from Geanakoplos (1997, 2003, 2010a, 2010b, 2016) and its extensions in Fostel and Geanakoplos (2008, 2012a, 2012b, 2014, 2015, 2016) and Geanakoplos and Zame (2014) are briefly described here and then elaborated more carefully in the following sections.

The first idea in the leverage cycle is that more leverage causes higher collateral prices. Simply put, if agents can borrow more to buy an asset, demand will increase and the price will rise. A blue house that can be used as collateral for a mortgage will sell for more than an identical red house that cannot. This runs contrary to a long tradition in economics epitomized by the celebrated Modiglian–Miller (M-M) theorem, which asserts that leverage does not affect the value of a firm. The only precedents for this contrary view seem to be in the work of Minsky (1977) and the economic historian Kindleberger (1978). Neither of these authors used a mathematical model to express his ideas, and neither had collateral explicitly in mind (Minsky was talking about a firm borrowing money, and by leverage, he meant a ratio of debt payments to income).[5] Both of them made the extrapolative (irrational) expectations of borrowers the linchpin of their theories.

The second idea (which extends the first) is that leverage can cause the prices of collateral to rise even higher than they would in a first-best world of unlimited trust and complete markets. Leverage can create a boom, in which collateral is priced much higher than the marginal consumption (or production) utility it brings to any owner. This, again, is contrary to the vision of some of the early pioneers of collateral studies who argued that when the borrowing is for the purpose of buying the collateral, trust limitations on borrowing would necessarily lower the collateral prices and curtail investment. They overlooked the important point that in the second-best world, where collateral is needed to guarantee the delivery of promises, collateral gains an added *collateral value* precisely because it is scarce collateral. In the first-best world it is possible to borrow without owning collateral, and to bet on collateral prices rising without actually owning the collateral, for example via options (Arrow securities!), while in the second-best world of reality, borrowing or betting might require the leveraged purchase of collateral, which boosts its price.

The third idea in the leverage cycle is that equilibrium in credit markets is not described by an interest rate but by an entire credit surface mapping every potential vector of credit terms into a different interest rate. Each different level of leverage corresponds to its own interest rate. In general, it makes no sense to talk about *the* interest rate. And it is a mistake to focus exclusively on the riskless interest rate.

Fourth, interest rates rise along the credit surface as leverage increases, in some cases so steeply that borrowers choose as if they had a hard leverage constraint. In those cases, a unique loan to value (LTV), and its corresponding interest rate, emerges. Binomial economies with financial assets fit this case.

The fifth idea in the leverage cycle is that leverage rises when uncertainty (more precisely, down risk) moderates and decreases when uncertainty or down risk rises, even more because of lender responses than buyer responses. It makes sense from the investor perspective to increase investment and borrowing when uncertainty declines. But much more is claimed, namely, that the credit surface gets looser when uncertainty abates so that for high leverage levels, the interest rate gets lower, despite the increased demand for borrowing. This can only be explained by the lenders increasing supply more than the investors increase demand. Uncertainty affects lenders more than investor-borrowers. Economists talk almost exclusively about *investors*' irrational exuberance or risk appetite or precautionary savings, overlooking the lenders. Uncertainty is both good and bad for an investor. For a lender, uncertainty worsens the downside but with no countervailing increased upside. It stands to reason that lenders should react more to uncertainty shocks than investors. The credit surface therefore steepens when uncertainty increases, compounding the precautionary incentive of investors to decrease leverage when facing increased uncertainty with a fixed credit surface by confronting them also with higher borrowing rates for the same leverage. In the cases with a hard LTV constraint, LTV goes down when uncertainty goes up.

Sixth, combining ideas one and five, when uncertainty goes down, collateral prices will go up, and when uncertainty goes up, collateral prices go down. When news is bad (about the expected future value of collateral) at the same time as uncertainty goes up, which Geanakoplos (2010b) called scary bad news, then collateral prices go down for two reasons. Similarly, on calming good news, collateral prices go up for two reasons. Somewhat surprisingly, the historical record seems to show that bad news does go hand in hand with increased uncertainty most of the time. This alternation between calming good news and scary bad news, resulting in leverage and prices going up together and then down together, is called the static leverage cycle.[10]

Seventh, the effect on prices of scary bad news (or calming good news) is greater in an already highly leveraged economy, because then there is an extra wealth effect. A leveraged purchase is a leveraged bet on the collateral price rising. When the price falls, the borrower-buyers lose their bet. Compared to where they would have been without the leveraged purchase, the leveragers are poorer. After getting repaid, the lender-sellers (lumped together) are richer. The transfer of wealth from high asset valuation agents to low valuation agents reinforces the forces in the static leverage cycle.[6] The real-time fluctuation in leverage, asset holdings, and asset prices is called the dynamic leverage cycle.

Thus, the collateral price falls after scary bad news for three reasons in the dynamic leverage cycle: the bad news (that makes everyone value it less), the transfer of wealth from high-valuation leveraged buyers to low-valuation lender-sellers, and the inability of old holders and new buyers to borrow much money.

Eighth, the mechanism that causes the *crash* in the dynamic leverage cycle is a margin call when old loans are coming due. A little bit of scary bad news can topple a highly indebted economy through two kinds of margin calls—one caused by the bad news reducing collateral prices and the other caused by the scary part of the news reducing leverage.[7] When the loans come due, the reckoning occurs because the borrowers need to find the money to repay the part of the loan that cannot be rolled over. In the first kind of margin call, lenders will have to reduce their borrowing (i.e., pay back part of their loan instead of rolling it over) to maintain the same LTV in the face of lower collateral prices. In the second kind of margin call, they will have to do the same to meet a lower LTV even if collateral prices are the same. If the leverage cycle theory of crashes had to be stated in a phrase of one or two words, it would not be panic; it would be margin call.

Ninth, the marginal propensity to hold the asset out of wealth is much higher for the leveraged buyers out of liquid wealth than out of wealth. At the extreme, collateral holders might have no way to raise cash to meet their margin calls except by selling the collateral (100% propensity) or reducing their consumption and rapidly driving up their marginal utility of consumption. Then the price fall is faster. Such a situation arises when investors specialize in one kind of asset or when margins rise across all their collateral. The crash comes when debts come due because that is when lenders have the opportunity to change LTVs and because the debt payments must come out of liquid wealth.

Tenth, the leverage cycle relies on the heterogeneity of agents in their valuation of the assets that serve as collateral and in their desire to borrow. This heterogeneity might arise from differences in risk aversion (the collateral is risky) or differences in their priors on how valuable the asset will be (optimists vs. pessimists) or differences in their utility of holding the asset (some like housing more than others) or differences in how productive they can make the asset (some people are better farmers than others) or differences in impatience (the asset enables borrowing).

Eleventh, because of the heterogeneity in valuations, the price of the asset can fall much more than any agent thinks the bad news warrants. Agents with the highest valuations are the ones who leverage the most and might go out of business in the crash. The new marginal buyer might have a much lower valuation than the old marginal buyer even if both buyers change their valuations by very little. Price is set by the marginal buyer, so the drop in price might be due more to the change in marginal buyer than to the change in any agent's valuation.[8]

Twelfth, debts, even on long-term assets, tend to be short term. This leads to much of the debt coming due over and over again, making the borrower-investors much more vulnerable to margin calls. The reason for this debt maturity mismatch is that lenders are willing to lend short term on much more favorable terms than on long term, because less can go wrong in the short term. The credit surface for long-dated debt is much steeper than the credit surface for short-term debt, even if the respective riskless rates are the same. Given this disparity in terms, borrowers choose to make themselves more vulnerable by borrowing short term. The credit surface resolves the puzzle of endogenizing the debt maturity mismatch.

Thirteenth, the crashing asset prices following scary bad news create a great opportunity for rich agents, or agents who can still borrow, to pick up bargains and make outsized returns. This does not contradict rational expectations. It illustrates that even risk-adjusted opportunities can be much higher at some moments than at other times.

Fourteenth, there are agents who are keenly aware of the opportunities to make outsized returns following a crisis. They hold their powder dry, waiting for their opportunity. The reason that their investments just following the crisis do not immediately pull the economy out of its fall is that they are so few in number. It is a rare investor who is optimistic enough to anticipate the opportunity after a crisis yet sufficiently pessimistic that they are willing to wait for a crisis.

Fifteenth, it is a well known but rarely explained empirical fact that asset prices fall faster than they rise. Although 20% crashes in prices over a day (say, for the stock market as a whole) rarely happen, 20% jumps in a day almost never happen. A leverage cycle explanation is that prices are more sensitive to shocks when the asset holders are highly leveraged, because that is when the wealth effect from the leveraged bet in the dynamic leverage cycle kicks in. When LTVs are close to 100%, they cannot rise much, but they can fall a long way, at precisely the most sensitive moment in the cycle. When LTVs are low, they can rise a long way, but by definition, this is at a less sensitive moment in the cycle.[9]

In March 2020, the LTVs on new structured mortgage loans plummeted almost overnight from 80% to 0%, and as a result, the mortgage Real Estate Investment Trust (REIT) sector almost collapsed. Overnight jumps in LTV of the same scale are never seen. Even if LTV jumped up as much, it would not increase prices as fast. After the Fed intervened, LTVs rose over a couple months to nearly their original levels by May 2020. But the return of prices was slower than the crash, because the REITs had deleveraged before the rebound in LTVs. The price rebound relied on new money coming in.

Sixteenth, another explanation in the leverage cycle for why price drops are much bigger than price jumps is that agents have heterogeneous priors.The most optimistic agents put greater weight on the high end of possible future prices, and they are the buyers. Because of leverage, relatively few buyers will be enough to hold all the assets and so even the marginal buyer (who sets the price) will be quite optimistic. A highly leveraged asset price will therefore lie near the top of the distribution of future possible prices, giving more room for price to fall than to rise.

A seventeenth idea is that the tranching and pyramiding of collateral is like leveraging on steroids. Each of them increases the value of collateral. During calm periods, financial innovations increase pyramiding and tranching and thus asset prices. This gets reversed in uncertain times.[11] Fostel and Geanakoplos (2012a, 2016) called this the financial innovation cycle.

Eighteenth, there are multiple kinds of collateral and, hence, multiple leverage cycles. One leverage cycle can spill over into another, even if the payoffs are completely independent. What seems like a flight to quality is sometimes better described as a flight to collateral.

A nineteenth idea is that the credit surface should be multidimensional, indexed by other credit terms such as credit rating in addition to LTV. A rise in uncertainty will make the totality of the credit terms tougher. Focusing only on one term, like leverage, drastically underestimates the credit terms effect that characterizes the leverage cycle. In fact, the leverage cycle might more accurately be called the credit terms cycle.

A twentieth idea is that monetary policy affects the whole of each different credit surface, even if it is directed at the riskless interest rate. The Fed needs to be aware that it might, for example, be affecting the whole of the corporate bond credit surface but only the high FICO end of the mortgage credit surface.

A twenty-first aspect of the leverage cycle is that increased uncertainty steepens the credit surface much more for low FICO individuals (and low credit rating corporations) than for high FICO agents, because their risk of default rises more. Crises will thus tend to worsen inequality. Government interventions like lowering the riskless interest rate tend to benefit only high FICO borrowers who are getting close to riskless interest rate loans.

Twenty-second, when loans are long term, a severe leverage cycle drop in collateral prices might leave many borrowers underwater. It is often good policy to partially forgive debt for underwater agents with low FICO scores, particularly homeowners. These borrowers have little incentive to repay more than the collateral is worth, since there is little room for their credit ratings to decline further. Once their houses are in the foreclosure process, they will not pay their mortgages or their house taxes, nor will they fix the house. They might even take the copper on their way out.

Partially forgiving can actually make lenders better off. Analogously, restructuring loans or resolving zombie corporations whose debt has not yet come due but who have no chance of repaying can be revitalizing.

Leverage Cycles Versus Panics: Bank Insolvency Runs Versus Bank Panic Runs

An alternative theory of market crashes likens them to bank panics, in which depositors run because they are worried that if they do not get their money out first, others depositors will take it themselves. According to this theory, the main goal of leaders should be to restore confidence, thereby moving the economy from a bad equilibrium to a good one. The theory has one central similarity with the leverage cycle in that it focuses attention on the lenders, or at least the depositors in banks and money market funds. In both theories, the lenders run away with, or substantially reduce, their loans in the crisis.

There are, however, important differences between the leverage cycle and the panic theories of crashes. In the leverage cycle, lenders increase margins (i.e., reduce their loans against the same collateral) because they anticipate that the collateral might not cover the old loan amount. As it pertains to banks, the leverage cycle could be called a theory of *insolvency runs*. Depositors regard the assets of the bank as collateral for their loans, and when they become aware that even with an orderly liquidation there is a risk that those assets may become insufficient to pay off their deposits, they will withdraw their money. By contrast, a panic bank run can occur even if the bank assets are certainly worth more than the assets, in an orderly liquidation, once depositors worry that other depositors will take their money out of the bank, forcing a disorderly liquidation of the assets.

The policy implications of the two theories regarding banks are very different. The leverage cycle theory of insolvency runs emphasizes transparency. The idea is that if the value of bank assets versus liabilities is public, pressure from depositors or regulators will force the bank to raise capital to restore safer LTV levels. Insolvency rarely comes all at once; it is generally a gradual process during which assets lose value a little bit at a time, say, because the Fed is raising interest rates or unemployment is rising. There is plenty of time to act before actual insolvency sets in, provided that people are aware of the growing problem. Bank run theorists argue the opposite, suggesting that opaqueness is a virtue because too much information might make depositors nervous and lead them to panic. Thus, banks are not required to mark many of their assets to market, which sometimes hides dwindling asset values. According to the leverage theory, efforts to forestall a panic run may make it more likely that there will be an insolvency run.

The main difference is that the leverage cycle applies to any situation involving collateral, whether or not it is connected to banks. The run-to-get-out-first story really only applies to banks. Collateral, unlike bank assets, is reserved for a single lender. No other lender can take a person's collateral by running. A margin call is the rational reaction to increased down risk, not an arbitrary panic that can be quieted by reassuring words that other depositors will not withdraw their loans.

The leverage cycle does not rely on irrational expectations. Nor does it rule them out. It might well be that in addition to rational expectations about changes in volatility, lenders might become irrationally exuberant or pessimistic. That would increase the amplitude of the leverage cycle.[12]

The leverage cycle does not rely on multiple equilibria, though it also has room for confidence and multiple equilibria.[13] But this has nothing to do with bank runs or first-mover advantages. The debt-fragility mechanism (described later), which makes prices fall faster than they rise, can also explain multiple equilibria when debts are big enough.

The Collateral Credit Surface

Default and Credit Terms Like Collateral

Default is missing in the traditional macroeconomics theory. Though defaults are most prevalent during crises, the possibility of default influences all credit transactions. Once the risk of default is recognized, we should expect lenders to require additional *credit terms* for a loan, like a maximum debt to income (DTI), or a minimum credit rating or credit score (FICO). The most important requirement is usually collateral.

The Credit Surface and Endogenous Leverage

How are lending terms endogenously determined in equilibrium? How can one supply equals demand equation for credit determine two variables, the price (i.e., the interest rate) and the collateral, not to mention all the other credit terms?

