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Fear of fire sales and the credit freeze

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Abstract

In early 2009, the supply of credit markets in industrial countries appeared to be tightening substantially. Was this because credit quality had deteriorated tremendously outside or inside the financial system? Or was it because bank balance sheets were "clogged" with illiquid securities? If the latter, why did banks not attempt to sell these securities? We argue in this paper that the existence of an "overhang" of impaired banks may itself reduce the price of potentially illiquid securities sufficiently that banks have no interest in selling them. In turn, this creates high expected returns to holding cash across the financial system and an aversion to locking up money in term loans. We discuss what this means for policies to clean up the banking system.

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In early 2009, the supply of credit in industrial countries appeared to be tightening substantially. For example, about 65 percent of domestic banks in the United States reported having tightened lending standards on commercial and industrial (C&I) loans to large and middle-market firms over the past three months, a continuation of a pattern seen in the previous quarter.[2] This percentage was above the previous peaks reported in 1990 and 2001. Ivashina and Scharfstein (2009) document that new loans to large borrowers fell by 47 percent in the last quarter of 2008, with new loans from bank lenders with steadier access to deposit finance falling less. They also show that term lending fell by considerably more than lending to revolving credit facilities (67 percent vs 27 percent).

Clearly credit quality deteriorates in a recession, which might suggest why banks were reluctant to lend. But lending across the quality spectrum seemed to fall in the last quarter of 2008, with new loans to investment grade borrowers down as much as new loans to below investment grade borrowers (Ivashina and Scharfstein (2009)). And, of course, the recessionary conditions themselves may not have been independent of bank lending.[3]

In what might seem a separate development, banks at that time also held on to large quantities of "Level 2" and "Level 3" assets – assets that were not frequently traded and for which the price was either based on models or largely hypothetical. In many cases, these were assets such as mortgage backed securities, for which a liquid market had existed, but where trading had dried up. The popular view was that there was a "buyers strike", as investors who traditionally had bought these assets had been seared by past negative returns and return

[2] The Federal Reserve Board's January 2009 Senior Loan Officer Opinion Survey on Bank Lending Practices.

[3] For overviews of the financial crisis, see Adrian and Shin (2008), Brunnermeier (2008), and Diamond and Rajan (2009).

volatility, and had abandoned these markets. Of course, an immediate question is why new "vulture" investors would not be attracted to these markets – the notion of a "buyers strike", at least over a substantial period of time, seems difficult to countenance. After all, there is always a price at which anything with positive value can be sold.

One explanation is that the banks themselves expected the value of these assets to rise and were reluctant to sell. This too seems implausible, at least prima facie. Why should banks have different expectations from the market, especially since the underlying factors driving the fundamental value of these securities, such as the state of housing markets, were common knowledge among those with expertise in trading mortgage backed securities? Another explanation is that banks were reluctant to recognize losses on these illiquid securities, since that would require writing down capital. Yet many of these banks had substantially more book capital than required by regulators. And the market could clearly see the quantity of level 2 and level 3 assets held on bank balance sheets, and must have incorporated estimates of their value into equity prices. It is implausible to argue that bank management were eager to create uncertainty about the true valuation of these assets, with the additional discount in equity valuation that would be implied, than to sell assets and remove uncertainty.[4]

We argue in this paper that the seizing up of credit and the overhang of illiquid securities are not coincidental, they have common roots. The intuition is simple. Let a set of banks have a significant quantity of assets that have a limited set of potential buyers. One example of such an

[4] Of course, one possibility is that what was going on was a form of forbearance -- if banks recognized all the losses, they would go below the regulatory minimum. Therefore, regulators were willing to suspend disbelief about asset quality so long as banks did not sell assets and make it impossible for regulators to continue the charade. Given that the authorities were attempting to get banks to clean up their balance sheets, and were willing to recapitalize banks up to a point, this explanation does not seem to us the most obvious one.

asset is a mortgage backed security which, in an environment where some mortgages have defaulted, can be valued accurately only by some specialized firms. Furthermore, let us assume that with some probability, the banks will need to realize cash quickly in the future. Such a need for liquidity may stem from unusual demands of the banks' customers, who draw on committed lines of credit or on their demandable deposits. It may also stem from panic, as depositors and customers, fearing a bank could fail, pull their deposits and accounts from the bank. Regardless of where the demand for liquidity comes from, it would force banks to sell assets or, equivalently, raise money, quickly. Given that the limited set of potential buyers or lenders for the bank's assets would have limited resources, the asset would have to be sold at fire sale prices (as in Shleifer and Vishny (1992)).

One consequence of the fire sale is that it may depress asset values so much that the bank is insolvent. This may precipitate a run on the bank, which may cause more assets to be unloaded on the market, further depressing the price. Equally important, the returns to those who have liquid cash at such times can be extraordinarily high.

Folding back to today, the prospect of a future fire sale of the bank's asset can depress its current value – investors need to be enticed through a discount to buy the asset today, otherwise they have an incentive to hold back because of the prospect of buying the asset cheaper in the future. More generally, the high returns potentially available in the future to those who hold cash today can cause them to demand a high return today for parting with that cash today. This will imply both low prices for illiquid assets and high interest rates charged for lending. Illiquidity can depress lending – a feature that may be absent in models where future asset values are uncertain for other reasons.

More surprising though, the bank's management, knowing that the bank could fail in some states in the future, do not have strong incentives to sell the illiquid asset today, *even though such sales could save the bank.* The reason is simple. By selling the asset today, the bank will raise cash that will bolster the value of its outstanding debt by making it safer. But in doing so, the bank will sacrifice the returns that it would get if the currently depressed value of the asset recovers. Indeed, because the states in which the depressed asset value recovers are precisely the states in which the bank survives, bank management would much rather prefer holding on to the illiquid assets and risking a fire sale and insolvency than selling the asset and ensuring its own stability in the future. This idea is clearly analogous to the risk shifting motive in Jensen and Meckling (1976) and the underinvestment motive in Myers (1977), though the bank "shifts" risk or under invests in our model by refusing to sell an illiquid asset than by taking on, or not taking on, a project.

Our simple model predicts that illiquid banks will be on a "seller's strike". It is not that the available market price is irrationally low, but that the alternative of holding on is more beneficial. The "ask" price it would take to get the bank to sell assets is too high given the price potential buyers will bid. Sales of the illiquid asset therefore dry up.

