Leverage Caused the 2007-09 Crisis

John Geanakoplos

1 The Leverage Cycle

There are two standard explanations of the cause of the 2007-09 crisis. The first is 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, on money markets, and on 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 as Treasury Secretary Timothy Geithner argued in his book Stress Test.

Greed and panic cannot be legislated away, or prevented by macroprudential policy.

At the World Econometric Sociey Congress of 2000, long before the crisis of 2007-09, I proposed another theory of booms and crashes: the leverage cycle, caused by a build-up of too much leverage and then a faster de-leveraging.[1] 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.[2]

Between 2000 and the 20007-09 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 delay the recovery, and stirred resentment that lingers today. Unlike greed and panics, the leverage cycle crash can be prevented by wise public policy.

The conventional view in macroeconomics had long been that cycles are caused by fluctuations in aggregate demand. These 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 interest rate centric view of macroeconomics is

[1] See Geanakoplos (2003).

[2] I added the forgiveness dimension to the leverage cycle in 2008 (see Geanakoplos-Koniak (2008), (2009)).

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 don't mean that the riskless interest rate set by the Fed is too high. They mean that at the going riskless interest rate, or anything close to it, they cannot get a loan, because lenders are afraid they might default. Default is what is missing in the traditional macroeconomics theory.

Once default is recognized as a possibility, we should expect lenders to require additional terms for a loan, like a maximum debt to income (DTI), or a minimum credit score (FICO). The most important requirement is usually collateral, and I concentrate on collateral here.

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 leverage is $5 = \$100/\$20$, 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 are in the same ratio as the leverage.

The new idea in the leverage cycle is that more leverage causes higher collateral prices. The only precedents for this 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). Both of them made the extrapolative (irrational) expectations of borrowers the linchpin of their theories.[3]

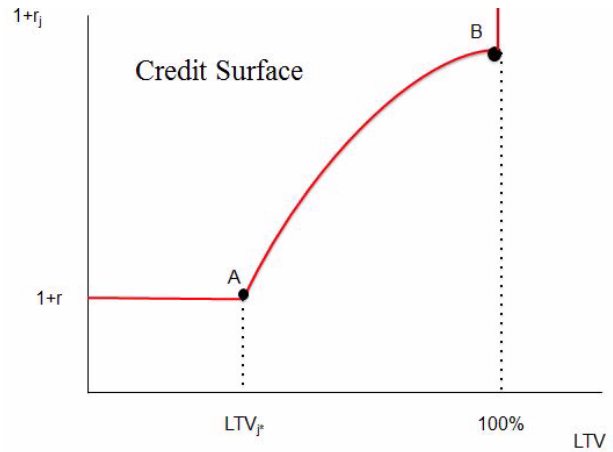
There are three mathematical concepts behind the leverage cycle. The first is that leverage can be made endogenous via the credit surface. Second that leverage increases when volatility, or more precisely, down risk, decreases. The third is that higher leverage makes for higher asset prices, all else equal. Each concept corresponds to a precise mathematical theorem in the case of binomial economies.

I had never heard the word collateral mentioned in any course I took as a graduate student, even in macroeconomics and finance. When I worked in the fixed income department at Kidder Peabody in the late 80s and early 90s, collateral came up in almost every conversation. I began to think about collateral as a theorist, and was immediately struck by a puzzle. How can one supply equals demand equation for a loan determine the price (or interest rate) on the loan and also the collateral rate or leverage or LTV on the loan? It seemed impossible that one equation could determine two variables. This same problem becomes even worse when one considers all the other terms of a loan, like FICO and DTI.

[3]Collateral appears in formal macroeconomic models first in Bernanke and Gertler (1986), and then simultaneously in 1997 in Kiyotaki-Moore, Holmstrom-Tirole, and Geanakoplos. One difference between my approach to leverage and the rest is that I emphasized the endogeneity of leverage and changes in leverage, while they did not.

I resolved this puzzle for collateral when I realized that I should be thinking about a different price for each different level of leverage. 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 what I called the Credit Surface.[4] More generally, one could imagine a credit surface with independent axes including LTV, DTI, and FICO, and a vertical axis giving the corresponding interest rate charged to a loan with any combination of those three characteristics.[5] I shall be content to stick with the collateral credit surface in this paper, though I return to the more general case in Section 3.