The literature has still to this day basically ignored this question. Sometimes, leverage is fixed exogenously or changed by an ad hoc rule (5% Value at Risk). Sometimes, a maximum leverage is fixed and borrowers can choose anything less. How can leverage be determined by demand and by the supply of lenders?

Geanakoplos (1997) provided the answer.[14] A loan should be defined by its promise and by the collateral put up to back it. Each pair (promise, collateral) is a different tradable financial instrument, with its own demand and its own supply and its own equilibrium price. Demand *and* supply determine the (different) price (i.e., interest rate) of every (differently) collateralized loan, and the quantity of loans at each collateral level. The graph of this market clearing interest rate at each leverage level or equivalently, collateral level, of the loan, together with the volume of loans, is called the credit surface.

A leveraged buyer has the choice of how big a downpayment to make, while paying the corresponding interest rate, and the lender has the choice of how much to lend, at each corresponding interest rate. Leverage and interest are indeed simultaneously endogenous. It turns out that when there are only two possible future states, every borrower and every lender will choose the same leverage. In such a case, a unique equilibrium leverage and interest rate emerge.

Of course, collateral is just one of many credit terms. A genuine, multidimensional credit surface would make the interest rate a function of a vector of terms like leverage, FICO, DTI, and others. Real-world lenders do, in fact, adjust their interest rates as a function of the credit terms. A project with the Federal Reserve has been initiated to display credit surfaces. They should be made available to the public and used by the Federal Reserve as a way of understanding and describing monetary policy. A few illustrative pictures are given in a later section.

Ignoring for now all credit terms except collateral, a loan should be defined by a pair (promise, collateral), not just by the promise, and each pair must have its own separate price. Fixing the collateral, bigger and bigger promises give rise to higher and higher leverage. At first, the loans are so small that the collateral fully protects the lender. But after a certain point, the loans are not fully protected and might default. They get riskier and riskier and the interest rises. The surface generated by the interest rate corresponding to each level of leverage is called the Collateral Credit Surface.[15] See Figure 1.

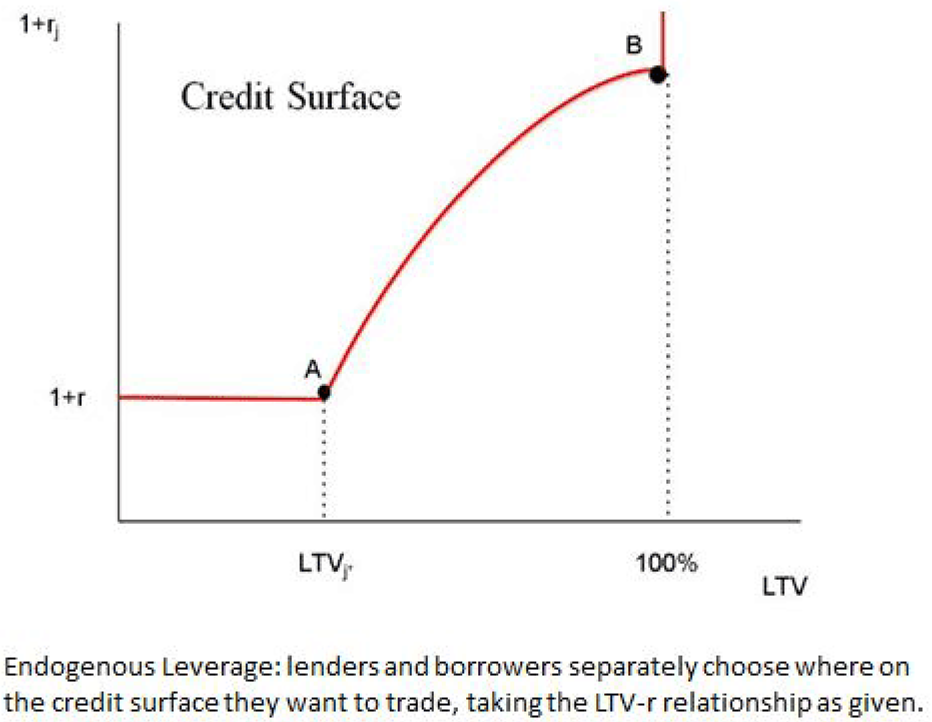


Figure 1. The collateral credit surface.

Borrowers and lenders each choose where they want to be on the credit surface. In equilibrium, for each level of leverage, there is a separate supply-equals-demand equation and a separate price. At many leverage levels, there may be zero supply and zero demand. The most interesting borrowers are not the ones on the flat part of the credit surface, who are able to borrow unconstrained quantities at the riskless interest rate as in the old style of macroeconomics.[16] The agents who are at Point A and beyond are often the pivotal drivers of fluctuations in economic activity, and they are constrained, because each time they try to borrow more (on the same collateral), they face a higher interest rate.

The credit surface also clarifies the meaning of tight credit. It is not the height of the riskless rate per se but the steepness of the credit surface that renders credit tight. Thus, in Figure 2, the bottom credit surface line is looser than the top credit surface line even though the riskless interest rate is the same.

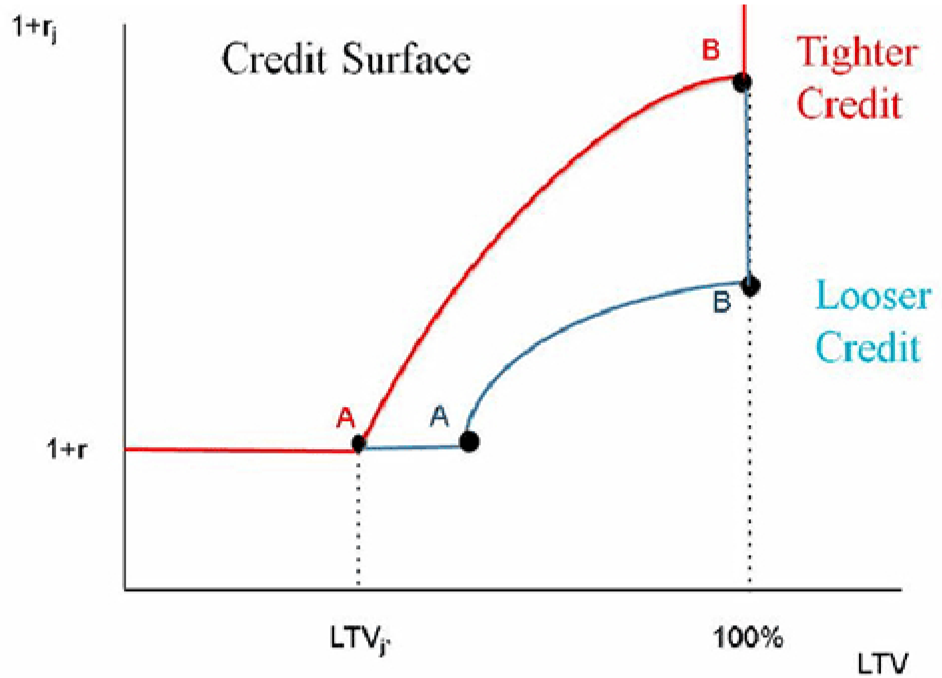


Figure 2. Loose and tight credit surfaces with identical riskless rates.

For Binomial Economies with financial assets, Fostel and Geanakoplos (2015) proved that the only leverage level that would be positively traded in equilibrium is the maxmin loan, which promises the maximum without any risk of default. This is Point A in Figure 1.[17] The theorem guarantees that in equilibrium, the credit surface rises sufficiently fast beyond Point A that nobody will choose to trade there. Leverage is completely endogenous, chosen freely by borrowers and lenders at any point, but the theory predicts exactly where it will end up.[18] Of course, the binomial assumption, that only two things can happen, is very unrealistic.[19] (It approximates reality best with very short-term loans, such as repurchase agreements [repos]). But the conclusion does not depend on the preferences of the agents or their endowments or their probability assessments of the future states or whether lenders' probabilities differ from borrowers' probabilities.[20] In the case of three or more states, the determinant of leverage is much more complicated. Equilibrium default is not only possible but even can be likely. There is no simple rule for equilibrium leverage, and different borrowers may leverage differently.[21] Also, as the number of states increases, the shape of the credit surface becomes more convex instead of concave.

Leverage and Down Risk or Volatility

The binomial no default theorem has an immediate consequence for leverage, which Fostel and Geanakoplos called the binomial leverage theorem. Geometrically, it is clear that Point A is defined by the worst-case scenario. With a little bit of algebra, they showed that in binomial models with financial assets, equilibrium LTV is equal to the worst-case gross return divided by the gross riskless rate of interest:

$$LTV = \frac{loan\ amount}{price\ of\ collateral} = \frac{1}{1+r}\frac{\text{worst collateral payoff}}{\text{price of collateral}}.$$

The theorem says that in binomial economies, leverage rises when the down risk abates, that is, when the world gets safer. One way this can happen is if expectations become so optimistic that returns on the collateral are anticipated to be higher in every future state.

Feeling optimistic and feeling safe often go hand in hand. But sometimes they can be quite different. If agents think there is more upside in just the best state, or just higher probabilities of the best state, the loan amount will not rise, but the price of the collateral will, paradoxically lowering leverage or LTV. Optimism thus has a less clear effect on leverage than down risk.

When risks are symmetric, the worst case is worse if volatility is higher. This shifts the credit surface up and to the left, as indicated in Figure 2. The theory then predicts that leverage will go down for assets whose expected volatility goes up.

It is surprising that volatility shifts the credit surface up and to the left, because every point on the credit surface balances demand and supply in equilibrium. More uncertainty typically reduces investor demand for investment and loans, and hence should move the credit surface down. Fostel-Geanakoplos (2015) proved that at least for binomial economies, the reaction of lenders to higher volatility is stronger and so on balance the credit surface always shifts up.

The great advantage of expected volatility as a marker of safety is that it is observable, either through the implied volatility of option prices or through recent volatility, which is highly predictive of expected volatility. And, indeed, margins (in, say, the commodities markets) almost always go up when either kind of volatility goes up. By contrast, it is notoriously difficult to quantify optimism about the increase in tomorrow's price; in stock prices, yesterday's direction does not predict today's direction.

Figure 3 shows the connection between margins in the commodities futures markets and the implied volatility of the underlying prices.

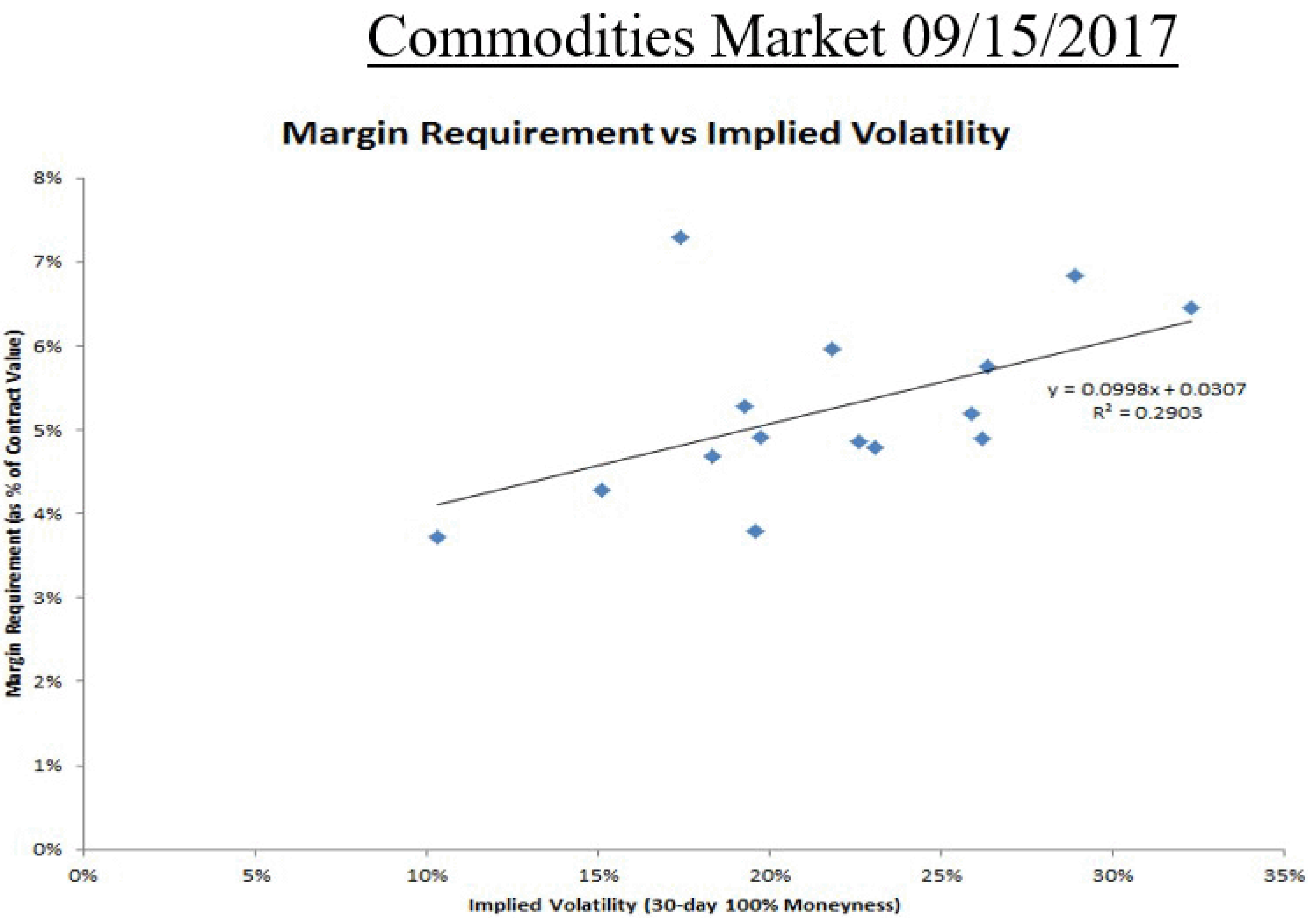


Figure 3. Volatility and leverage.

Source: Ellington Management Group.