The model allows us to examine various possible interventions in the market that can get lending going again. These interventions aim to get the illiquid assets away from the banks that could be faced with liquidity demands, increase the available liquidity to buy these assets (through the authorities lending to potential buyers), or bolster the capital of illiquid banks so they do not become insolvent. By stabilizing the financial system and eliminating the possibility of fire sales, the authorities can eliminate the potential for high returns to be made in the market, and increase the relative profitability of lending, thus increasing its magnitude. We examine various proposals, including the possibility that banks may have to be coerced into selling assets.

In section I, we present the model. In section II, we examine the sources of illiquidity; in section III we explore interventions. In section IV, we relate the paper to the literature, including papers by Acharya, Gale, and Yorulmazer (2009), Allen, Carletti and Gale (2009), Allen and Gale (1998, 2000, 2003), Allen and Carletti (2008), Bhattacharya and Gale (1988), Bolton, Santos and Scheinkman (2008), Diamond and Rajan (2005), Heider, Hoerova and Holthausen (2009), Holmstrom and Tirole (1998), Shleifer and Vishny (1992, 2009), and Stein (2009). We will describe the relationships once we have described our model. We conclude in section V.

I. The Model

A set of identical banks at date 0 each owns financial assets (for example, mortgage backed securities) that will be worth Z at date 2. The bank is financed with demand deposits (or overnight paper) of face value D, with $Z > D$. For now assume each bank has a local monopoly on financing so that it pays an interest rate of 0. Depositors can demand repayment at date 1 or date 2. Everyone is risk neutral.

At date 1, banks face a liquidity shock with probability q, where a fraction f of their depositors withdraw. We will be more explicit about the sources of this shock later. Depositors demand cash (they cannot trade in the financial asset market and will not accept the asset in lieu of cash[5]). The bank will have to sell some of its asset for cash to meet this liquidity demand. The bank can raise money in anticipation of the shock by selling assets at date 0 for P_0 per unit of

[5] Depositors could be thought of as unsophisticated and hence unable to accept or trade mortgage backed securities or bank loans.

date-2 face value, or it can sell assets, after the shock has been realized at date 1, for P_1 per unit of date-2 face value. Note that if the liquidity shock does not hit at date 1, the bank will not part with the asset at that date for a per unit price less than 1.

Prices and Trading with Unlimited Liability

Let us assume there are buyers who are not subject to liquidity shocks (such as banks with more liquid assets or longer term liabilities, private equity, or Warren Buffet) who can buy at date 1 after the shock hits, paying cash. We will describe how the price and trading are determined at date 0, given the date-1 price, first when the seller has unlimited liability and then when he has limited liability. We will show that trading can dry up at date 0 in the latter case. We will describe the buy side and market clearing in much greater detail after outlining the fundamental force driving the model.

The buyer is indifferent between buying at either date if the price gives him same expected date 2 payoff per dollar spent, so long as the return is greater than the return on cash (so $P_0 \leq 1$ and $P_1 \leq 1$). The highest date-0 bid price of the buyer solves $\frac{1}{P_0} Z = q \frac{1}{P_1} Z + (1-q)Z$, or

$$P_0^{bid} = \frac{1}{q\frac{1}{P_1} + (1-q)} \tag{1.1}$$

Now consider the bank's decision on when to sell. If the bank postpones any sale until after the shock has hit at date 1, it will have to sell a fraction η_1 of the asset such that $\eta_1 Z P_1 = fD$, or $\eta_1 = \frac{fD}{ZP_1}$. If $\eta_1 > 1$, then the bank would be insolvent and unable to raise fD.

For now, we assume that it is either solvent or it has unlimited liability, so it can raise the necessary amounts (potentially from its other assets) to pay withdrawing depositors and the depositors who stay till date 2. The payoff from selling at date 1 with probability q is:

$$q\left[(1-\eta_1)Z-(1-f)D\right]+(1-q)\left[Z-D\right]$$

$$=q\left[(1-\frac{fD}{ZP_1})Z-(1-f)D\right]+(1-q)\left[Z-D\right]$$

$$=Z-D-qfD(\frac{1}{P_1}-1).$$

In words, the bank pays an expected "illiquidity" cost of $qfD(\frac{1}{P_1}-1)$ whenever it has to sell at date 1, which happens with probability q, for a price $P_1<1$. Alternatively, the bank can sell at date 0 for P_0 and hold cash from date 0 to 1, to cover the case where it needs liquidity. If it sells early on date 0, it must sell a fraction of the asset given by $\eta_0=\frac{fD}{ZP_0}$. The bank's payoff from selling just enough to meet the liquidity need is (note that with probability q the proceeds of sale of the fraction η_0 of the asset exactly pay off the fD of deposits):

$$q\left[(1-\eta_0)Z-(1-f)D\right]+(1-q)\left[(1-\eta_0)Z+\eta_0P_0Z-D\right]$$

$$=q\left[(1-\frac{fD}{ZP_0})Z-(1-f)D\right]+(1-q)\left[(1-\frac{fD}{ZP_0})Z+\frac{fD}{ZP_0}P_0Z-D\right]$$

$$=Z-D-(\frac{1}{P_0}-1)fD. \qquad (1.2)$$

That is, by selling at date 0, the bank will pay the "illiquidity" cost of $(\frac{1}{P_0}-1)\,fD$ up front with certainty, which includes the cost of raising cash even though there might be no actual need. The bank is indifferent between selling at date 0 and date 1 when $(1-\frac{1}{P_0})\,fD = qfD(1-\frac{1}{P_1})$ or

$P_0^{Ask} = \dfrac{1}{q\frac{1}{P_1}+(1-q)}$. This is also the bid price (see (1.1)), so trade will take place at both dates so long as the date 0 price bears this relationship to the (yet-to-be-determined) date 1 price.

Limited Liability, Fire sales, and No Trade

We assumed above that the bank was solvent or it had unlimited liability. What if the bank becomes insolvent conditional on the liquidity shock at date 1, and has limited liability? Clearly, the banker will never sell at date 0 if he fails even after doing so. Intuitively, the banker, maximizing the value of equity, will want to maximize the value of the bank's assets conditional on survival. Since the bank survives only in the state with no liquidity shock, and because the asset pays off most when the banker holds it to maturity rather than if he sells it prematurely for a possibly discounted price $P_0 \leq 1$, the banker prefers to hold the asset rather than sell it.