See Diagram 1 Credit Surface



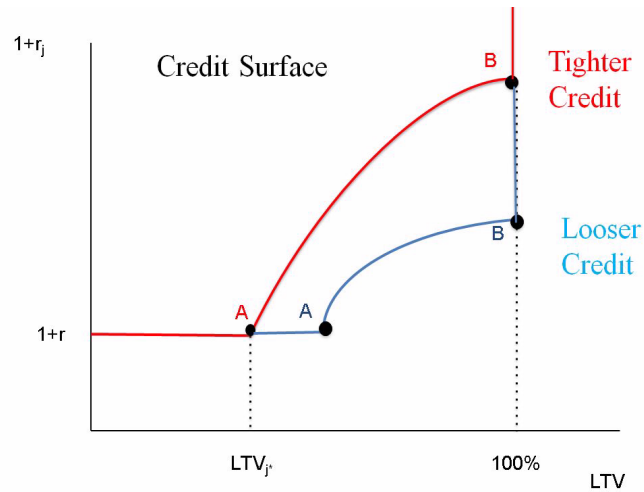
Endogenous Leverage: lenders and borrowers separately choose where
On the credit surface they want to trade, taking LTV and r as given
Rational choice of contract, given (rational) expectations about future

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. 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.

[4] See Geanakoplos (1997).

[5] See Geanakoplos (2016). One could also imagine different axes corresponding to different kinds of collateral, depending on the precise legal rights for the confiscation of the collateral.

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



Rational choice of contract, given (rational) expectations about future

For Binomial Economies with financial assets, my student Ana Fostel and I 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 the point A in Diagram 1.[6] 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. Of course the binomial assumption, that only two things can happen, is very unrealistic. But the conclusion does not depend on the preferences of the agents or their endowments or their probability assessments of the future states.[7]

The binomial no default theorem has an immediate consequence for leverage, which Fostel and I 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, we showed that in binomial models with financial assets, equilibrium LTV is equal to

[6]See Fostel-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 trinomial economies, where the most interesting borrowers might indeed be to the right of point A. Loans to the left of point A are overcollateralized. If we ignore the irrelevant extra collateral, we could say those loans are maxmin loans on a smaller collateral base.

[7]In Geanakoplos (2003) I had proved the same theorem, but only under the additional hypothesis that agents are risk neutral.

the worst case gross return, divided by the gross riskless rate of interest

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

When risks are symmetric, the worst case is worse if volatility is higher. It has been known among Wall Street traders that margins (in say the commodities markets) go up when volatility goes up. The binomial leverage theorem asserts that leverage is determined by volatility, or more generally, down risk, and it does not depend on utilities or endowments or the number of traders, or the type of financial asset.

The third key mathematical idea is that 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 downpayment, 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.[8] Fostel and Geanakoplos (2014) proved that in any binomial model with financial assets, constraining leverage below the equilibrium maxmin value always lowers the value of an asset, assuming that the risk free interest rate does not change.[9]

The link between leverage and asset prices contradicts the famous Modigliani-Miller 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 is left with 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 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 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.

[8] Imagine all the buyers arrayed on a vertical corresponding to their valuation of the asset. The marginal buyer is the agent whose valuation is equal to the price. The higher valuation agents will be buyers, and the lower valuation agents will sell the asset. As the natural buyers get access to more borrowing, a fewer number of them can buy all the assets, creating a higher marginal buyer, and thus a higher price.

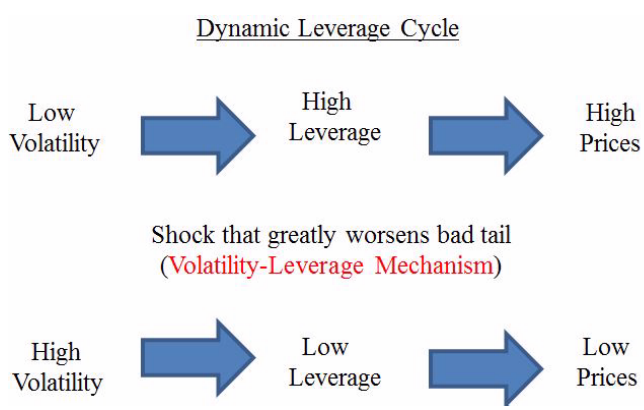
[9] If the interest rate rose as agents leveraged more, agents would discount the cash flows from the asset more harshly, and so their lower valuations would party offset their gain in purchasing power, leaving the final collateral price ambiguous.