Similarly, Figure 4 shows the connection between margins in the commodities futures markets and the recent volatility of the underlying prices.[22]

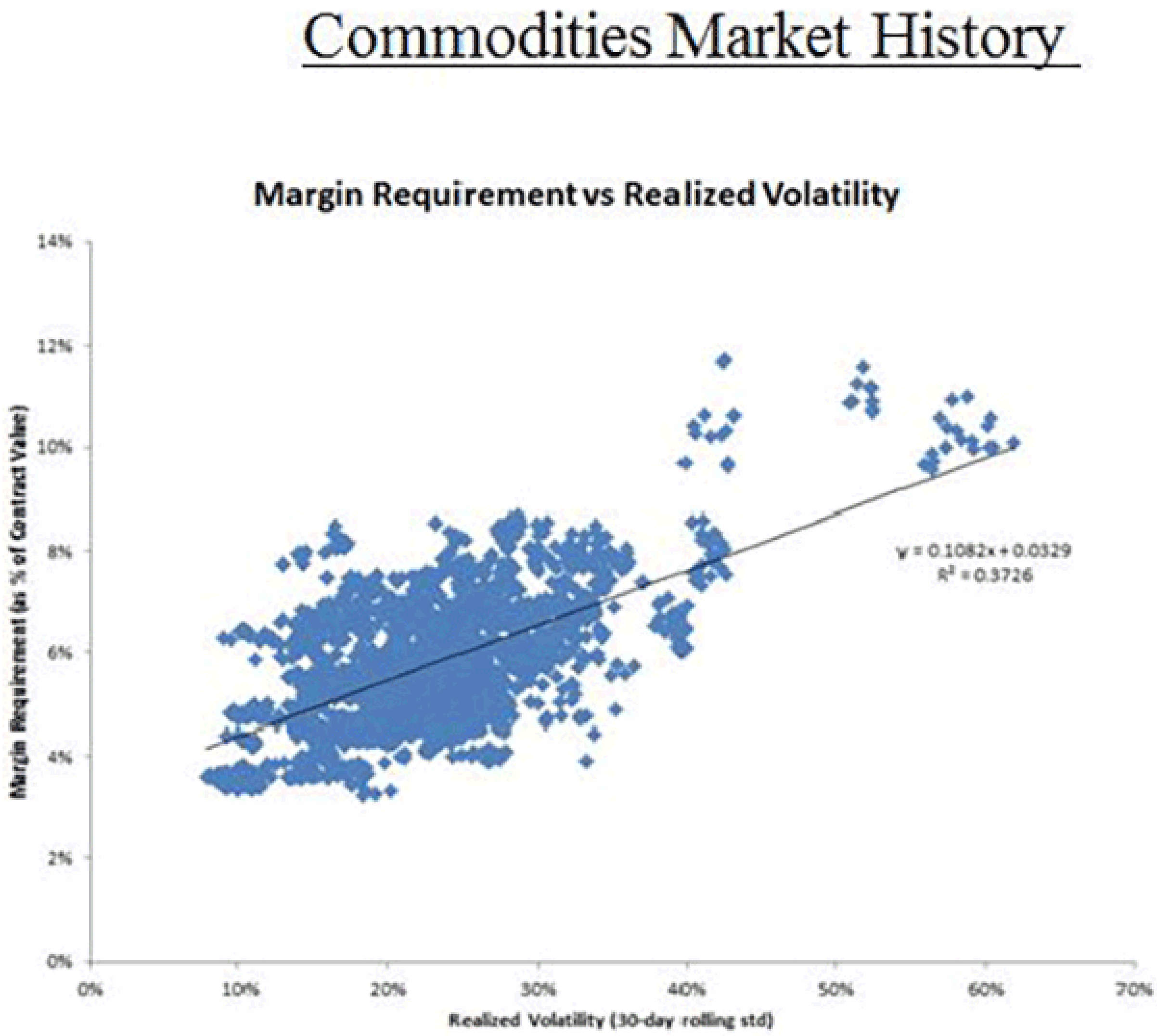


Figure 4. Historical volatility and leverage.

Source: Ellington Management Group.

Leverage and Asset Prices

All else equal, more leverage increases asset prices. The reason is almost self-evident, yet it had not really been examined in the literature. With a smaller required down payment, more buyers can express their demand for the collateral (houses or mortgage-backed securities, etc.), and the same buyers can buy more units, leading to greater demand and a higher price, provided there is heterogeneity in the valuations agents place on the asset. Fostel and Geanakoplos (2012a, 2016) proved that in any binomial model with financial assets, constraining leverage below the equilibrium maxmin value, for example by prohibiting leverage altogether, always lowers the value of an asset and decreases investment, assuming that the risk-free interest rate does not change.[23] The magnitude of the price effect brought on by the change in leverage depends on the heterogeneity of agent valuations. The more heterogeneity, the bigger the leverage-price effect.

The link between leverage and asset prices contradicts the famous M-M theorem, which asserts that prices should be unaffected by leverage. One difference is that Modigliani and Miller did not explicitly discuss collateral. They did have in mind a firm, which, to be sure, might be thought of as collateral for its bond issuances. But they overlooked that their argument depends on the reliability of non-firm debt as well. Their argument, as clarified by Stiglitz (1969), is essentially the following. Suppose a firm issues a debt promise of D and raises the rest of its money by issuing equity of value E. Suppose it does not default on D in any state of nature. If the firm were restricted to sell a promise $D' < D$, then it would have to issue more equity E'. The bondholders who had previously purchased the promises $D-D'$ would be disappointed at losing access to riskless debt, and the equity holders would be forced to absorb more equity, and tamer (less leveraged) equity, possibly reducing their expected returns. The M-M theorem is proved by noting that the equity holders could themselves issue the missing debt $D''=D-D'$, thereby giving the market the same debt it had before and, at the same time, releveraging the equity E', so it becomes just like E. In essence, the reduced leverage at the firm level is compensated by increased leverage at the investor level.

One flaw in this M-M proof is that collateral is not generally transferable; just because the firm can be used as collateral does not necessarily mean the equity can be used as collateral. The equity holder might have a different propensity to repay, perhaps not as reliable as the original firm, so D'' would not be treated by the market as a perfect substitute for D. When leverage goes down for the economy as a whole, there are real consequences.

For example, consider a new homeowner who is limited (say, by regulation or by a worse down risk in housing prices) to taking out a mortgage at a smaller LTV. The homeowner would simply have to come up with a bigger down payment, since taking out a second loan would not be permitted by the regulation or by the worse down risk, and might not be able to buy the house. There are no outside agents who could increase their borrowing by using the new homeowner’s potentially higher equity to help buy the house. The drop in debt will necessarily have real consequences, for the economy and for the price of the house.

This same argument applies word for word to the purchaser of any asset, such as a mortgage-backed security. The only situation in which the M-M logic partially applies is the one they had in mind. The buyer of firm equity could indeed use the equity as collateral for a further loan, thus compensating for the lower debt/equity ratio at the firm level. But the flaw emerges here as well when looking one step deeper. If increased firm down risk reduces firm debt, the equity may increase in size but the bigger downside will also prevent a completely compensating increase in equity-backed debt, so total leverage will go down, and the firm price will fall for that reason. See Figure 5.

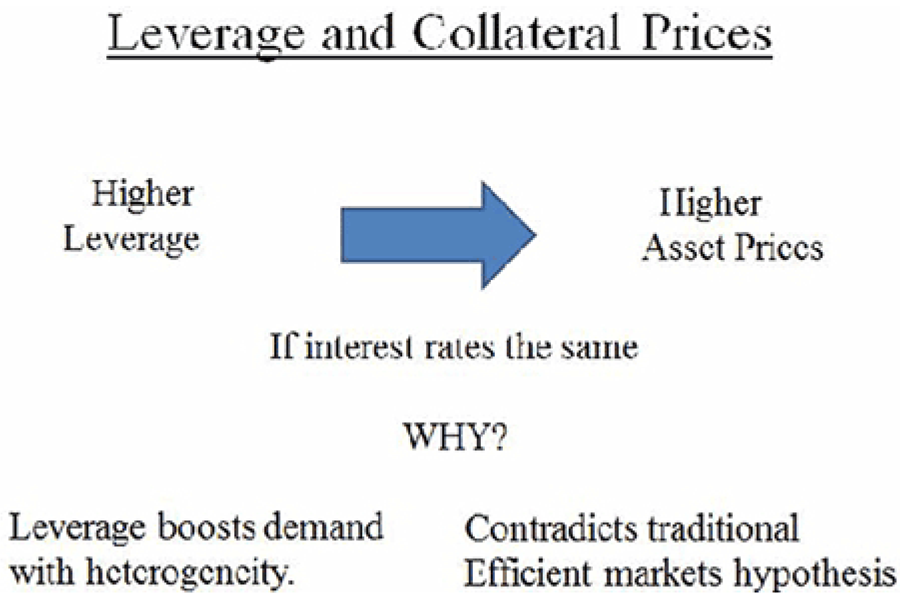


Figure 5. Leverage and asset prices.

Leverage Prices Versus First Best Prices

If higher leverage on a single collateral permits more borrowing that makes its price higher, then does enabling unlimited borrowing for everything (with the proviso that all debts are eventually repaid as in the Arrow Debreu economy) raise asset prices still more? Geanakoplos (2003) shows that on the contrary, the leverage economy collateral price can be much higher than its Arrow Debreu price. Fostel and Geanakoplos (2012a) show more generally that for a whole class of binomial economies with financial assets, if all future consumption comes from dividends of assets, then those special assets which can be collateralized will trade for higher prices than they would in the Arrow Debreu economy. The lack of trust, which limits the amount of money that can be borrowed to buy any asset, can paradoxically cause the price of those assets that are good collateral to boom.

The Static Leverage Cycle

The leverage cycle typically moves from good news that reduces volatility and flattens the credit surface to higher leverage and then to higher asset prices. Eventually, the news worsens and uncertainty rises, which leads to a steeper credit surface, lower leverage, and falling asset prices. This is expressed in Figure 6.

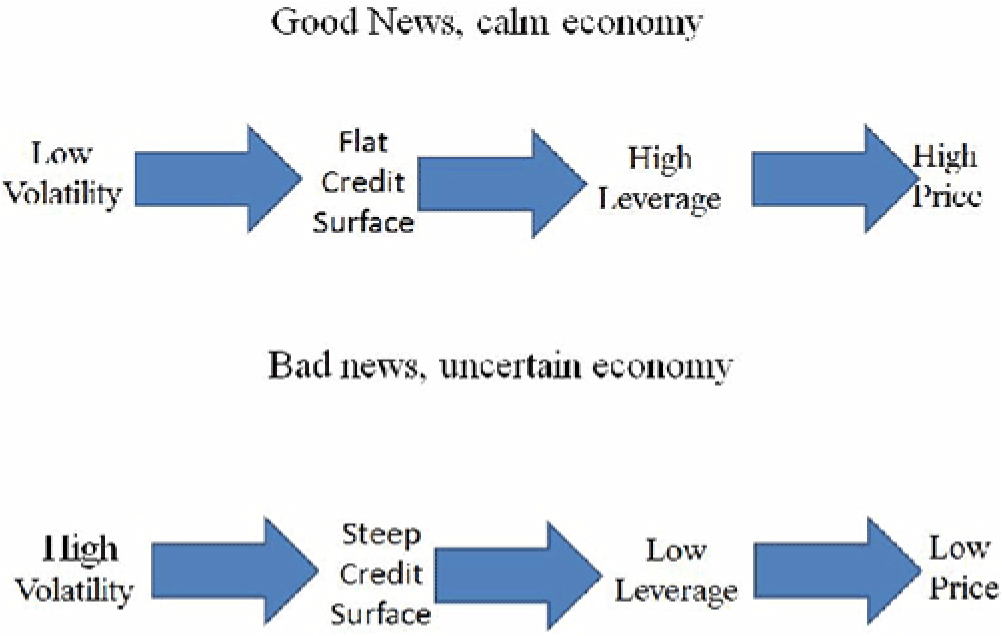


Figure 6. The static leverage cycle.

Needless to say, a steady alternation between good news and bad news will create a cycle in asset prices. The novel contribution of the leverage cycle is that an alternation between low uncertainty and high uncertainty (that is, in the second moment, instead of the first moment, of the asset price distribution) will also create a cycle in prices because leverage will rise and fall. This volatility-induced price oscillation can occur even if every individual's expectation of the mean of future payoffs remains constant.

The amplitude of the price cycle is magnified when good news and calming news occur together, because good news and calming news raise asset prices for different reasons: the first, directly and, the second, through higher leverage. In particular, an increase in expected outcomes that also reduces the downside will increase prices by much more than the increased expectation.

The coincidence between good news and reduced uncertainty, or bad news and increased uncertainty, is not rare. As Figure 7 shows, volatility usually does go up (as measured by the VIX) when news is bad (as measured by a fall in the S&P 500).

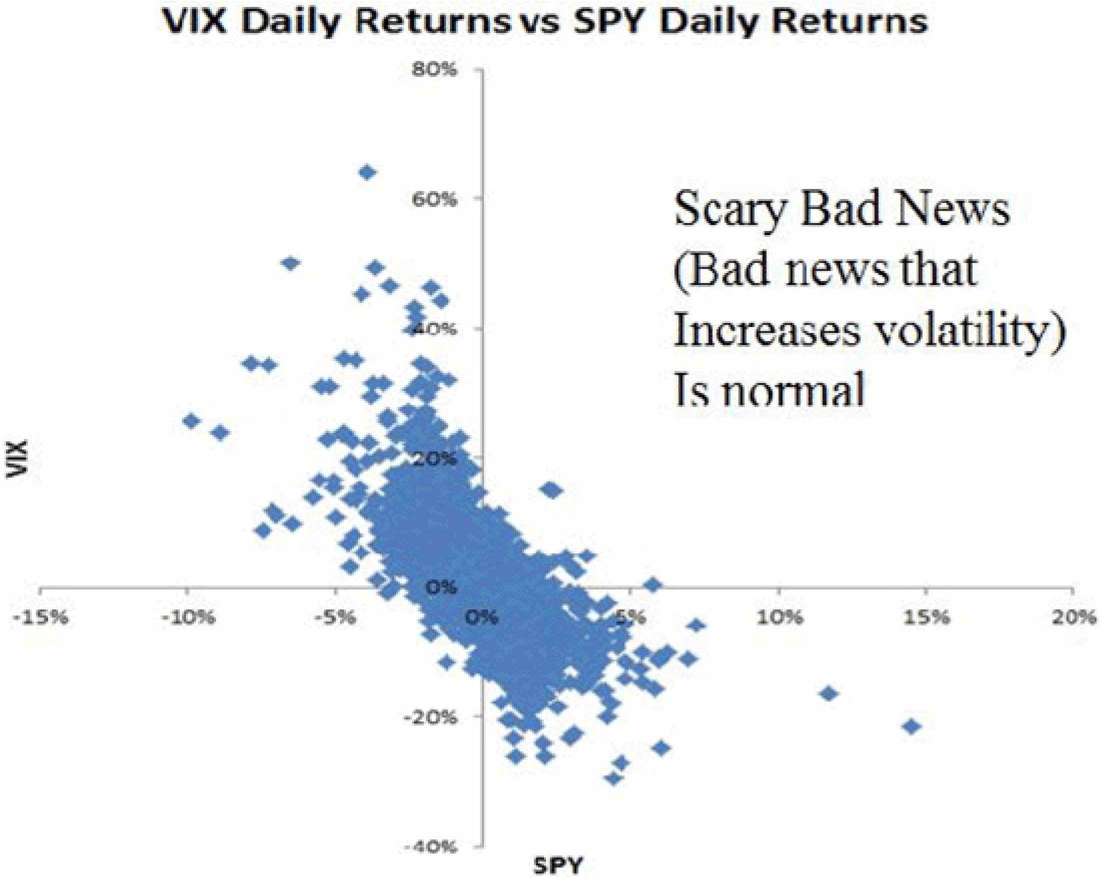


Figure 7. Bad news and high volatility.

Source: Ellington Management Group.