Now consider the case where the bank survives if it sells assets at date 0 for P_0 but it fails at date 1 if the liquidity shock occurs because assets are sold at fire sale prices.[6] From our previous analysis, the bank is willing to sell at P_0^{ask} at date 0 if the price allows it to avoid failure

[6] We can allow the bank debt to be bailed out by the deposit insurance corporation, so long as the banker/equity is wiped out.

and if $Z - D - (\frac{1}{P^{ask}_0} - 1) fD \geq (1-q)(Z-D)$, where the right hand is the bank's expected payoff with no asset sales, given it fails conditional on the liquidity shock hitting. This requires $\frac{1}{P^{ask}_0} \leq 1 + \frac{q(Z-D)}{fD}$, which simplifies to $P_0^{Ask} \geq \frac{1}{1+q(\frac{Z-D}{fD})}$. We also know that given the price P_1, the market is willing to pay $P_0^{bid} = \frac{1}{1+q(\frac{1}{P_1}-1)}$. The bid price is less than the ask, that is, no asset is offered for sale at prevailing prices at date 0 if $\frac{1}{P_1} - 1 > \frac{Z-D}{fD}$. Simplifying, this condition is $fD > P_1\left[Z-(1-f)D\right]$, which is satisfied if the bank is insolvent conditional on selling to avoid the liquidity shock at date 1. We have

Proposition 1: If the bank is insolvent at date 1 conditional on the liquidity shock, it will never sell the asset at the bid price at date 0, even if by doing so it could remain solvent. No trade will take place for the asset at date 0.

In sum, so long as the "fire sale" price of the asset is so low at date 1 so as to drive the bank into insolvency, and the date 0 price reflects that future fire sale price, there will be no trade at date 0 – the market will freeze up. Intuitively, there is no point selling at date 0 for cash if the banker will not avoid failure at date 1 by doing so – the sale simply causes him to accept a discounted value for the asset in all states, including those in which he could hold it to maturity. Even if the banker could avoid failure doing so, he does so by making a transfer to the depositors in the state of the liquidity shock (from value he would have enjoyed if he held the asset to maturity in the state with no liquidity shock). Limited liability allows him to avoid having to make this transfer. Since the date-0 ask price with unlimited liability is exactly equal to the bid price, the date-0 ask price with limited liability has to be higher for the selling bank to be indifferent between selling and not. Hence no trade will occur.

The underlying intuition is a combination of an aggregate liquidity shortage leading to fire sale prices (Allen and Gale (2004), Diamond and Rajan (2005)), and risk shifting (Jensen and Meckling (1976)) or underinvestment (Myers (1977)). The banker focuses on the value he will get conditional on the bank surviving. Rather than selling at the date-0 illiquid value in order to bolster the value of depositors (akin to the Myers debt overhang problem), he would rather focus on preserving value in the survival states by holding on to the illiquid asset to maturity (akin to the Jensen and Meckling risk shifting problem). The risk shifting incentives of the banks make them unwilling to sell the assets because they will be giving up their option to put the assets to the debt holders at a low price conditional on the liquidity shock.

Note that from the banker's perspective, a sale of assets is equivalent to a sale of stock for cash. For the same reason that the bank will not sell assets for cash, it will not sell stock for cash given the prevailing prices in the market place. This is a form of underinvestment (Myers (1977), Ivashina and Scharfstein (2008)) whereby the bank will not issue stock because of the value transfer that goes to debt in states of insolvency, but it stems from the potential future (and current) fire sale prices at which illiquid assets will have to be sold.[7]

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[7] An oft mentioned rationale for why banks hold on to illiquid assets rather than selling them is the notion that their prices will go up in expectation. Indeed, it is easily shown that the price of the asset does rise in expectation so that $P_0 < qP_1 + (1-q)$. However, this is merely an artifact of Jensen's inequality and the need for returns to equalize over different horizons.

In sum then, as expectations of date-1 liquidity fall so that the bank is insolvent conditional on the future shock, date-0 trading spontaneously dries up. Our model suggests then that the reason banks hold on to illiquid assets instead of trading them is they believe the price of the asset will be much higher conditional on their own survival.

II. The Sources of Illiquidity

Thus far, we have not described where the price P_1 comes from. Clearly, this is critical to our analysis, for without a low P_1 there would be no illiquidity or potential insolvency at date 1, and no market freeze at date 0. Let the weight of the potentially "illiquid" banks we have described so far be normalized to 1. We will now distinguish between securities and loans on the bank's portfolio, which will add richness to our analysis, and not qualitatively affect our previous analysis. Let fraction β of each bank's assets be composed of the financial security we have described so far. Let fraction $(1-\beta)$ of its assets be loans with face value Z maturing at date 2. We will assume these loans can be recalled by the bank at date 1. The bank's loan portfolio has differing liquidation values, with the range uniformly distributed between 0 and Z, that is loans can be liquidated for values ranging from nothing to full face value. We assume loans cannot be sold at date 0 (they have little value in another lender's hands) nor can they be recalled immediately (the borrower has no cash at date 0).

Liquid buyers (private equity, hedge funds, and liquid banks) can purchase the financial asset at either date, and start with θ in cash at date 0. Assume for simplicity that they are equity financed. Also, let these buyers also have the possibility of making term loans to industrial firms. If R is the date-2 return on a dollar lent at date 0, let the available volume of loans returning greater than or equal to R be $I(R)$, with $I(1)=\overline{I}$ and $I'(R)<0$. Loans made by liquid banks return nothing at date 1, though at the cost of additional unneeded complexity, we could assume they do. Liquid buyers can store any excess funds at date 0 at a rate of 1.

Timeline

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Date 0	Date 1	Date 2
Illiquid bank sells securities (or not). Liquid buyers buy securities, make loans, and hold cash.	Liquidity shock hits (or not) and depositors withdraw from banks. Banks decide loans they want to liquidate. Banks sell securities and buyers buy with cash.	Loans and securities pay off. Banker consumes proceeds after paying deposits. Buyers consume.