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 homeowner who is limited (say be regulation, or by a worse down risk in housing prices) to taking out a mortgage at smaller LTV. She would simply have to come up with a bigger downpayment, since taking out a second loan would not be permitted by the regulation, or by the worse down risk. There is no outside agent who can use her equity to increase his leverage. The drop in debt will necessarily have real consequences, for the economy and for the price of the houses. 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 if we go one step deeper. If a regulation limits the leverage that can be used by agents using firm equity as collateral, or if the equity returns from firms have greater down risk, then leverage will go down at the agent level as well as at the firm level, and collateral prices will fall.

Putting these three mathematical concepts together gives the two mechanisms that drive the leverage cycle. The first mechanism involves abrupt changes in anticipations of down risk. An awareness that the down risk is worse, even if unlikely, may cause expected cash flows to decline. But more importantly, it causes leverage to go down which will also cause asset prices to go down. We can express this diagrammatically where we illustrate the effect of scary news (news that increases uncertainty, or more precisely, down risk)

Diagram 3



The second mechanism arises from high levels of debt. I call it the income redistribution effect. 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. 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. So why does high debt make for fragile economies?

The answer comes from an old microeconomic dichotomy called the income and substitution effect.When the price of a good 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. 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 seller poorer, which means he might want less of everything, including Y. In more dramatic words, the further the price goes down, the more he 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.[10] A drop in the price of Y effectively redistributes income from the sellers to the buyers, in proportion to how much is sold. If the marginal propensity to spend on Y out of income is higher for the sellers, then their income induced drop in consumption of Y will be greater than the buyers' income induced increase in consumption. In aggregate, the income effect will tend to reverse the substitution effect. Unlike the income effect, the substitution effect is invariant to the quantity sold. Hence for bigger sales, the aggregate income effect diminishes the stabilizing aggregate substitution effects more. With big enough sales, the aggregate demand curve for Y will be close to flat.[11] 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.[12]

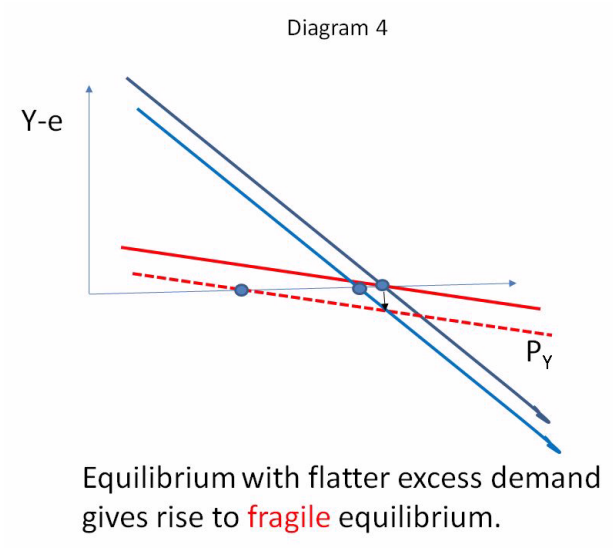
See Diagram 4, which illustrates how the same vertical shock down will produce a small change in the equilibrium price of an economy with steep demand (i.e. with

[10]The famous Slutsky equation says that the income effect is the product of the marginal propensity to consume and excess demand. Since in equilibrium the excess demand of the sellers of Y must be the negative of the excess demand of the buyers, the aggregate income effect on Y is the product of the difference between the sellers' and the buyers' marginal propensities to consume Y and the excess demand of the sellers for Y.

[11]With still bigger sales, the income effect will reverse the substitution effect, and demand will be increasing. But that means there are multiple equilibria.