The Dynamic Leverage Cycle

The static leverage cycle is just a comparative statics exercise. It does not take into account that over time good news is self -reinforcing. Two successive pieces of good news raises prices more than both pieces at once, because along the way, the enthusiastic leveraged buyers win their bets and make more money. On top of that, if lender expectations are naively (but perhaps not unrealistically) extrapolative, then successive good news will enable investors to leverage more.

Most importantly, the static leverage cycle does not take into account that the economy is more vulnerable *while* it is highly leveraged. The Dynamic Leverage Cycle recognizes that the up and down legs of the Static Leverage Cycle don't just alternate; they also follow each other. Bad news then transfers wealth away from the leveraged owner, who has effectively made a bet on the asset price rising by leveraging. With agent heterogeneity, this transfer of wealth causes a further price decline.[24] The down cycle is thus more severe when following the up cycle than it would be on its own.

In summary, the dynamic leverage cycle gives rise to booms and busts through three forces. On the downside, bad news decreases every agent's valuation of the asset, reducing its price. Scary news decreases leverage, further shrinking its price. Finally, the wealth transfer from enthusiastic buyers who lose their leveraged bets to reluctant buyers of the asset further dampens the price. The up side reverses all three effects. This dynamic aspect of the leverage cycle is emphasized by the amendment to Figure 6 shown in Figure 8.

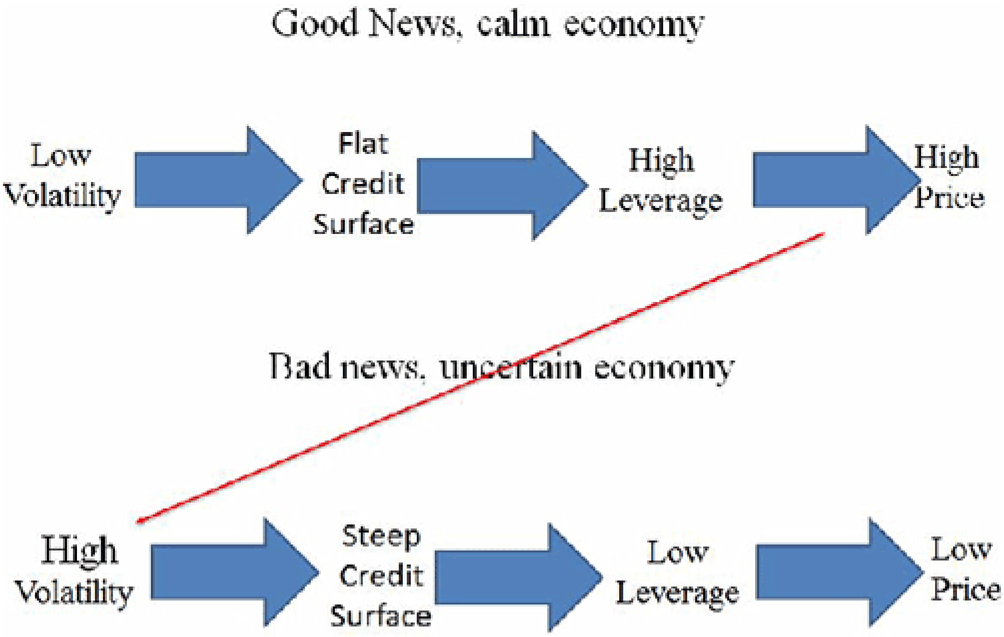


Figure 8. Dynamic leverage cycle.

Of course, there should also be an arrow pointing from the end of the down cycle up to the left, to the beginning of the up cycle. But that arrow is weaker, at least at first, because it proceeds from a state of low leverage where the wealth effect is smaller. The line drawn in the diagram that results from scary bad news moves prices much faster than the undrawn line resulting from calm good news.

Liquidity and Margin Calls

The full power of the dynamic leverage cycle is unleashed in periods when loans are coming due and collateral holders have few other liquid assets. That is when crashes occur. When loans come due they must be paid, or else rolled over. That gives the lender a chance to make a margin call. The transfer of wealth is more consequential because it is liquid wealth; the margin call must be paid immediately. Agents who loses $1 might want to reduce spending by a few cents over each period of their life. If they are simultaneously cut off from further borrowing, they may be forced to sell $1 of something immediately. If the collateral is the only liquid asset they have, then they must sell it. Effectively, their marginal propensity to spend on the asset out of wealth becomes

100%. By comparison, the agent who has no debt and becomes $1 richer is likely to have far less than 100% marginal propensity to spend on the asset. The gap in marginal propensities to spend is much greater out of liquid wealth than out of wealth in general. .

The static and the dynamic leverage cycle can produce gradual rises and declines in asset prices. When the loans are long term, the borrowers may not be forced to sell, and the eventual decline in prices may not show up as trade volume plummets. Something like that has been happening in 2022-23 in New York commercial real estate. A crash occurs if all the loans come due at once and many asset holders are forced to sell at the same time.

Endogenous Short-Term Loans: Liquidity Mismatch

Short-term loans such as repo loans come due every period. This makes the economy much more vulnerable. The question is, Why do borrowers take out short-term loans knowing that this exposes them to margin calls that have the potential to force them to make disastrous fire sales?

The answer is that the credit surface for long-term loans is much steeper than for short-term loans, because lenders who fear default are well aware that more can go wrong in the long term than in the short term. Borrowers then choose short-term loans.

Debt-Fragility Mechanism and Propensity-to-Spend Reversal

The wealth effect in the dynamic leverage cycle is a special case of the debt-fragility mechanism described in Ben Ami and Geanakoplos (2017). This mechanism gives another reason why the missing extra line in Figure 8 is weaker, and why prices can go down much faster than they go up. It also explains why multiple equilibria might emerge when big debts come due.

Debt crises have always been linked to fragile economies. Historically, in times of debt troubles, politicians often make speeches about restoring confidence. President Roosevelt said you have nothing to fear but fear itself. Bernanke and Geithner said similar things about restoring confidence, as did Prime Minister Tsipras of Greece. Mario Draghi said the European Central Bank (ECB) would do whatever it takes. All of them seemed to believe that by changing expectations, they could move the outcome a long way. In other words, they thought the economy was fragile: A small push could cause a big shift. Or talk alone, without any push, could change the outcome, as in moving from one equilibrium to another. So how does high debt make for fragile economies and multiple equilibria?

Fragility arises if sellers have a higher marginal propensity to spend on a traded asset Y, out of the last dollar of wealth, than the buyers. When the price of Y goes down, the substitution effect is that agents will try to buy more of it, because, all else equal, it is more attractive by virtue of being cheaper. This tends to stabilize prices by preventing them from falling further. But if an agent is already selling Y, then all else is not equal. There is an additional income effect. The lower price makes the sellers poorer, which means they might want less of everything, including Y. In more dramatic words, the further the price goes down, the more they might have to sell. The usual stabilizing effect of lower prices raising demand can be reversed for sellers. In the language of demand theory, the income effect counteracts the substitution effect for the sellers. On the other hand, the income effect reinforces the substitution effect for the buyers. As the price goes down, they effectively get richer, and for that reason they want to buy more, beyond their pure substitution effect. The crucial observation is that if the marginal propensity to buy Y (out of an additional dollar of wealth) is higher for the sellers than for the buyers, then the sellers' income effect will be stronger. In aggregate, the income effect will tend to reverse the substitution effect.

Normally the buyers, being buyers, have higher marginal propensity to spend than sellers. However, there is often a propensity-to-spend reversal when the sellers are selling leveraged assets to pay off debt.The high marginal propensity to spend agents leveraged to buy the assets. A margin call forces them to sell the asset, thus causing the propensity to spend reversal.

If a propensity to spend reversal prevails, then bigger sales diminish the stabilizing aggregate substitution effects more, because the aforementioned income effect is proportional to the quantity of sales. When there is a large debt that is coming due, then there must be a large sale to pay the debt. Hence the name debt-fragility mechanism.

When leverage rises, asset prices rise, so borrowers are borrowing a higher percentage of a higher number. Thus, with higher leverage, borrowing goes up for a squared reason, so debt can skyrocket. This sets the stage for the propensity-to-spend reversal and the debt-fragility mechanism.

With big enough sales and propensity-to-spend reversal, the aggregate demand curve for Y will be close to flat. But a flat demand curve means that equilibrium prices will have to move dramatically to restore equilibrium after a small shock. The economy is fragile. Thus, a little bit of bad news can have a big effect on prices in an economy with large sales of some good. With still bigger sales, the income effect will completely reverse the substitution effect, and demand will become upward-sloping. But that means there are multiple equilibria. In that case, restoring confidence, without any spending, could make the economy move from one equilibrium to another.[25]

See Figure 9, which illustrates how the same vertical shock down will produce a small change in the equilibrium price of an economy with steep demand (i.e., with a dominant substitution effect) but produce a large change in the equilibrium price of an economy with flat demand (i.e., with a dominant propensity-to-spend-reversal income effect).

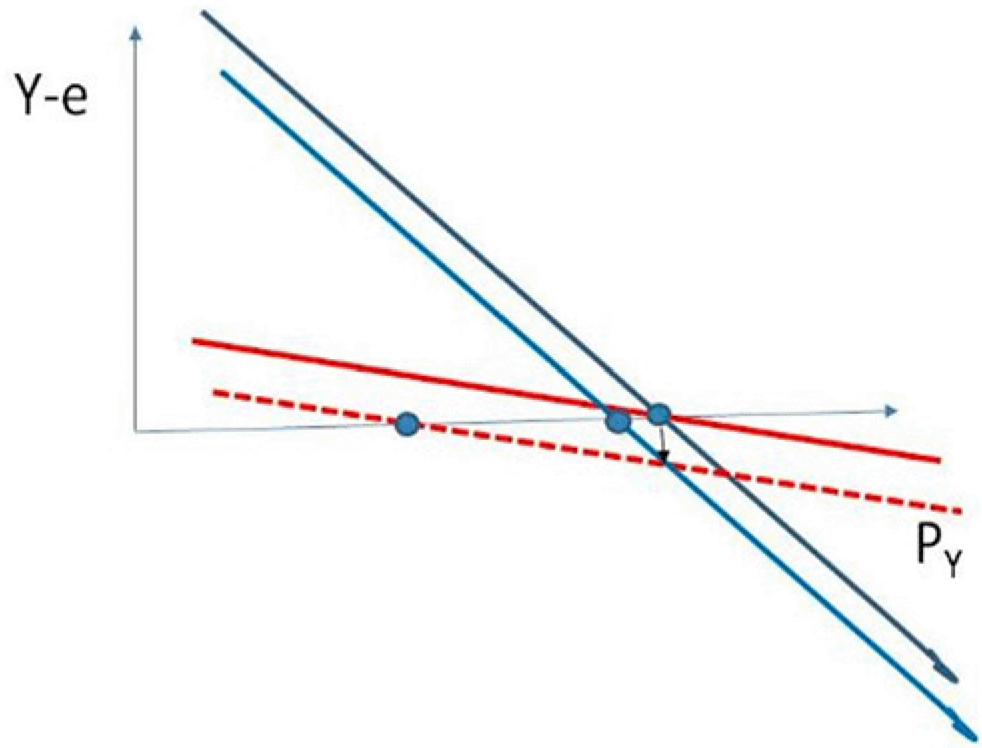


Figure 9. Equilibrium with flatter excess demand gives rise to more fragile equilibrium.

The debt-fragility mechanism is partly accounted for by the previously discussed wealth transfer from the losing leveraged bet after bad news. If the leveraged bet losers sell even more after repaying their debt, then a pure propensity-to-spend reversal is achieved that pushes prices further down. The important point is that after good news, when the leveraged buyers win their bet, further purchases of the asset display the normal propensity to spend. The substitution effect will be dominant, and price rises will brake the expansion. The rise in prices is slower than the fall.

A Simple Model of the Leverage Cycle Crash

The volatility-leverage mechanism together with the debt-fragility mechanism at the tail end explains how a little bit of scary bad news can have a huge effect on asset prices. The leverage cycle described in Geanakoplos (2003) and Geanakoplos (2010b) goes like this. A long period of low volatility leads to a flatter credit surface and thus increased leverage and laxer credit standards generally. That raises asset prices and increases activity. But it also makes the economy more vulnerable, because of the double boost to new debt of higher asset prices and higher leverage. A little bit of bad news decreases everybody's valuations and lowers prices a little. But as has been seen at the outset, the most leveraged buyers will lose the highest fraction of their wealth from the price drop. They are likely to be the highest valuation–highest marginal propensity-to-spend buyers, and their disappearance (or reduced purchasing power) from the wealth transfer discussed earlier further reduces asset prices. If the news is scary, as well as bad, the increased uncertainty steepens the credit surface and lowers leverage. Thus, asset prices drop for three reasons: the bad news, the wealth transfer away from high leverage–high valuation–high marginal propensity-to-spend agents and the drop in leverage, reducing old and new buyers' ability to borrow and demand assets. As the bad news gets worse, the drop in asset prices accelerates because the leveraged high marginal propensity to spend asset holders may choose to sell beyond meeting their debt obligations because of their huge wealth loses, which kicks off the debt-fragility mechanism.

Asset prices and activity will stay low as long as uncertainty remains high and the credit surface remains steep. And as Geanakoplos (2010a) added, if the long-term debt is too high relative to the lower asset prices, full repayment may become impossible. With a big enough disparity, partial forgiveness may be the only way out of the recession.