Fire Sales and Lending

Let us now derive prices. At date 0, the implied interest rate on term loans has to match the return from buying the financial asset, that is, $\frac{1}{P_0}$. This means the amount lent by potential buyers at date 0 is $I(\frac{1}{P_0})$. Intuitively, the long term effective interest rate, and thus the extent of long term lending, is determined by the price of financial assets in the market.

Similarly, conditional on the liquidity shock at date 1, the illiquid bank will liquidate any loan at date 1 with liquidation value greater than P_1Z. This means the total value of cash generated this way is $\frac{1}{Z}\int_{P_1Z}^{Z} xdx=\frac{Z}{2}\left(1-\left(P_1\right)^2\right)$. Again, the implied interest rate used to judge whether to continue loans or not at date 1 is $\frac{1}{P_1}$, which depends on the price of financial assets, and hence available liquidity, on that date.

If $\theta - \overline{I} \geq fD$, then $P_0 = P_1 = 1$, there is no illiquidity, all industrial projects are funded, and no loans are liquidated. The asset will trade for full face value Z at all times. But if $\theta - \overline{I} < fD$, the asset will trade at a discount to face value. For the banks' date-1 needs for cash to be met, it must be that

$$(1-\beta)\frac{Z}{2}\left(1-\left(P_1\right)^2\right)+\left[\theta - I\left(\frac{1}{P_0}\right)\right] = fD \tag{1.3}$$

Also, we know that in equilibrium, $P_0 = \frac{1}{q\frac{1}{P_1}+(1-q)}$. Substituting in (1.3), we can solve for the single unknown, P_1. Note that this is a valid solution provided the bank is solvent. When the bank does not sell any securities at date 0, the necessary condition for solvency is

$$\left(1-\beta\right)P_1 Z.P_1 + \left(1-\beta\right)\frac{Z}{2}\left(1-\left(P_1\right)^2\right)+\beta P_1 Z \geq (1-f)DP_1 + fD \tag{1.4}$$

The first term on the left hand side of (1.4) is the value of the loans that it has not liquidated, the second term is the amount collected from liquidated loans, and the third term is the value of securities held. The first term on the right hand side is the value of deposits to be paid out while the second term is the value of deposits withdrawn. So long as (1.4) is met, the bank will be solvent even if it sells more securities at date 0 (because $P_0 > P_1$).

As P_1 falls, it becomes harder to meet the solvency constraint – illiquidity leads to insolvency as in Diamond and Rajan (2005). If the potential liquidity demand f and bank debt D are very high or the available cash liquidity net of industrial demand, $\theta - I$, low, so that (1.4) is not met, then the bank will be insolvent when the illiquidity shock hits and trading will cease at date 0. We have

Lemma 2: *(i) An increase in potential liquidity demand, f, or bank debt, D, as well as a decrease in the relative size of liquid entities, θ, will lead to a lower current and future expected price of the long dated asset Z. (ii) An increase in the probability of the liquidity shock, q, will lead to a decrease in the date 0 price P_0 and an increase in the date 1 price P_1. (iii) There is a level of f and D above which, and a level of θ below which, all sales of the long dated asset Z cease at date 0.*

Proof: Omitted.

Lemma 2 (i) is straightforward. Turning to lemma 2 (ii), an increase in the probability of the liquidity shock will make the returns to holding cash to buy assets at date 1 higher, so the date 0 price of the asset has to fall. In turn, however, this implies less lending, so more cash will be available to meet the liquidity demand, and the date 1 price of the asset will rise. Lemma 2 (iii) suggests that as expected liquidity conditions deteriorate, there will eventually be a "sudden stop" in date 0 trading as banks become insolvent conditional on the liquidity shock.

Proposition 2: An increase in potential liquidity demand, f, the face value of bank debt, D, or the probability of the liquidity shock, q, as well as a decrease in the relative size of liquid entities, θ, will lead to a reduction in date-0 lending.

Proof: Omitted.

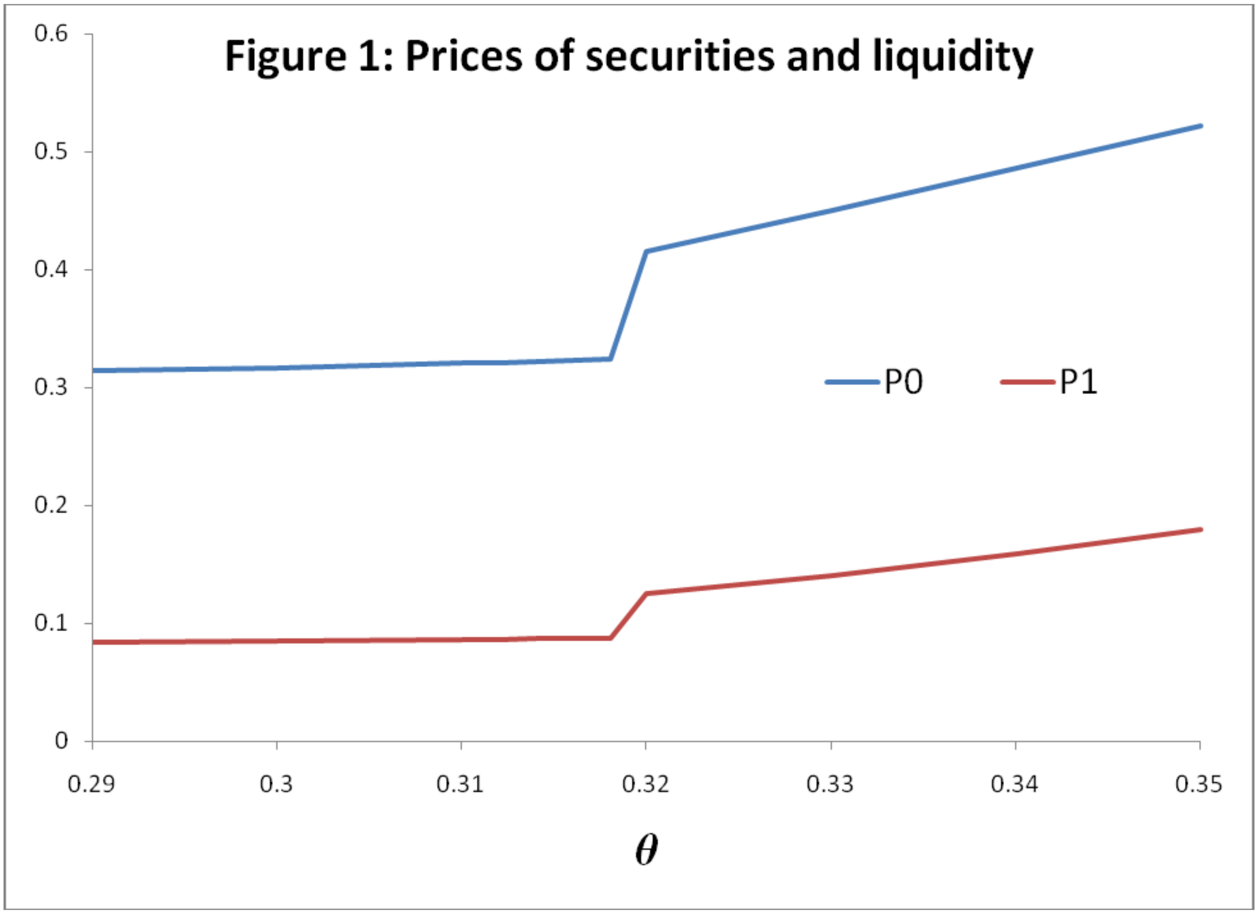
As the returns to buying illiquid assets increases, date-0 lending slows. Indeed, if date-0 trading in the long dated asset halts, liquid buyers may have plenty of cash on their balance sheet which is not being lent, in anticipation of buying assets cheaply at a date-1 fire sale. To the outsider politician, this may seem excessive caution (after all, the liquid buyers have no fear of liquidity shocks), and they may want to mandate more date-0 lending for the liquid buyer. However, as we have argued, this could well be an equilibrium phenomenon.