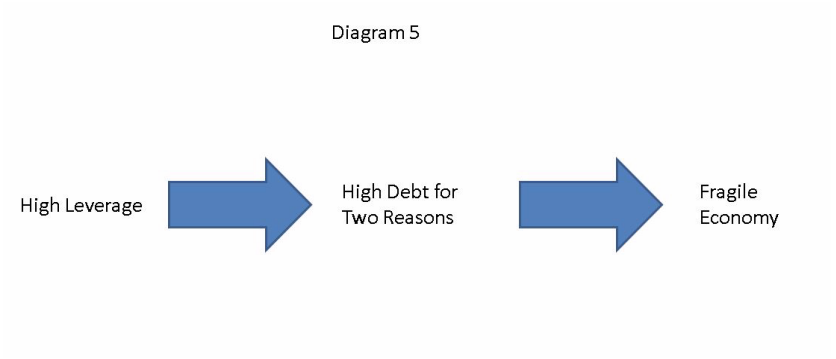
[12]This is worked out in Ben Ami - Geanakoplos 2017.

a dominant substitution effect), but produce a large change in the equilibrium price of an economy with flat demand (i.e. with a dominant income effect)



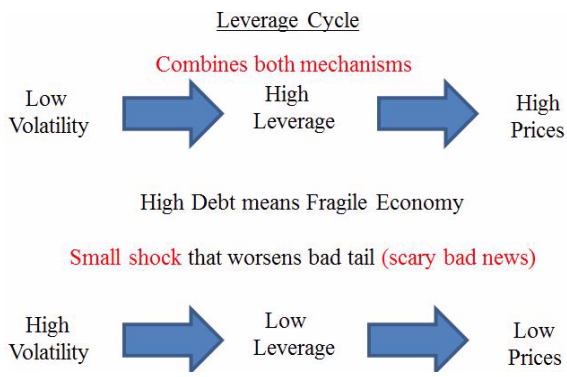
When there is a large debt that is coming due, then there must be a large sale, either of some good or of more promises, to pay the debt. If collateral is scarce, and if leverage is low, then there is a hard cap on the sales of new promises, and so there must be sales of some good or asset. Economies that have large short term debts therefore are perpetually in a vulnerable situation, because they perpetually have enormous sales. If the marginal propensities to consume are markedly different between sellers and buyers, then they are fragile.

When leverage rises, asset prices rise, so borrowers are borrowing a higher percentage of a higher number. With higher leverage, borrowing goes up for a squared reason, and so debt can skyrocket. Thus by increasing debt, leverage can also make the economy fragile through the income redistribution mechanism. See Diagram 5



Putting the volatility-leverage mechanism together with the income redistribution mechanism, we see that a little bit of scary bad news can have a huge effect on asset prices.

See Diagram 6



Thus the leverage cycle I described in 2003 goes like this. A long period of low volatility leads to a flatter credit surface and thus increased leverage, and laxer credit standards generally (for the same reasons). 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. But as we saw at the outset, the most leveraged buyers will lose the highest fraction of their wealth. They are likely to be the highest valuation - highest marginal propensity to spend buyers, and their disappearance (or reduced purchasing power) 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 final drop in leverage reducing old and new buyers' demand for assets.[13] Asset prices and activity will stay low as long as uncertainty remains high and the credit surface remains steep. And as I added in 2008, if the 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.

The leverage cycle as I told it does not rely on extrapolative or irrational expectations. It can perfectly well occur with rational expectations, as in my model. The story does depend on heterogeneity in asset valuations and marginal propensities to buy out of income. I motivated this heterogeneity by different priors, meaning my agents were all completely rational Bayesians, aware of all the possible states of nature, but put different prior probabilities onthe down state. There could have been other ways to explain the heterogeneity, including differences in risk aversion or differences in utility for the assets, as I have demonstrated in later work. My early leverage cycle work had rational updating; the cycle would have gotten even

[13] Another driver of the crash is the sudden emergence of CDS. CDS is a way for pessimists to leverage their short selling of the asset. For the same reason that leverage increases asset prices when buyers can leverage more, so too does increased access to leverage by the short sellers of the asset lower its price. I had not anticipated CDS in 2003, but added them to the story in 2010.

more dramatic with extrapolative expectations. I do not discount the importance of irrational expectations, but merely note they are not needed for the story. Different beliefs are not indispensable for the story, but they can play an important role, as they did in my model.