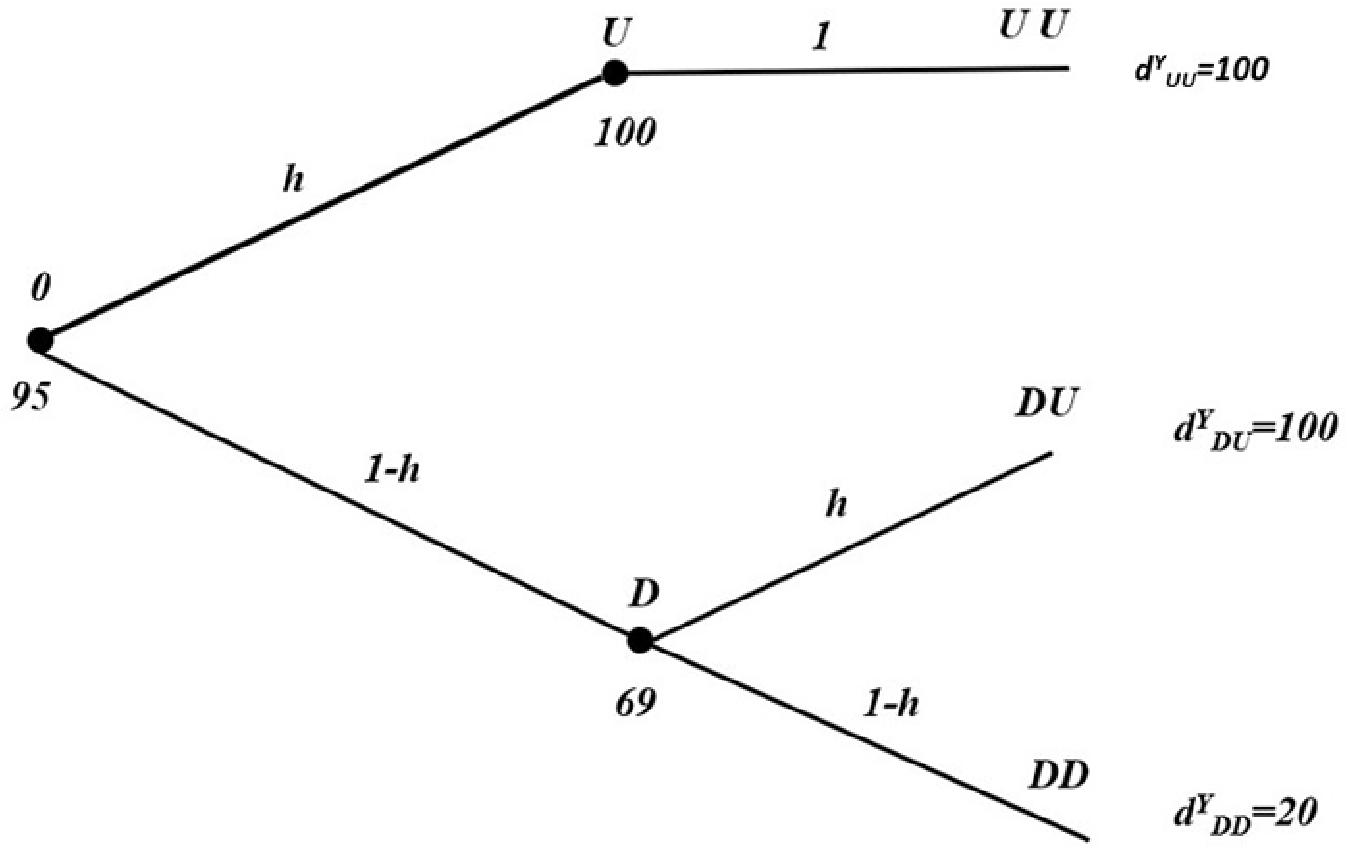


Figure 10. Asset payoffs, agent *h* probabilities on each branch, and endogenous asset prices at nodes 0, U, D. The price crashes from 95 at node 0 to 69 at node *D* with little, but scary, bad news.

The leverage cycle and crash can be described in a simple special case taken from Geanakoplos (2003, 2010b) that also illustrates the idea of a marginal buyer. Suppose all the agents in the economy are arrayed in a vertical line according to their valuations of an asset, with the highest valuation at the top and the lowest valuation at the bottom, as in Figure 11. For simplicity, think of a continuum of agents, valuing each unit of the asset at levels independent of how much they buy. Imagine that agents $h \in [0, 1]$ value the asset *Y heterogeneously,* according to their expectation of its dividends d_s^Y, as in Figure 10. Agent heterogeneity is due to different priors: Each agent *h* assigns the probability h to good news (up) at each node s of the tree. Optimistic agents with a high h value the asset Y more than pessimistic agents with a low h. The reader can easily check that for $h = .87$, the expected terminal payoff of Y from state 0 is $98.6 \approx (.87 * 1 \; * 100) + (.13 * .87 * 100) + (.13 * .13 * 20)$. After bad news at D, the expected terminal payoff drops 9 points to $89.6 \approx (.87 * 100) + (.13 * 20)$

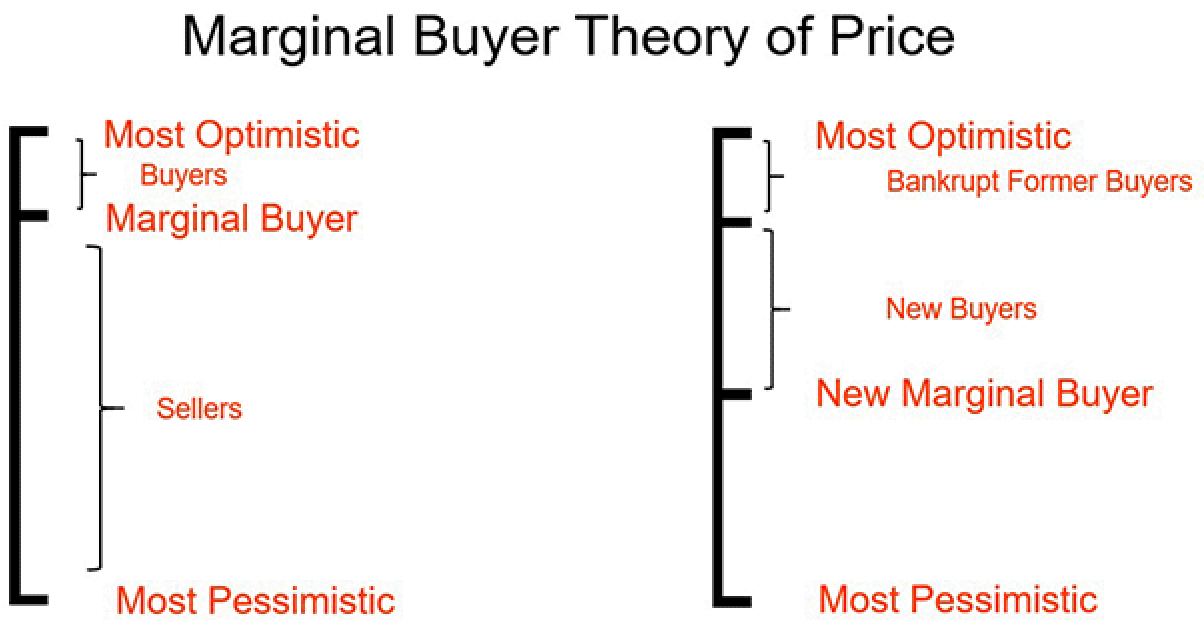


Figure 11. Leverage cycle and crash due more to change in marginal buyer than bad news.

Whatever the asset price p_s in state $s \in \{0, \; D\}$, some agent h_s^*, called the marginal buyer, will think it is fair. More optimistic agents $h > h_s^*$ will buy the asset, and less optimistic agents $h < h_s^*$ will sell it, as shown in Figure 11. When leverage is high, each agent can spend a lot of borrowed money to buy many units of the asset, and few buyers will be required to purchase all of Y. With few buyers required to purchase all of Y, the marginal buyer will be high up the line, as indicated in the left side of Figure 11. Since the marginal buyer's valuation determines the price, the price will be high. (Conversely, when leverage is low, the marginal buyer will be lower and the price will be low.)

In the expansionary part of the leverage cycle at state 0, volatility is low, because the ensuing price of Y varies between 100 at U and 69 at D. As explained in the maxmin leverage theorem, in equilibrium in this binomial economy, every buyer will use each unit of Y to take out a one-period loan promising exactly the maximum value for which there will be no default. At state 0, the promise will be $69 = \min \; (100, 69)$, the value of Y in state D. A leveraged buyer only has to pay cash equal to the price net of the borrowing to buy each asset. The marginal buyer turns out to be $h_0^* = .87$ who is high up the line because only the top 13% = 1-.87 of agents are needed to buy all the assets, as indicated in the left side of Figure 11. Since the marginal buyer's valuation determines the price, the price will be high, at 95, as indicated in Figure 10. The LTV at 0 is 69/95 = 74%. The credit surface at 0 is like the loose credit surface of Figure 2. The price of 95 is much higher than the Arrow Debreu price for this economy. The absence of trust, which curtails lending except via collateral, paradoxically creates a boom in price far above what it would be in an idealized economy with complete trust.

When bad news comes at *D*, every agent, including the marginal buyer, values the asset less, so the asset must fall at least a little in price. Nobody thinks it should fall 26 points. Recall that the marginal agent *h*=.87 thinks it should drop only 9 points. The initial fall in the asset price causes leveraged investors to lose considerable wealth, even if they do not plan to trade the asset, because they are leveraged. Worse, the news is *scary* because it indicates an even bigger price drop is possible in the next period. Anticipated volatility is higher. The ensuing price of *Y* from *D* varies between 100 at *DU* and 20 at *DD*, a much wider gap than from state 0. The credit surface at *D* is like the tight credit surface of Figure 2. Leverage must drop at D. Hence, with all their short term loans coming due, leveraged holders of *Y* get both kinds of margin calls and, with no other liquid assets, must sell in order to pay back their loans, causing them to sell more and more as the price falls further. On the right-hand side of Figure 11, an extreme case is considered in which the old buyers lose all their wealth. The asset must then be held entirely by more pessimistic agents. The new marginal buyer is necessarily further down the line and more pessimistic.

The new buyers at D will not have access to as many borrowed funds. In fact, by the maxmin leverage theorem, they will promise just 20 on each unit of *Y* collateral, giving an LTV of 20/69 = 29%, as seen in Figure 10. Thus, even at a lower price, there will need to be many more buyers than previously, and the gap down from the original marginal buyer to the new marginal buyer will be very large, as seen on the right-hand side of Figure 11. The price will then reflect the valuation of a much more pessimistic buyer. The fall in price is due more to the change in marginal buyer, occasioned by the wealth losses of the optimists and the curtailment of leverage, than it is to the bad news itself. The price drops 26 points, much further than any agent thinks it should. The price drops mostly because the marginal buyer drops from $h_0^* = .87$ to $h_D^* = .62$.

The crash at *D* is a great opportunity for optimistic investors. Agents near $h_0^* = .87$ think they have an expected return at 0 from investing in *Y* of 98.6/95 or 4%. From *D*, they think their expected return is 89.6/69 or 30%.

All the agents rationally anticipate the consequences of the crash at *D*. Agents just below $h = .87$ realize that their expected return from *D* is almost 30%, while it is less than 4% from state 0. Hence, they keep their powder dry at 0, choosing to hold cash earning 0% instead of 4% with *Y* so that they can be prepared to take advantage at *D*. There are not enough investors like them, who anticipate that the opportunity will be great at *D* and also think *D* is likely enough to wait for, to prop up the price at *D*. Buyers just above h = .87 don't think the probability of D is high enough to keep their powder dry.

The optimists $h > h_0^* = .87$ who fully leverage at 0 to buy *Y* realize that they will be blown out of their positions at *D* by a margin call and lose everything. They also know that if they borrowed long term, then at *D*, they would not be margin called or forced to sell. The longer loan would allow them to hold on for the turnaround to 100 at *DU*. Nevertheless, they choose to borrow short term despite the margin call risk because the long-term credit surface is so steep. From the binomial maxmin leverage theorem, we know that the only long-term promise that might be traded is 20, the lesser of the two distinct long-term outcomes. If they borrow short term, they can promise 69. For them, the extra return from 0 enabled by higher short-term leverage outweighs the risk that creates at *D*, because as optimists they regard *D* as so unlikely. Maturity mismatch is endogenous.

The leverage cycle crash is related to so-called fire sales. For a good account of the important literature on fire sales, see Shleifer-Vishny (2011). There are, however, several differences. The most important is that the leverage cycle injects the critical element of varying and endogenous leverage. The fire sale literature misses the over-valuation and buildup of debt due to the soaring leverage and the sudden transition from high leverage to low leverage, which plays a vital role in all crashes. It also misses the aftermath during which the credit surface is still steep and new borrowing remains low. The fire sales literature addresses part of the middle game without discussing the opening or the endgame. The fire sales literature uses language like deleveraging without actually endogenizing asset leverage. It does, however, include the idea of heterogeneous buyers and the loss in price when high-valuation buyers are forced to sell to low-valuation buyers.[26]

Evidence From the 2008 Financial Crisis

The lead-up to the 2007–2009 financial crisis, the crisis itself, and its aftermath give some evidence for the leverage cycle connection between collateral prices and leverage and volatility. In Figure 12 we see the connection between the price of a portfolio of AAA subprime bonds (on the right scale) and the LTV lenders offered to the hedge fund Ellington Capital on similar bonds (on the left scale). As the figure indicates, leverage and prices fell together during the 2007–2009 crisis and eventually rose together in the recovery. Note also the brief but dramatic drop in LTV in 1998 that connects with the collapse of the hedge fund Long Term Capital.

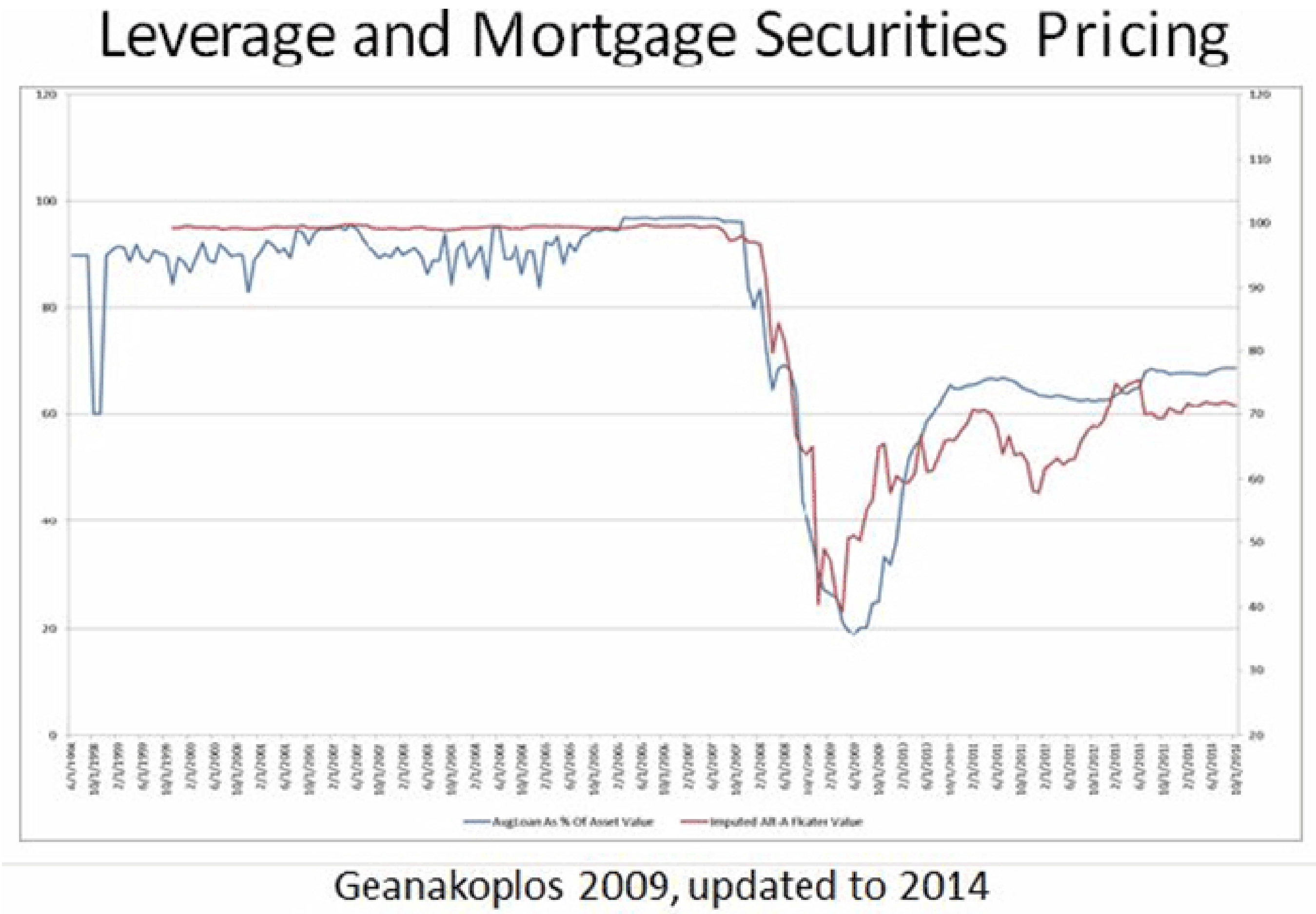


Figure 12. Leverage and mortgage securities pricing.