An Example

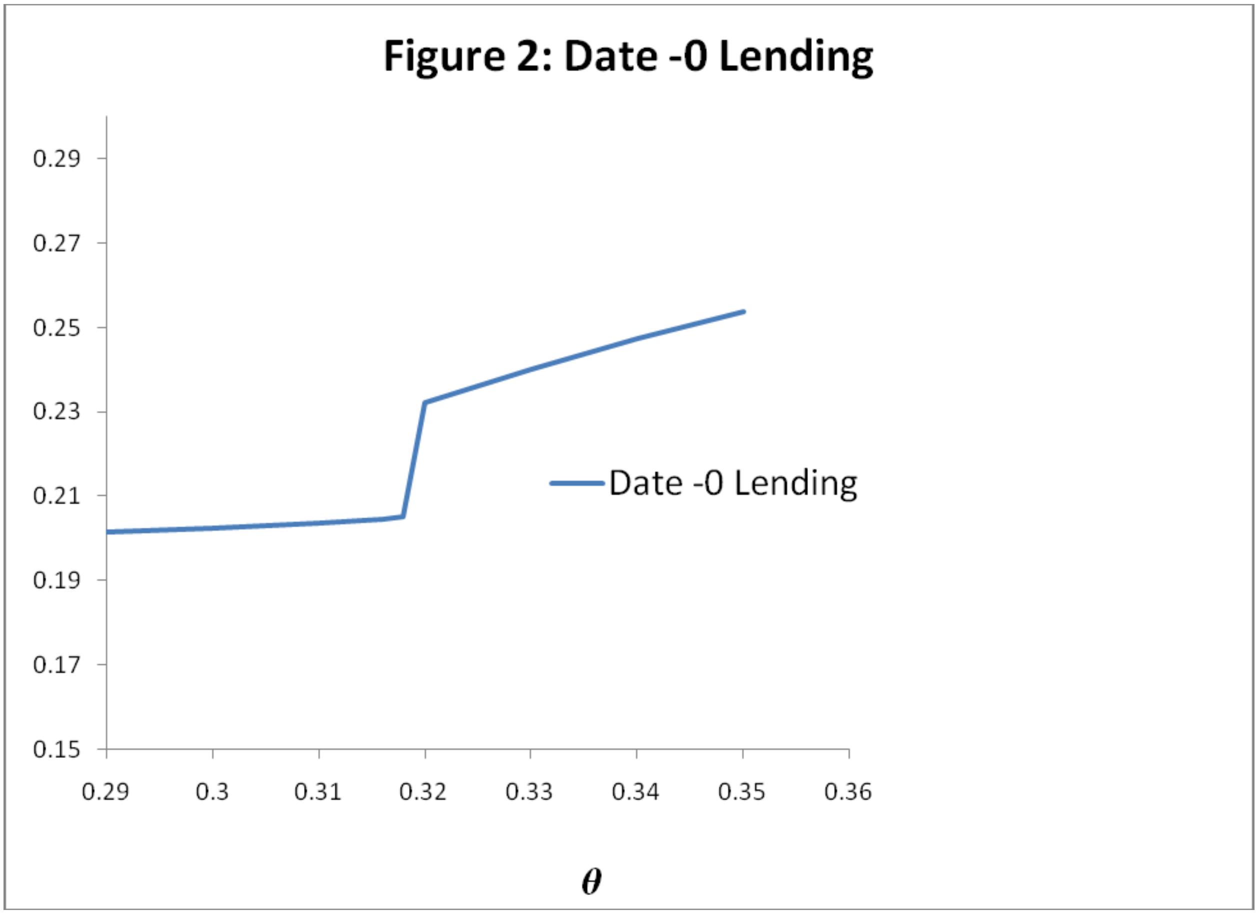
Let the base case be Z=2, θ=0.3, f=0.58, q =0.2, β=0.5, $I(1/P_0) = 0.3*1.2^{1-\left(\frac{1}{P_0}\right)}$. Given these parameters, P_0=0.354, P_1=0.0988 and the amount of date 0 lending is 0.215. The bank could sell just 24% of its securities holdings at date 0, not sell any securities at date 1, and be solvent. However, if it does not sell any at date 0, it will find it has to sell 86 percent of its securities portfolio at the depressed price conditional on the liquidity shock, and will become insolvent. Yet it prefers not to sell, because the value of equity is higher conditional on no sale than conditional on the date-0 sale, for reasons we have explained.