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 overvaluation and build up 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 more recent 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.[14]

2 The 2007-09 Crisis

The crisis of 2007-09 did not happen out of the blue. There was a long period of increasing leverage and rising asset prices. Moreover, the crisis itself was not an overnight panic, like one sees in bank runs. It lasted for at least two years, and the aftermath carried on for many years after that, despite the most extraordinary central bank interventions in history.

Diagram 7 illustrates the rise and fall in LTV over time on a portfolio of AAA floating rate MBS that Ellington Capital Management has followed since 1998, superimposed on an index of prices for similar securities kept by Morgan Stanley. As can be seen, LTV was around 90% before the 2008 crisis, then jumped down to 60% for a few months in the 1998 crisis, then returned to its previous level. Around 2005 it went up to 95%. But as scary bad news came out about subprime securities in 2007, leverage came down and the asset prices came down. And then they both went up together.

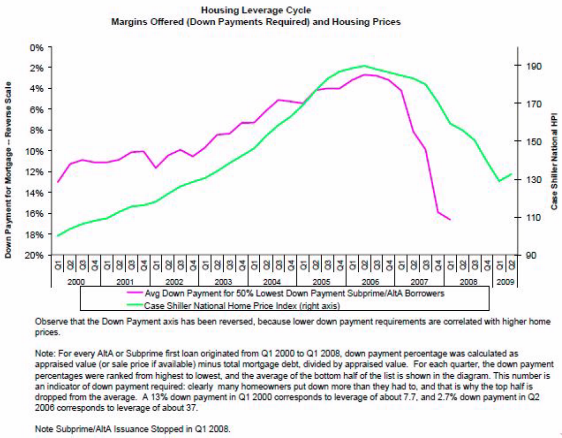
Diagram 7 here:

[14] 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.

Leverage and mortgages securities pricing

A similar story can be seen in the housing market. Diagram 8 shows the Case-Shiller housing index, which rises by 90% from 2000 to the third quarter of 2006, then drops 30% after the crisis begins. Superimposed is the graph of average LTV for the top half (ranked in order of leverage) of all Alt-A and subprime non-government loans. It starts with margins at 14% in 2000, and goes to margins of 2.7% in the same quarter as housing markets hit their peak. Afterward, housing and leverage fall together.

Diagram 8 Here



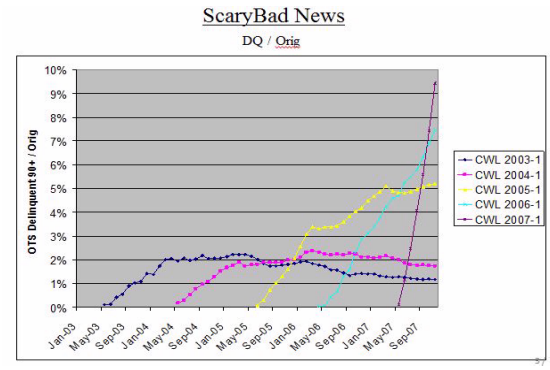
By any measure, volatility was low in the period preceding the crisis of 2007-09. Indeed Ben Bernanke dubbed the period the Great Moderation. Volatility soared during the crisis, and then eventually subsided, all in parallel to the changes in leverage and asset prices. All that remains is to describe the scary bad news that triggered the crisis.

Many people suggest the drop in housing prices caused the crisis. But that begs the question, what caused the drop in housing prices? It is easy to see why housing

prices might have stopped going up in 2006. Leverage stopped going up because it could not go higher. LTV has a natural upper bound at 100% if there is little penalty for default. (Subprime borrowers have low ratings, and so the credit score loss of defaulting is not so big). By 2006, the *average* LTV for the top half was aleady 97.3%, meaning that a lot of them were close to 100%. And many of these were negative amortizing loans that really should be counted as higher LTVs. But even if housing prices couldn't go higher, that still leaves the question why did they fall?

In my opinion,the trigger to the crisis was the increase in subprime delinquencies. For many consecutive vintages of Countrywide loans, the percentage of original balance that were currently delinquent would slowly rise from 0% at origination to about 2% and stay there. But in diagram 9 we see that by the beginning of 2007 the delinquency rate for 2005 vintage loans had already reached 4%, and the delinquency for 2006 vintage loans had already reached 3%.