Source: Ellington Management Group.

In Figure 13, the connection between the Case-Shiller housing index and the leverage on nongovernment mortgages from 2000 to 2009 can be seen. Again, leverage and the asset price move together.[27] The great crisis of 2007–2009 was the culmination of a double-leverage cycle, in mortgages and in mortgage securities.

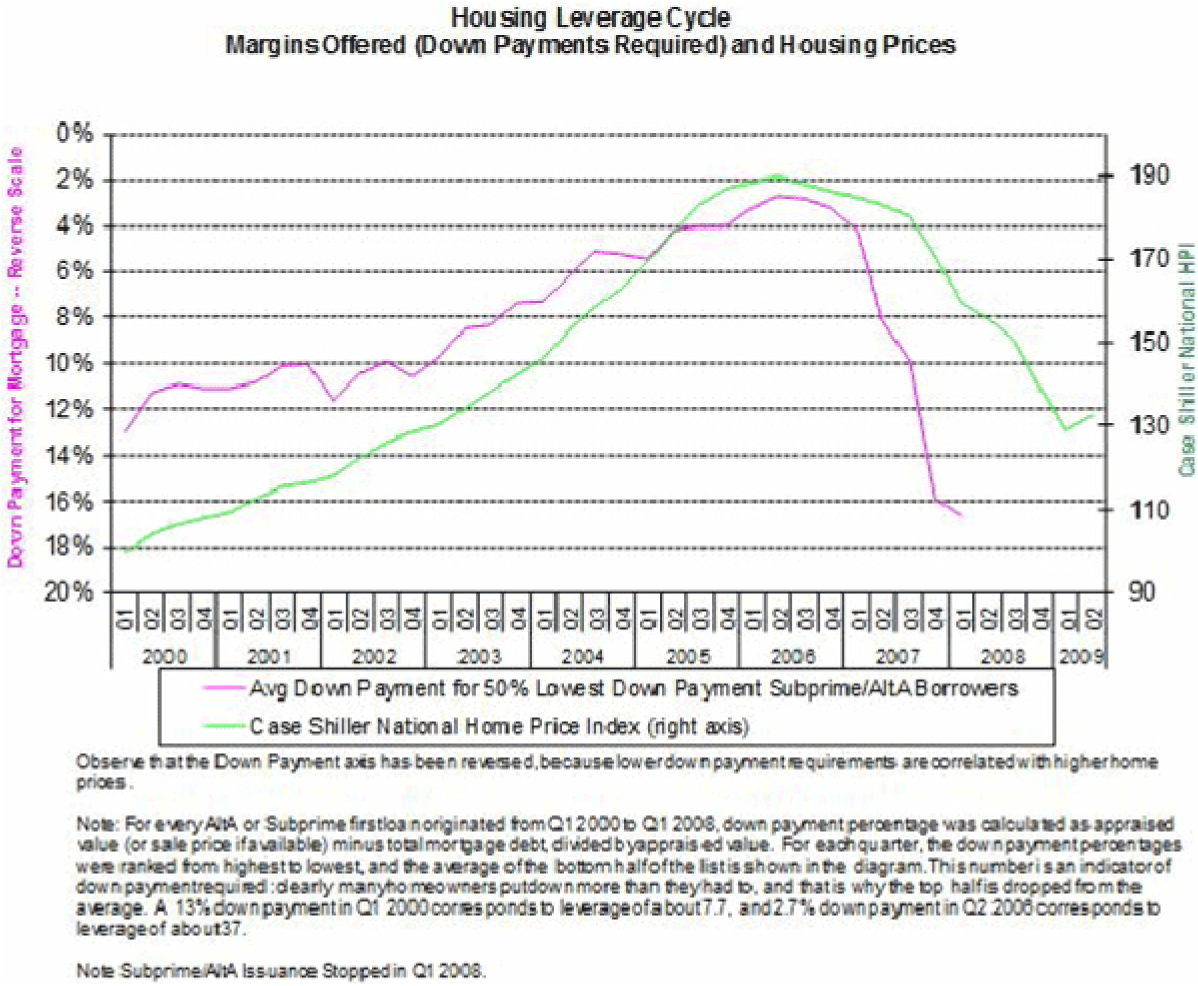


Figure 13. Leverage and housing prices.

Source: Case Shiller Index taken at that time.

Finally we see in Figure 14 that volatility did dramatically rise in the 2007–2009 crisis and again in the COVID-19 crisis mentioned in the first section. The relevant volatility for the mortgage market in 2007–2009 would be in the housing market, which is harder data to get, rather than in the stock market. But these data are very suggestive.

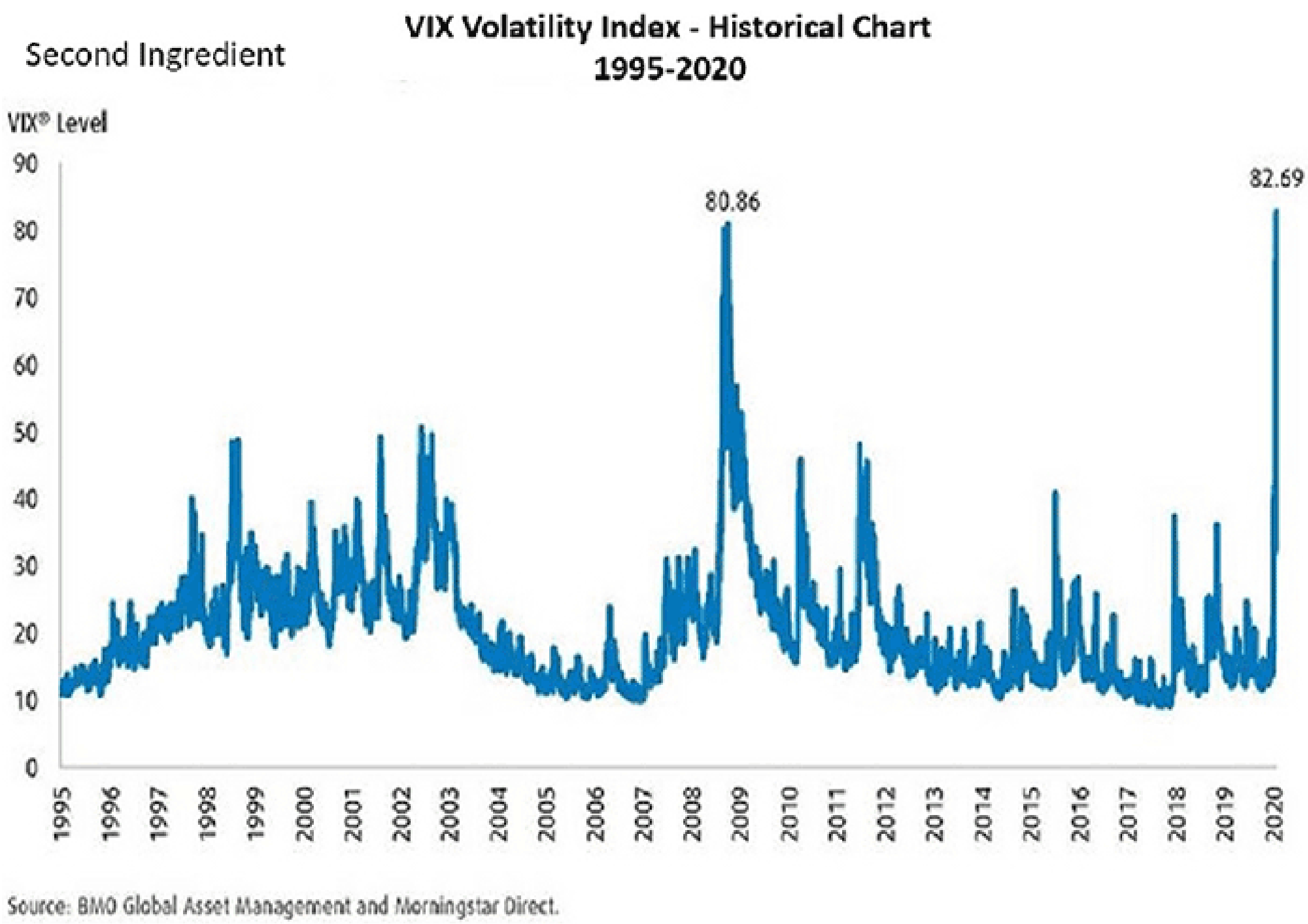


Figure 14. Volatility index 1995–2020.

The Financial Innovation Cycle

Seventy years ago, more and more goods became usable as collateral for leveraging. Forty years ago securitization and tranching, especially of mortgage-backed securities, emerged and grew dramatically. Finally, over the last fifteen years , the CDS mortgage market suddenly blossomed at the end of the securitization boom. After the crisis of 2007–2009, the complexity of these instruments declined but is now on the rise again.

Fostel and Geanakoplos (2012a, 2016) argued that there is a financial innovation cycle that follows and boosts the leverage cycle. The financial innovation cycle made the crash of 2007–2008 bigger than it would have been otherwise.

In periods of quiet, financiers innovate to stretch the available collateral. When a single asset can be used to collateralize multiple loans, it is stretched. When collateral backs promises that are, in turn, used as collateral to back further promises, which Geanakoplos (1997) called pyramiding, the original collateral is effectively reused and thus stretched. Leverage can be thought of as buying an asset while simultaneously borrowing. But it can equally well be thought of as a way of cutting the collateral into two pieces, a bond, and a risky junior piece. Cutting the bond into still more pieces, which involves pyramiding and tranching, is a more advanced financial innovation, requiring more complex record keeping, a more sophisticated court system, and accommodating tax laws. By skillfully cutting the collateral into appropriate pieces, entrepreneurs can sell the pieces for more than the original collateral. Competition then bids the whole collateral price up to the sum of its parts. The search for profits from scarce collateral through financial innovation makes collateral more valuable, over and above its payoff value. Leverage raises the prices of assets, and tranching raises their prices still more. And they rise higher because the financial innovation comes in stages and not all at once. Once the prices get high enough, which unfortunately is the moment when the indebted economy is becoming especially vulnerable, sometimes another financial innovation called CDS is introduced which enables the pessimists to bet against the asset. Optimists sell the CDS insurance instead of leveraging to buy the asset. This tends to lower asset prices. A little bit of bad news can then lead to a great crash.

The run-up to the crisis of 2007–2009 fits the pattern of the financial innovation cycle perfectly. Throughout the later 1990s and 2000s, higher LTV loans, called subprime loans, began to be initiated by the private sector. These, in turn, were collected into pools, which were then tranched. Some of the tranches were tranched into further tranches called CDOs. The subprime market grew from almost nothing in 1990 to over US$1 trillion in 2006. Housing prices skyrocketed from 2000 to 2006. At the end of 2005, a small group of investors who thought housing prices and mortgages were overvalued pushed to get the indexed subprime mortgage CDS market established so they could bet against the subprime mortgages. The indices stayed high for about 11 months but then cracked at the end of 2006 on the release of delinquency reports for subprime mortgages. The housing market tumbled soon afterward. Had the CDS been trading robustly from the beginning, prices might not have gotten so high.[28]

Multiple Leverage Cycles

Many kinds of collateral exist at the same time, hence there can be many simultaneous leverage cycles. Each one has its own credit surface. Collateral equilibrium theory not only explains how one leverage cycle might evolve over time, but it also explains some commonly observed cross-sectional differences and linkages between cycles in different asset classes, like Flight to Collateral and Contagion, as demonstrated in Fostel and Geanakoplos (2008).[29]

It is commonly observed that in times of crisis, some assets retain their value (or even rise in value) while others lose value. This situation is often called a flight to safety. Another way to describe the situation is a flight to collateral. The safe assets, with low volatility, turn out to be the assets that can be leveraged more.[30]

A second commonly observed phenomenon is that when bad news hits one asset class, the resulting fall in its price seems to migrate to other assets, even if their payoffs are statistically independent of the original crashing asset. There are two reasons for this contagion connected to crossover investors. As was seen in Element 7, the leverage cycle in an asset amplifies the bad news and creates wealth redistribution away from the most optimistic buyers of the asset. If these buyers are also crossover holders of a second asset, their losses in the first asset might force them to raise money by selling the second asset. Moreover, the leverage cycle price decline in the first asset will make these buyers feel there is a special opportunity there, leading them to withdraw even more money from the second asset to take advantage. These two reasons for withdrawign demand for the second asset lead to price declines there.

Two examples of this kind of spillover into seemingly unrelated markets involve the mortgage market and emerging markets bonds in 1997–1998 and in 2007–2008. In 1997, a crisis started in Asian and Russian emerging markets and was followed within 6 months or a year by a sudden downturn in mortgages. (See the mortgage securities leverage graph in Figure 12.) In 2007, a crisis in mortgages seemed to migrate to emerging markets.

As mentioned earlier, the great crisis of 2007–2009 was the culmination of a double leverage cycle, in two separate but interrelated markets, mortgages, and mortgage securities. Declining cash flows in one asset induce lenders to tilt the credit surface in the other. George Soros's principle of reflexivity includes the proposition that historical crashes invariably involve disasters in two separate but interrelated markets (see Soros, 2009). Leverage rose in housing and in mortgage securities together. The trouble with mortgage delinquencies depressed mortgage securities prices, which led mortgage originators who wanted to sell their loans into pools to cut back on housing leverage, which depressed housing prices, which indicated future default losses, which reduced mortgage security prices.