Bank runs and Inefficiency

Thus far, we have ignored any additional consequences of bank insolvency. However, if banks are financed with demand deposits or overnight paper subject to runs, then insolvency will precipitate a run on the bank. This will cause the bank to liquidate all its loans, with attendant consequences to its borrowers. It will also sell all its assets for whatever price they get, further depressing the date-1 price of the asset, and thus further depressing the date-0 price (which anticipates the date-1 price), and date-0 lending. Indeed, if the bank is run when it is insolvent, P_1 will be obtained not by solving (1.3) but from $P_1 = \frac{\theta - I(\frac{1}{P_0})}{\beta Z}$. There will be an abrupt drop in asset prices as soon as the probability that banks will become insolvent in the future turns non-zero.



In Figure 1, we plot date 0 and date 1 security prices as we vary the amount of available cash with liquid buyers, θ. At levels of θ below 0.31, the illiquid banks will fail conditional on the liquidity shock, and will be run. Securities prices are low and lending even lower. Interestingly, an increase in liquidity from 0.29 to 0.3 makes little difference in prices or lending because it does not alter the fact that the bank will be run, and that the date-1 fire sale prices conditional on the shock will be very low, so date-0 prices will be low. However, if enough liquidity is infused into the system so that the bank is not insolvent at date1, securities prices are considerably higher at date 1 and date 0, and consequently, date-0 lending (see Figure 2) jumps.



In sum then, the private sector bank does not internalize the consequences of its own illiquidity and failure on future economy-wide liquidity conditions, on future available returns, and thus on current required returns and lending today. While the bank could sell today and avoid future failure, it prefers not to, focusing instead on maximizing value in the future states it expects to survive in. Liquidity is truly a public good here.

Key Assumptions

It may be useful to discuss our key assumptions. We have referred to the bank's required need at date 1 of *fD* of cash as a liquidity shock, without specifying the source. It could be a need by depositors for working capital for their own businesses during a period of limited liquidity, or represent a fear based withdrawal by some (uninsured) depositors or other short-term creditors who come to doubt the bank's viability. One example is the loss of access to interbank loan markets where other banks anticipate future problems with the bank and prefer to collect before the bank fails or is closed (as in Smith (1991)). Diamond-Rajan (2005) provides a general equilibrium model of this type of run-based withdrawals with a shortage of liquidity, stressing the two-way causality between illiquidity and insolvency.

The key contractual element that can lead to a market freeze is that short-term debt can be withdrawn (or committed lines of credit can be drawn down) before the assets mature. If there was no possibility of needing to sell assets before date 2, then the market values of the assets would not be depressed by forced fire sales and the market would not freeze because the bid and ask prices would converge. The assets are illiquid here because the set of (equally) informed buyers is limited and they have finite borrowing capacity (as in Shleifer and Vishny (1992)).[8] Hence buying capacity, rather than asymmetry of information between buyers and sellers of assets, drives our results. Of course, over time we would expect that if there were substantial quantities of illiquid assets, more potential buyers would acquire the necessary skills. So illiquidity of this kind would, at best, be a medium term phenomenon.

Furthermore, term lending (as opposed to overnight lending) would be curtailed so long as lending was done by *either* the illiquid banks or their potential buyers. In other words, it is because of the future high expected cost of capital/rate of return for entities that suffer the

[8] The notion is that any buyers outside the set of the skilled would find it hard to tell the few bad securities from the majority of good ones, and could well face a substantial lemons problem if they tried to buy.

liquidity shock or can buy illiquid assets that today's required rate of return is high and lending is depressed. For entities who can borrow from institutions outside this group, lending would be less constrained (though, of course, there are many channels through which illiquidity can spill into the rest of the economy).

Finally, banks are assumed to have local monopolies over their depositors, and as a result changes in the expected return offered in secondary markets available to banks do not lead banks to change the interest rates offered to depositors. Also, when a bank subject to liquidity shocks sells assets early and reduces the default risk to depositors, the deposit rate does not fall. So long as depositors receive at least an expected rate of return of zero (which we assume to be their outside option), they do not demand additional compensation for greater default risk.

These assumptions are so that we can focus on the essential driving force of the model. More generally, we could have one portion of bank debt (such as insured deposits or long term debt as in Myers (1977)) that is relatively insensitive to bank actions, while another portion of debt (such as overnight borrowing, uninsured demand deposits, and cash in brokerage accounts) is sensitive to the bank's health and susceptible to run. The implications would be qualitatively similar.

III. Interventions

Let us now turn to interventions. What can the authorities do to unfreeze the market (when illiquid banks anticipate failing conditional on the liquidity shock and thus are unwilling to sell securities at date 0) and allow more credit to flow? One immediate issue is that the authorities may not have expertise to buy the asset, which is why there is only a limited pool of firms with excess funds that could buy it from the illiquid banks in the first place. Assume though that the authorities are willing to put in additional money, although they know some of it will be dissipated, either in fees to firms that can buy the asset on their behalf or in losses made in buying assets the authorities do not have great expertise in. Nevertheless, it is useful to explore the levers the authorities can push.

A pure *capital* infusion is for the authorities to give the bank long term claims against the government (government bonds that pay out at date 2) in exchange for equity claims on the bank (claims that pay off after deposits are paid at date 2). A pure *liquidity* infusion is for the government to buy the financial asset directly from the market, or to make risk free loans of cash to liquid buyers so they can deploy it to buy the asset. Finally, there are combinations of the two possible – for example, by taking an equity claim against the bank in return for an infusion of cash, the authorities supply both capital and liquidity.

Close Some Banks at Date 0

If some banks are insolvent, the authorities can close them (if the banks are not "too big to fail"). To select those that should be closed, it will have to determine the value of assets, for which it will have to hire experts. It will also have to hold the illiquid assets in some holding entity (similar to the Resolution Trust Corporation) and sell them over time once the likelihood of the liquidity shock falls. Closure thus allows the authorities to remove the overhang of illiquid assets, and bring down required rates of return, but it does not absolve them of the need to value assets or pump in capital and liquidity (to finance the holding entity).

The problem comes when the banks are solvent today and thus cannot be failed, but could become insolvent in the future – as in our model. Closure may not be an option for the "walking wounded". It may also not be an option for the banks that are difficult to fail for a variety of reasons.