Diagram 9 here



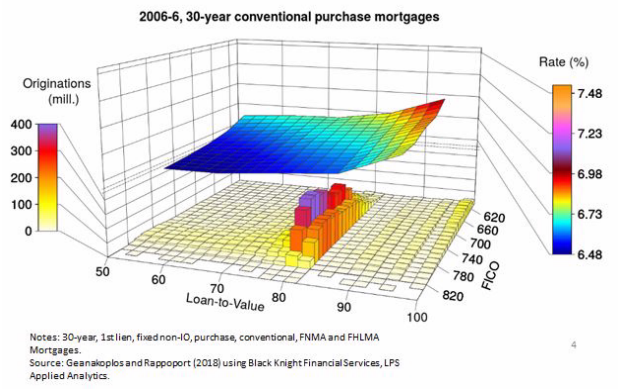
These are tiny numbers, but the fact they had broken through the old 2% threshold caused investors to worry that the number might go much higher. The down risk was much greater. Traditional macroeconomists would expect the prices of these loans to go down, and indeed the BBB subprime bond index collapsed in early 2007. I identified that at the time as the beginning of the down phase of the leverage cycle. But more importantly, lenders did not just increase the interest rate they charged on new subprime loans. They increased the margins, as can be seen in Diagram 8 These higher downpayments closed a large number of potential buyers out of the housing market, and (in my opinion) that led to the fall in housing prices.

3 Central Bank Policy

The policy implications of the leverage cycle are that Central Banks should smooth the cycle, restraining leverage in booms, and in the acute stage of the crisis, propping up leverage. If in the aftermath, depressed asset prices are too low relative to debts, debt must be partially forgiven.

The Washington Federal Reserve has worked with me to produce credit surfaces like the following.

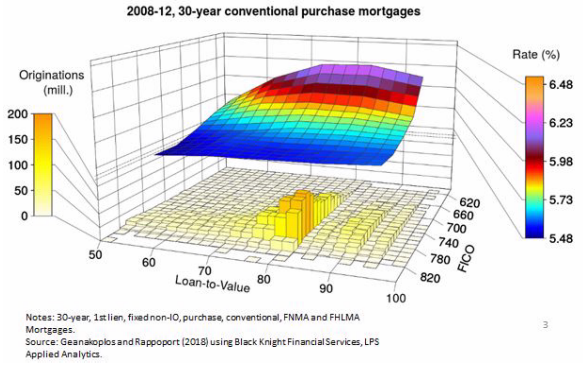
Diagram 10



The picture shows the average interest rate charged on all FNMA and FreddieMac loans in the second quarter of 2006 as a function of LTV and FICO. Loans with the highest FICO and lowest LTV, in the soutwest 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 the government programs, there is a difference in interest rate depending on credit standards. But the curve is generally quite flat, indicating a loose credit surface.

Consider next the credit surface in the last quarter of 2008. It is much steeper, and the number of low FICO high LTV loans is much less.

See Diagram 11



Here, after the crisis has started, the credit surface for even the best borrowers gets much steeper. The low FICO high LTV loans completely disappear. In my opinion the FED should produce these Credit Surface pictures for the general public each quarter. Not only that, but they should be produced for the Corporate Credit Surface, and the Unsecured Consumer Loan Credit surface. This will give economists and business people a much better picture of credit conditions in the economy. I

also think the FED should be aware of how their changes in the riskless rate (in the southwest corner) affect the whole credit surface of each type. They should use the language of the various credit surfaces to explain their policy aspirations. Do they hope the mortgage credit surface will steepen, or just the corporate credit surface. Finally, if there are parts of some credit surface they wish to affect, then they should use unconventional tools to targe those areas. For example, at the current time the credit surface is still very unkind to medium-high FICO borrowers. If the FED wanted, it could purchase loans of that type, which would bring down their rates. If the Fed thought that housing prices were rising too rapidly, it might declare, as Stanley Fischer did as head of the Bank of Israel, that no loans could be issued with kess than 60% required LTV.

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