The Credit Terms Cycle and Central Bank Policy

As mentioned at the outset, leverage is just one of many terms that come with loans, besides the interest rate. In boom times, many credit terms get relaxed, not just leverage. It is important to keep track of all of them. The general credit surface is the loan interest rate as a function of its various terms, including LTV, DTI, FICO (or credit score), and, of course, maturity. Not all of these terms can be displayed easily in the same picture. By picking any two credit terms, such as LTV and FICO, David Rappoport at the Washington Federal Reserve has worked with Geanakoplos to produce credit surfaces like Figure 15.[31]

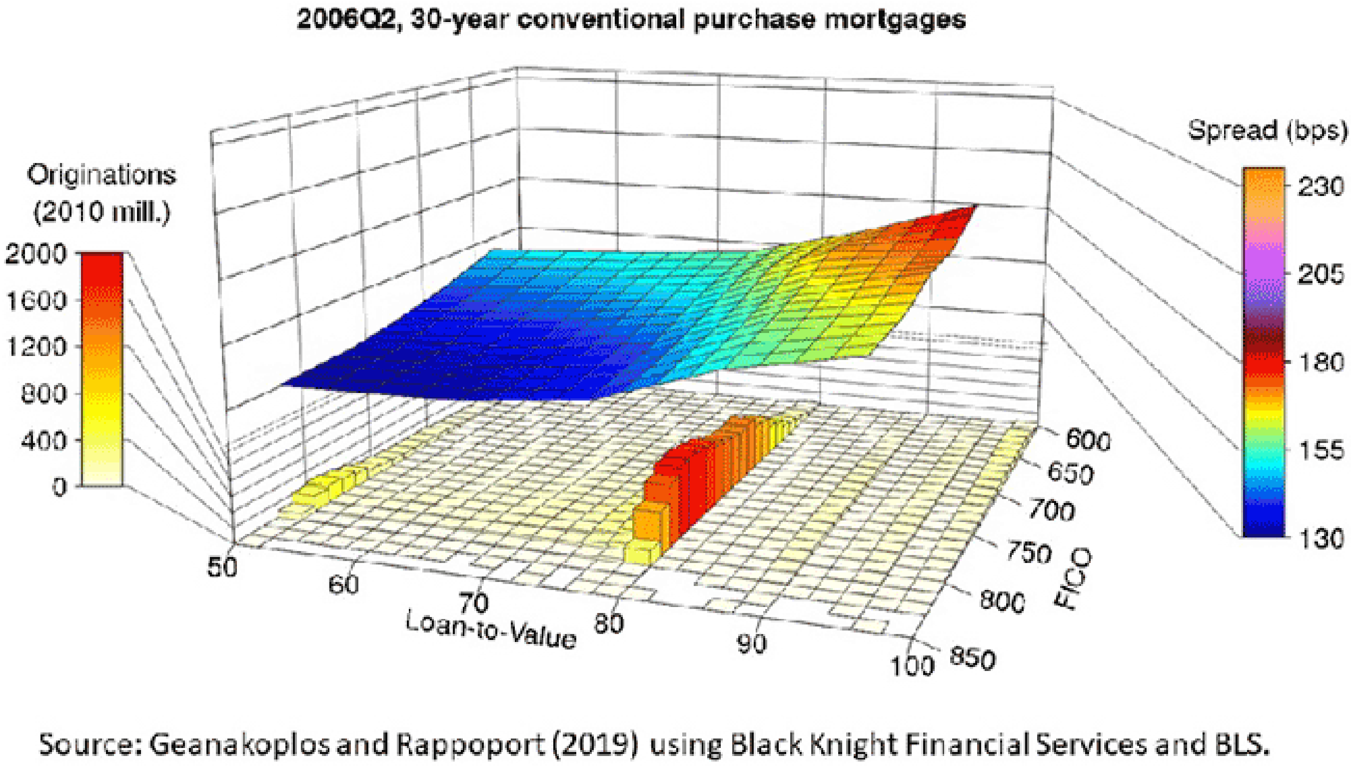
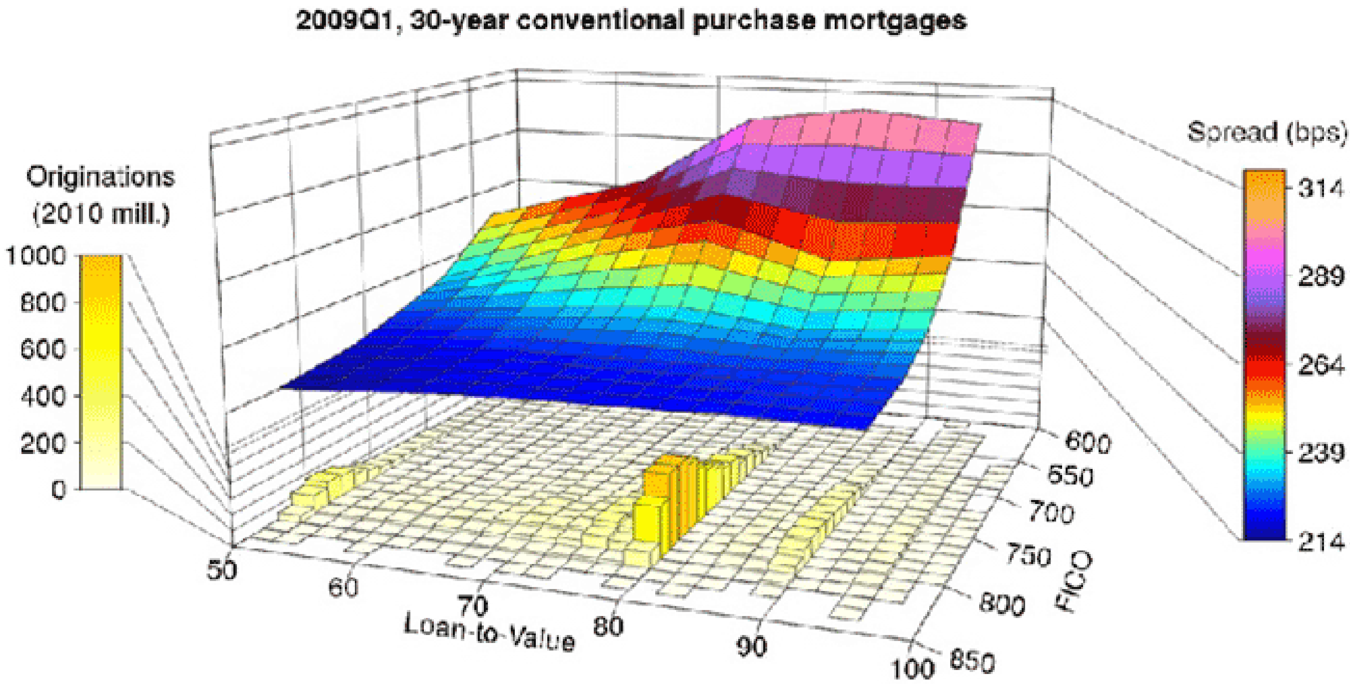


Figure 15. The mortgage credit surface just before the 2009 crisis is flat.

The picture shows the average interest rate charged on all fixed-rate FannieMae and FreddieMac mortgage loans in the second quarter of 2006 as a function of LTV and FICO. Loans with the highest FICO and lowest LTV, in the southwest corner, are the safest loans. Loans with the highest LTV and lowest FICO, in the northeast corner, are the riskiest loans. Even for the conforming group of households who passed many hurdles to get into government programs, there is a difference in interest rate depending on credit characteristics. But the curve is generally quite flat, indicating a loose credit surface. The rectangular blocks below the surface give the volume of loans at the point on the surface just above. One can see that the bulk of the loans were given with less than 80% LTV. But there is a significant number with LTV close to 100% and FICOs around 650.

Consider next the mortgage credit surface in the first quarter of 2009, after the crisis had started. It is much steeper, and the number of low-FICO, high-LTV loans is much less. See Figure 16.



Source: Geanakoplos and Rappoport (2019) using Black Knight Financial Services and BLS.

Figure 16. The mortgage credit surface during the 2007–09 crisis is steep, especially for low FICO loans.

Seven years after the crisis subsided, we can see that the credit surface has again become flat for high-FICO agents. But for low-FICO agents, the credit surface is still steep. In the long aftermath of credit cycle crashes, low-FICO agents still find it difficult to borrowsee Figure 17

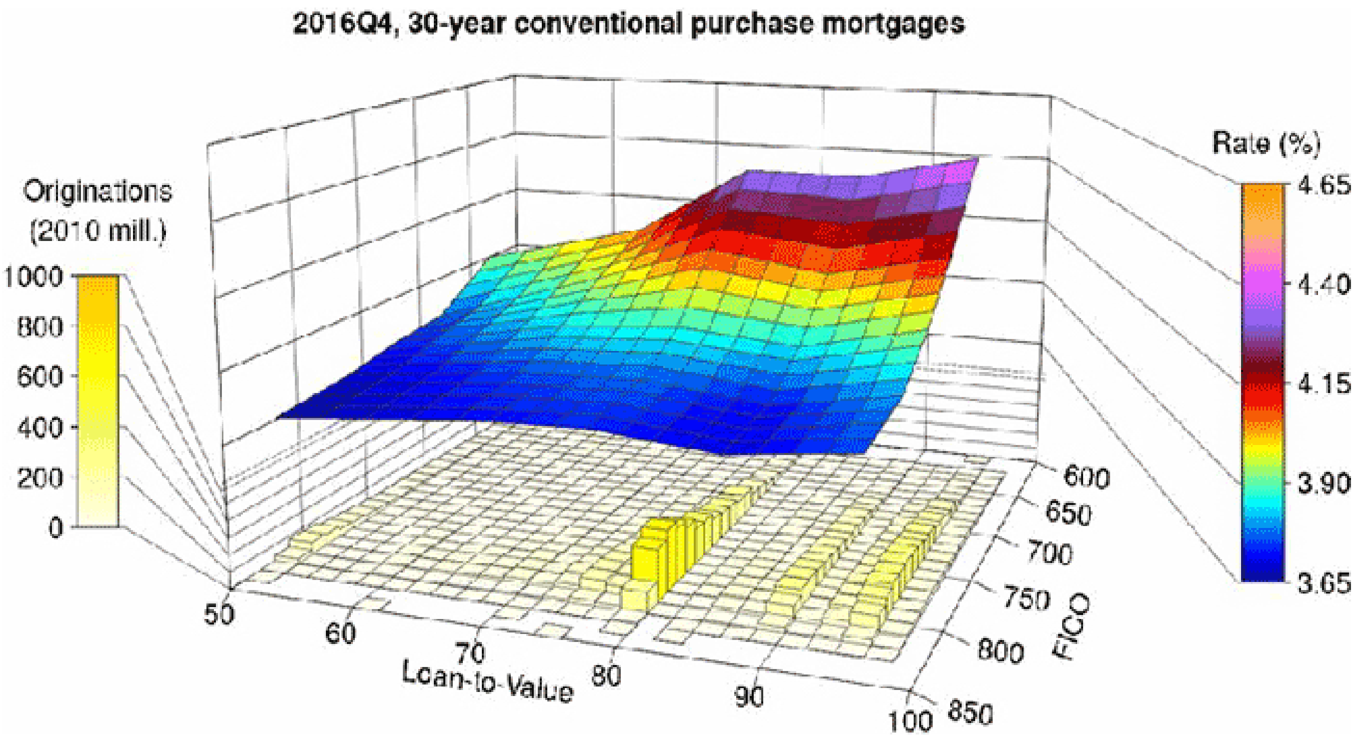
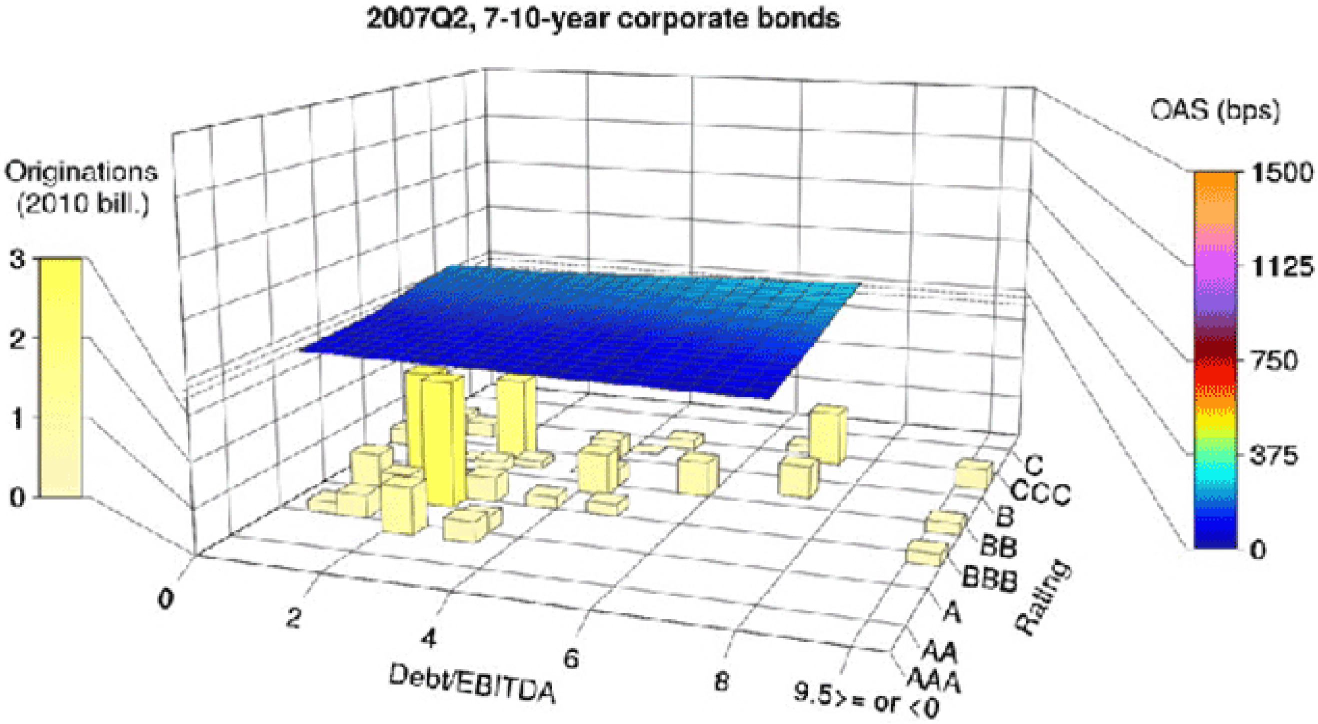


Figure 17. The mortgage credit surface after the 2007–09 crisis remained steep for low FICO borrowers.