Asset purchases at Date 0

The authorities can offer to buy assets at market prices at date 0 so as to drive up their price and drive down anticipated returns. The problem, however, is that at the price the liquid investor wants to pay, the bank will not sell. We saw that the bank will sell only at or above $P_0^{Ask} = \frac{1}{1+q(\frac{Z-D}{fD})}$. This will, for example, be the price that banks will set in a reverse auction.

Note that it does not depend on the price P_1 that will obtain at date 1 conditional on the liquidity shock because the banker does not internalize that low price. By contrast, recall the private market was willing to pay $P_0 = \frac{1}{q\frac{1}{P_1}+(1-q)}$, which increases in the available liquidity, θ.

Interestingly, therefore, the difference between the date-0 hypothetical private market price and the price the authorities will have to pay increases as the available liquidity falls.

Authorities will have to pay more than private buyers would be willing to pay to induce a sale (even if the auction is competitive), not because assets are irrationally underpriced today (there is no "buyers strike"), but because banks are unwilling to part with assets at currently depressed prices (there is a "sellers strike"). Note though that the higher payment is compensation to the banker for foregoing the option to put depressed assets to debt holders. To the extent that the authorities internalize this cost, for example because they insure the deposits, then the authorities may be better off paying and avoiding worse damage. Of course, the political support for paying bankers more in the midst of a crisis is small, and the banker gets paid only because of his implicit threat to do his bank worse damage by neglecting to sell assets.

Banks are willing to sell on date 0 for less than the "no fire sale" price (of one), and as a result the government would not lose money from this transaction. However, the government has no expertise in valuing these assets, so one interpretation is that the government must offer a subsidy to the private buyers of $P_0^{Ask} - P_0^{bid}$ to get them to buy the assets at date 1. The treasury's public/private partnership could be interpreted as a subsidy of this type.

Recapitalization

If the authorities are willing to infuse capital they could help when the problem is primarily one of solvency (if when date 1 interest rates go high enough to generate enough liquidity to meet depositor needs, the bank is insolvent). Indeed, this is the situation in our initial example. If, for instance, the authorities were willing to give the bank bonds of value 0.018 at date 1 that would pay off at date 2, they could save the bank from being run. This would increase the date-1 security price above the "run" price, and increase lending at date 0.

A commitment to inject capital (through subsidized equity commitments or debt guarantees) as needed to keep the bank from failing does create moral hazard because the employees will be bailed out no matter how poorly they act. Moreover, this intervention does not induce the banker to sell securities early (because the banker knows his stake will be severely diluted even if the bank is rescued, and thus his down side payoff is very low much as the situation where he is run). It does keep some assets off the market by preventing a run, and hence could boost securities prices, and thus lending.[9]

Liquidity

The authorities could also inject liquidity immediately or in the future (the increase in θ in our earlier example could come from the authorities or from entities funded by the authorities), thus boosting the price of assets and enhancing solvency and lending. Of course, a little increase in liquidity may not be sufficient to boost security prices enough to make banks solvent. For the liquidity infusion to have effect, either banks will have to be forced to sell or enough liquidity may be needed to be injected to boost securities prices enough that banks no longer anticipate insolvency. If the government is limited in the resources it can put to work, sometimes recapitalizations may be a more direct and less resource intensive way of achieving its objective (see Diamond and Rajan (2005) for a more detailed discussion).

Note that infusing liquidity (buying at the market price or lending to potential buyers) is different from targeting a particular asset price. The problem in targeting asset prices is the difficulty of assessing when they are depressed because of fundamentals and when they are depressed because of illiquidity. The value of committing to inject a fixed quantity of liquidity (as opposed to supporting a certain price level) is that prices will not typically move if fundamentals are genuinely low but will move up with beneficial effects if illiquidity depresses prices.

[9] Kryzanowski and Roberts (JMCB 1993) argue this method allowed many Canadian banks to recover their health in the period 1992 to 1940

Forced Asset Sales

Suppose the authorities are reluctant to pay above market, reluctant to recapitalize, and reluctant to infuse additional liquidity. There may be too little liquidity in the system for the authorities to save every bank. Nevertheless, the authorities may be able to intervene judiciously in forcing asset sales and thus keep some banks and their borrowers afloat, even if they do not enhance available liquidity.

Intuitively, if the authorities select a sub-sample of the banks and force them to sell assets at date 0, those banks will avoid being run and hold off dumping all their assets at date 1. As a result the date-1 price of the financial asset could be higher, allowing the date-0 price to be higher, and thus more lending to take place. The success of such an intervention turns on whether the bank absorbs liquidity on net by failing or releases it. On the one hand, the failing bank dumps all its securities and thus absorbs liquidity. On the other, it recalls loans from industrial borrowers and thus effectively releases liquidity into the financial system. The net effect depends on parameters, as we see now.

Consider our initial example again. Given the parameters, banks will fail conditional on the liquidity shock, and will not sell assets at date 0. They will be run at date 1, and be forced to dump securities on the market. They sell additional securities of market value of 0.012 during a run. They will also recall all loans, generating cash amounting to 0.0036. On net, therefore, a failing bank will absorb liquidity of 0.0084 per bank. Banks would be solvent through the liquidity shock if they were forced to sell securities at date 0. Of course, not all banks can do this and survive if liquidity is not augmented. But even if only some banks can be kept from failing, the amount of date-1 liquidity absorbed would be reduced, thus elevating prices and reducing date-0 lending.

IV. Risky vs Illiquid Assets

Risky assets

What if the assets were merely risky instead of being illiquid? Not only will this have different implications for our basic results, it will also have different implications for the success of interventions. Suppose the date 1 price, P_1 , was low because date 2 payments were expected to be low. In the context of our model, this would imply that the date 2 value would not always be Z, but would be Z with probability 1-q and have an expected value of $P_1 < Z$ with probably q. In this case, the asset is liquid and the rate of return from buying them at the low price at date 1 is the normal expected rate of return (zero each period).

Note that the ask price required by the risky bank would be the same as derived earlier, because the bank's payoff from not selling is (1-q)(Z-D) as before. The bid price would be somewhat higher than the bid price we found earlier (because buyers require a zero expected rate of return in the future, implying that their highest bid would be $qP_1 + (1-q)Z > P_o^{Bid}$). Because the hurdle rate for new lending by potential buyers is normal, their lending would not be depressed by expectations of future fire sales. Injecting future liquidity would have no effect on current or future asset prices. The market would still be frozen. Either all the existing banks could be saved by forcing them to sell at date zero if $qP_1 + (1-q)Z \geq D$, or none could be saved

More generally, to explain both a general credit freeze, including few new loans by healthy unlevered buyers, and a freeze in securities markets, the fear of fire sales is, we believe, a more relevant model.

Selective sales by a few banks would not be helpful. In addition, because there is no liquidity-based pricing, the buyer's bid price would be the fundamental value of the asset, and any purchases above this price (perhaps due to government subsidy) would be unprofitable. When there is no illiquidity, there is no reason for the government to subsidize purchases even if were to bear the cost of bank failures.

Illiquid and Risky Assets

If we combine uncertainty about asset value and liquidity based pricing, then there remains a gap between bid and ask prices, and the ask price remains unchanged (because the bank's payoff from not selling is (1-q)(Z-D) as before). If there is sufficient risk in the date 2 value of the asset, for a given amount of illiquidity, then the ask price will exceed the fundamental value of the asset. The risk shifting incentives of the banks make them unwilling to sell the assets because they will be giving up their option to put the assets to the debt holders at a low price conditional on the liquidity shock. In this case, there is a trade off for the government. If there is liquidity pricing and banks must sell assets at fire sale prices, government deposit insurance may lose more than the amount which they need to overpay to induce banks to sell the illiquid and risky assets.

Let P_1 reflect both illiquidity and a reduced date 2 value of the bank's assets in the state in which the shock hits. Even in a liquid market, the expected date-2 value would be below Z, but the forced sale by the bank at a low date-1 price (due to a withdrawal of fD, or a run forcing all assets to be sold), will reduce the date-0 bid price that buyers will pay. The possibility of a reduced date-2 value reduces the fundamental value of the asset and the possible fire sale increases the expected return that buyers require at date 0. Subsidizing purchases at date 0 allows some banks to avoid being run at date 1, reducing the number of assets sold, and increases the date 1 price. This reduces the expected return that buyers require at date 0, but if the date-2 value is sufficiently reduced, the subsidy could push the value of the assets above their fundamental (no illiquidity) value. Put differently, authorities could overpay if not careful. This suggests that with risky fundamentals, it is desirable to both subsidize purchases and force banks to sell at date 0.

V. Related Literature

Some recent work has explained market freezes by asymmetric information, along the lines of the original insight of Ackerlof (1970). Bolton, Santos and Scheinkman (2008) and Heider, Hoerova and Holthausen (2009) present interesting models of securities sales based on private information of existing banks about the value of their assets. For example, in Bolton, Santos, and Scheinkman (2008), long horizon investors cannot tell whether short horizon investors sell because they need liquidity or because they have adverse information about asset quality. This leads to a price discount, which gets worse over time because the potential seller gets to know more about the asset. The seller thus has to decide whether to sell now in response to a liquidity need, or to attempt to ride out the crisis with the possibility of selling in the future at a much greater discount. There are both immediate trading equilibria and late trading equilibria, with the latter resembling our trading freeze. The clear difference in our model is the assumption of no information asymmetry.

Acharya, Gale, and Yorulmazer (2009) show that borrowing freezes can arise when the information structure in the market shifts from one where the arrival of no news is good news and the asset price goes up to one where the arrival of no news is bad news and the asset price goes down. In the latter situation, the borrowing capacity of a bank may be very low when it intends to roll over its borrowing repeatedly. The shift in information structure in the market can, therefore, cause lending to banks to dry up. Our paper explains, by contrast, why long term lending to industry, where there is no rollover risk, can dry up.

Allen, Carletti and Gale (2009) present a model of freezes due to illiquidity without asymmetric information (with limited liquidity as we assume), but without any risk of default. The market freezes there when there is ample liquidity but most of the liquidity risk is systematic rather than bank specific. The interbank market freezes because each bank wants to hold liquidity on its balance sheet rather than choose to borrow or lend it when nearly all banks will borrow or lend (rather than take offsetting positions).

There are closely related studies of aggregate liquidity shortages. Diamond-Rajan [2005] model contagious bank failures due to limited aggregate liquidity. In their model, there is both individual bank risk about the proportion of their loans that generate liquid repayments quickly and aggregate uncertainty about the supply of liquidity. The potential failure of enough banks forces banks to call in bank-specific loans. Banks choose to increase interest rates to attempt to attract deposits from other banks, and this can bring down all other banks when liquidity is too low. The model assumes that the deposit market is competitive and that all assets, including bank deposits and short-term debt, must offer the same return as the loans that banks make and all those that are not called in early. The model we present in this paper has similar features, except we assume that deposit markets are local monopolies (or at least require a lower return than bank assets, and the return does not move one for one with returns in asset markets). The effect of limited liquidity is via the price of banks' tradable assets, which affects the rate of return expected in the market over time, and thus lending.

Our paper is also related to Shleifer and Vishny (2009), where banks expand and contract lending based on their ability to securitize loans in a sentiment driven market. In their model, parameters are assumed such that banks would not want to hoard cash in order to buy assets when market sentiment falls. This then drives the pro-cyclicality of lending. However, banks would hoard securities and not sell them at such times, in anticipation of a recovery in prices. Our rationale for why banks hoard securities is different, since there are buyers in our market who are not infected by negative sentiment. The reason in our model is that banks prefer the higher return they get conditional on survival by holding on to the asset to the unconditional return they get from selling.

The model of illiquid asset markets where prices are set by the quantity of liquidity in the market is closely related to that used in Bhatacharya-Gale (1987) and Allen-Gale (1998, 2003). The model of limited liquidity in Holmstrom-Tirole (1998) relies on collateral value as the limit to liquidity of an asset, rather than limited purchasing power. Allen-Gale (2000) produces liquidation of bank assets due to insolvency links caused by defaults on interbank lending.

Conclusion

This paper is written in the midst of the most severe financial crisis since the Great Depression. While our model is simple, it offers a way to think about the problems that ail financial markets. The simple message is that credit will not flow freely again unless the problem of institutional overhang is dealt with – unless the solvency of illiquid institutions is assured, or the illiquid assets they have are moved to entities that will not unload them quickly. The task of the authorities is to facilitate such a clean-up at minimum cost to the taxpayer. We have suggested some possible interventions that could be effective.

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