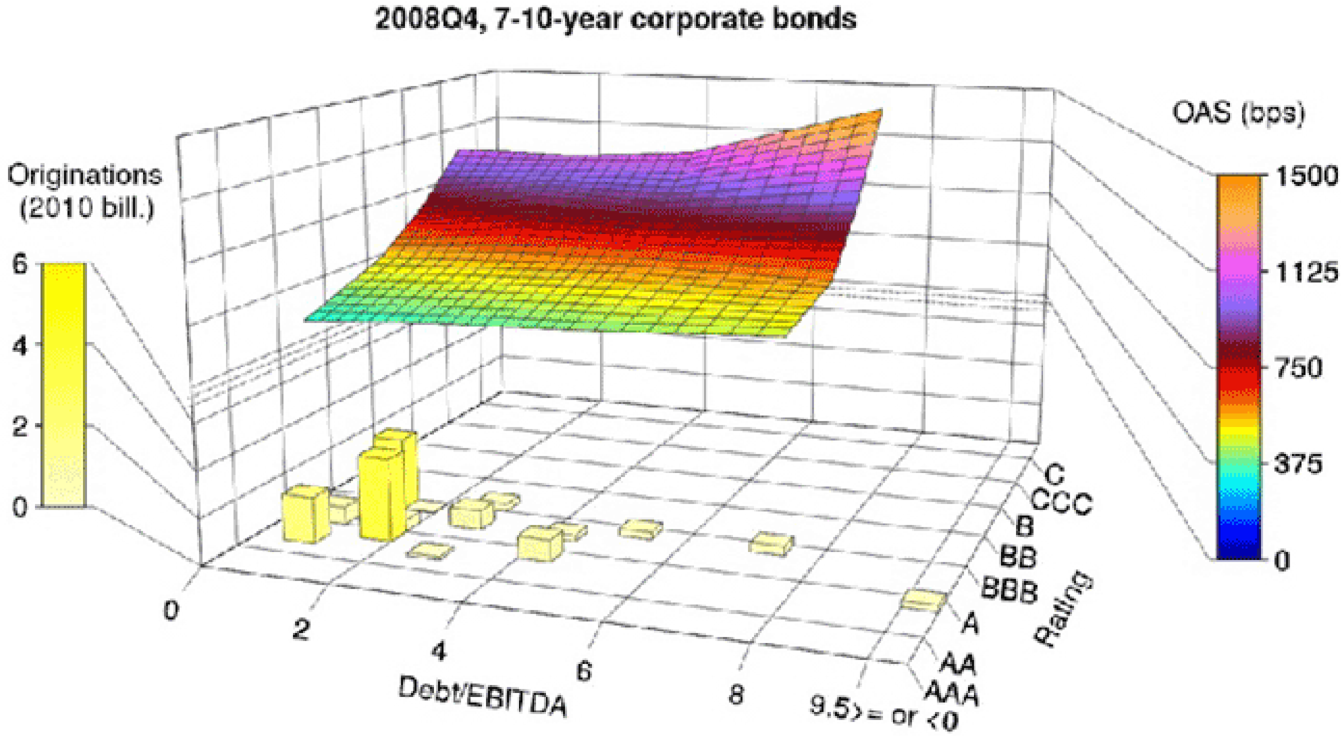
In Figure 18, the corporate bond credit surface for 2007 is shown.[32] As it was for mortgages in 2006, the corporate bond credit surface is very flat.



Source: Geanakoplos and Rappoport (2019) using ICE, Bond Indices, Mergent FISD, CRSP/Compustat, Compustat, and BLS.

Figure 18. The corporate credit surface before the 2007–09 crisis was flat.

In the fourth quarter of 2008, the credit surface became remarkably steeper, making it much more difficult to borrow. See Figure 19. The reader should be aware that the credit surfaces do not always move in tandem. In late 2019, for example, the corporate credit surface had again become very flat, but the mortgage credit surface at the low-FICO end had not. The Fed should be aware of which parts of which credit surface its policy affects. Perhaps it could use the language of credit surfaces to explain and assess its policy.



Source: Geanakoplos and Rappoport (2019) using ICE, Bond Indices, Mergent FISD, CRSP/Compustat, Compustat, and BLS.

Figure 19. The corporate credit surface got higher and steeper during the 2007–09 crisis.

Forgiveness

In 2008 and 2009, Geanakoplos and Susan Koniak wrote two op-eds in the *New York Times* advocating partial forgiveness for subprime loans.[33] They argued that once homeowners with bad credit ratings fell far enough underwater, they were likely to default on their loans and that lenders who insisted on receiving full satisfaction would wind up with less money in the end than if they partially forgave some of the debt. They went on to predict that subprime debt would not be forgiven because the loans were all securitized in pools controlled by servicers who had no incentive to write down principal during a crisis. The bondholders, who ultimately receive all the cash flows and might have an incentive to forgive, did not know the names of the homeowners or the identities of the other bondholders and did not have the legal right to modify the loans anyway. Geanakopolos testified two times in Congress about these matters, and 17 hedge funds also testified that they would like to partially forgive the subprime debt that paid their bonds.

The example Geanakoplos and Koniak (2009) gave in favor of forgiveness was of a $160,000 subprime loan, backed by a house that had fallen in value to $100,000. Why should a homeowner, who did not have a good credit rating to protect, pay 60% more than the house was worth, when they could walk away with no penalty? Foreclosing when the homeowner stopped paying turned out to be even worse than we predicted. The average subprime mortgage foreclosure recovered about 25% of the principal, which, in Geanakoplos and Koniak's example would have been $40,000. The reason, as they argued, is that it can take 2 or 3 years to get the foreclosed homeowner out of their house, during which time they do not pay their mortgage or pay their house taxes or fix their house. And on the way out, they might take all the copper. By partially forgiving the loan down to $90,000, the lender likely would have gotten the whole $90,000, either because the homeowner would keep paying their coupon (lowered by the principal reduction) or because they would sell the house for the profit of $10,000 and pay off the whole loan. On top of that, Geanakoplos and Koniak added a clause that if the house values miraculously turned around and the homeowner sold the house for more than $100,000, then half the appreciation would be owed to the lenders, up to the point where the original loan was made whole.

Reducing principal for seriously underwater homeowners independent of whether they are delinquent creates no moral hazard incentive to stop coupon payments.[34] Larry Summers and others in the administration felt that by writing down grossly underwater mortgages before they defaulted, the lenders might lose money on borrowers who would have paid the entire principal back in the end, even though they were underwater. The facts say otherwise about a timely forgiveness policy. For 2005–2007 loans that reached 120% LTV or more by January 1, 2008, about 75% went into foreclosure, with losses on average of about 75% per foreclosure (giving total losses of about 56% of the unpaid balance of all active loans in 2008 that reached LTV above 120%). Many of these loans defaulted even though they got coupon payment reductions. By contrast, a policy that wrote down principal to just below 100% LTV would have cost about 35% of the unpaid balance (UPB), and might have eliminated almost all the foreclosure losses.[35] And some of the 35% would have been recouped from the borrowers that never defaulted when their houses regained their value.

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Notes

1. Much of this introduction is taken from Geanakoplos (2019), part of which was, in turn, taken from Geanakoplos (2010b) and Geanakoplos and Zame (2014).

2. Fraud and market manipulation, as Bankman-Fried is accused of committing, can be prevented by supervision.

3. See Geanakoplos (1997, 2003, 2010b) and also Fostel and Geanakoplos (2008).

4. Geanakoplos added the forgiveness dimension to the leverage cycle in 2008 (see Geanakoplos and Koniak, 2008, 2009).

5. Collateral appears in formal macroeconomic models first in Bernanke and Gertler (1986), and then simultaneously in 1997 in Kiyotaki and Moore (1997), Holmstrom and Tirole (1997), and Geanakoplos (1997). One difference between these is that Geanakoplos (1997) emphasized the endogeneity of leverage and changes in leverage, while the others did not. Geanakoplos (1997) and Geanakoplos and Zame (2014) put collateral into general equilibrium.

10. An interesting question is why bad news and uncertainty increase and decrease together. Fostel and Geanakoplos (2012b) showed that given the choice of two investment projects with the same distribution of final output, investors prefer the one in which bad news creates more uncertainty (rather than the reverse), starting in intermediate periods after bad news, because it can be leveraged more initially.

6. More precisely, assuming that the borrower-buyers have a higher propensity to spend on assets out of wealth, the decline in demand from the now poorer borrower-buyers is greater than the increase in demand from the now richer lender-sellers.

7. It sometimes happens that when the world gets scarier, lenders who have signed contracts guaranteeing that they won't change margins (i.e., LTV or leverage) make margin calls falsely claiming that collateral prices have fallen.

8. In Geanakoplos (2003, 2010b) the identity of the marginal buyer dramatically changes in the crash. In Fostel and Geanakoplos (2014) the marginal utility of the collateral to the leveraged buyer collapses in the crash, due to the bad news, a drop in consumption, and especially the drop in how much it can be leveraged. The leveraged buyer nevertheless retains the collateral because he does not run out of money and because the marginal utility of the collateral to the lender remains even lower.

9. A complementary point is that in the boom when the collateral prices go up, the borrower-buyers have to spend more on their purchases, reducing their wealth. When the collateral prices go down, the old borrower-buyers are forced to sell; they get poorer and must sell still more. This is called the debt-fragility mechanism.

11. On the downside, CDS (collateralized default swaps) sometimes get introduced for assets near their peak prices (as with mortgages in 2005 and Greek bonds in 2011) to satisfy the desires of shortsellers. CDS allow agents to bet that the asset prices will fall, but more importantly, lure potential buyers of assets into selling the CDS insurance instead, thus bringing down the asset prices.

12. See Thurner, Farmer, and Geanakoplos (2012) for a model of traders who follow behavioral rules based on extrapolating trends from the past. They find that leverage creates fat tails for asset prices. See Bordalo et al. (2018) for a more sophisticated treatment of expectations.

13. For multiple equilibria in the leverage cycle, see Brunnermeier and Pedersen (2009).

14. A similar solution to the problem of endogenous default penalties was provided in Geanakoplos et al. (2005).

15. See Geanakoplos (1997).

16. The flat part should be at the riskless rate because there is no risk. When the lenders must pay a regulatory-capital penalty for making some kinds of loans, the rate on the flat part of the credit surface might exceed the riskless rate for unpenalized holdings of government bonds.

17. See Fostel and Geanakoplos (2015). Financial assets give no direct utility for holding them (like a painting would), and their future dividends do not depend on who holds them. Think of a share of GE stock or of a mortgage-backed security. Thus, in binomial economies with financial assets, leverage to the right of Point A will never be observed. This is not true for houses or paintings or for financial assets with trinomial states, where the most interesting borrowers might indeed be to the right of Point A. Loans to the left of Point A are over-collateralized. If irrelevant extra collateral is ignored, those loans could be said to be maxmin loans on a smaller collateral base.

18. Points to the left of A (but not to the right) are possible, but they involve over-collateralization and so can be treated the same as Point A.

19. Everybody has to know that only two things can happen, and agree on which two things can happen, although not necessarily on their probabilities.

20. In Geanakoplos (2003), the same theorem is proved but under the additional hypothesis that agents are risk neutral.

21. The question of what expectations lead to more leverage in case there are more than two states is quite complicated. The biggest advance was made by Simsek (2013). See also Phelan (2017).

22. A recent paper Benmelech et al. (2021) gives longitudinal evidence that when the payoffs of corporate firms become stressed and more uncertain, they issue more collateralized debt, which sells at much tighter spreads than their uncollateralized debt.

23. If the interest rate rose as agents leveraged more, agents would discount the cash flows from the asset more harshly, and so their lower valuations would party offset their gain in purchasing power, leaving the final collateral price ambiguous.

24. The original borrower-buyer presumably spends a higher proportion of each marginal dollar on the asset than the original lender or seller. (That's why they leveraged to buy the asset.) The loss of wealth of the borrower-buyer therefore reduces demand more than the augmentation to the wealth of the lender or seller increases demand.

25. This is worked out in Ben Ami and Geanakoplos (2017).

26. More subtly, the fire sales literature conflates valuation with marginal propensity to spend out of income, though to be sure the two often go hand in hand, as when there are linear utilities.

27. In Adelino et al. (2018), the authors argued that housing mortgage leverage did not rise leading up to the crisis, or fall afterward. They announce the surprising nature of their findings as "contrary to popular beliefs," including of most of Wall Street. Let me mention several ways in which their interpretation of the data strikes me as wrong. First, Adelino, Schoar, and Severino acknowledge that DTI rose dramatically leading up to the crisis. So credit terms manifestly became looser. The credit surface is multidimensional, as mentioned at the outset and emphasized more in a later section. LTV is not a standalone variable. Inverting the credit surface and writing LTV as a function of interest rate and other credit terms, such as DTI and FICO, the LTV surface got looser according to their own analysis. Second, LTV is a subtler measure when talking about a long-term loan (such as a mortgage) as opposed to a short-term loan (such as a repo). With a more appropriate measure of LTV, they would have found a big rise during the mid-2000s. Goodman (2019) constructs a risk index of mortgages and finds that it rose substantially in the mid-2000s. The mid-2000s were famous for introducing riskier mortgages, such as interest-only mortgages, negative amortizing mortgages, and floating rate mortgages (whose initial interest is lower, especially with teaser rates for the first 2 or 3 years). These became 30%–40% of all the originations in that time period. They defaulted much more frequently in the crisis than conventional mortgages with comparable borrowers. The reason these mortgages are regarded as riskier is that the borrowers pay less over the early years of the mortgage. Mortgage default is much more likely on a day in the 3rd year than on the very first day. The mortgage payments through the 3rd year are a smaller fraction of the original debt with the riskier mortgage. A measure of LTV that corresponds to the scheduled LTV in the 3rd year (assuming stable housing prices) would have risen in the mid-2000s. Third, Adelino, Schoar, and Severino focus their attention on new mortgages. But, of course, mortgage refinancing, especially cash-out refinancing, was notorious for higher LTVs during the mid-2000s, in part because the appraisal value used in the LTV calculation was widely viewed, even at the time, as inflated. It is simply not true that LTV on refinanced loans does not affect housing prices. Homeowners in need of cash can sell their homes, but if they can borrow more without selling, then the homes do not go on the market. An important reason housing prices fell rapidly during the crisis is that homeowners could not refinance their loans and were forced to sell. Fourth, and most importantly, by their own measures, Adelino et al. show that private lending standards, including LTV, did indeed get looser in the run-up to the crisis of 2007–2009, consistent with the diagram in Figure 13. Adelino et al. say that the looser private standards were compensated by stricter risgovernment lending during the same time. (By "government," they do not mean Fannie and Freddie, which themselves were

delving for the first time into subprime-like loans but rather Federal Housing Administration loans.) They lose track of this distinction when later they emphatically declare that lenders did not change their LTV standards. The economy is much more vulnerable when the private sector is holding high LTV loans and the government is holding low LTV loans than it is in the reverse situation.

28. A similar story unfolded with Greek sovereign debt. After Greece gained entry into the European Monetary Union in 2000, it was able to borrow more money. Eventually, Greek banks were buying Greek sovereign bonds, at very high LTV, since the capital requirements for sovereign debt were so low. As the ratio of debt to Greek GDP rose, investors became more jittery. When the Greek crisis started just after the revision of Greek deficit numbers, Prime Minister Papandreou blamed it all on the CDS market.

⮥ Hale et al. (2018) similarly describes the exponential rise of bitcoin price and the subsequent crash as the result of financial innovation.

29. In this section, Fostel and Geanakoplos (2008) is followed.

30. In the language of Fostel and Geanakoplos (2008), they have more collateral value.

31. Gilchrist and Zakrajsek (2012) is one of the leading papers to call attention to the empirical importance to economic activity of the extra interest rate (spreads) that borrowers must pay on lower rated debt. The credit surface encompasses all the dimensions of lending terms simultaneously. The leverage cycle is a theory of how all these spreads are determined in equilibrium, and how they affect asset prices.

32. There are complications in presenting simple interest rates for different bonds at different times, if, for example, some of the bonds are callable and others are not. For corporate bonds, the interest rate is replaced with something called the option-adjusted spread, which adjusts for the option value of the bonds. These details are not discussed here due to space considerations.

33. See Geanakoplos and Koniak (2008, p. 9). A fuller discussion appears in Geanakoplos (2010a).

34. It might create an incentive to take out bigger loans. To the extent that higher leverage raises home prices and makes the economy more vulnerable, the practice of writing down principal makes leverage constraints more important.

35. Writing down a 120% LTV loan by 25% would give a new LTV of 90%.

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