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Fear of fire sales and the credit freeze

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Abstract

In early 2009, the supply of credit in industrial countries appeared to decline. Could this be because bank balance sheets were "clogged" with illiquid securities? If so, why did banks not attempt to sell them? We argue that an "overhang" of impaired banks that may be forced to sell soon can reduce the current price of illiquid securities sufficiently that banks have no interest in selling. This creates high expected returns to holding cash for potential buyers and an aversion to making term loans. We discuss the implications for policies to clean up the banking system during a financial crisis.

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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.[1] 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. 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.[2]

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 volatility, and had abandoned these markets. Of course, an immediate question is why new

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

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

"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.[3]

We argue in this paper that the seizing up of term credit and the overhang of illiquid securities are not coincidental, they have common roots, and have potential explanatory power beyond the Crisis of 2007-2009. 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 asset is a

[3] 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.

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 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. Moreover, this systemic overhang will affect lending by both impaired banks as well as healthy potential investors, a feature that distinguishes this explanation from those where the reluctance to lend is based on the poor health of either the bank or its potential borrowers.

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". The prospect of the fire sale reduces what buyers are willing to pay. However, sellers hold on, not because the available market price is irrationally low compared to its value in the near future, but because 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 in the future, and increase the relative profitability of lending today, thus increasing its magnitude. We examine various proposals, including the possibility that banks may have to be coerced into selling assets.

This paper is more than about the current crisis. It suggests that the prospect of institutional fragility and future fire sales can itself depress lending. Thus, there is an inherent source of adverse feedback in any financial crisis, which is why an imperative for recovery is to "clean" up the financial system.

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 $Z > D$.[4] 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. We assume until section IV that Z is a constant, which means that the assets are not risky when held to maturity. The model's primary implications are clear in this simple setting.

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 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

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[4] For a model of why this might be the optimal form of financing for a bank in a world where aggregate liquidity shocks are low probability, see Diamond and Rajan (2001).

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

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 $P_0 \le 1$ and $P_1 \le 1$). The highest date-0 bid price of the buyer solves $\frac{1}{P_0} = q\frac{1}{P_1} + (1-q)$, 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

$\eta_1 ZP_1 = fD$, 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):

$$q\left[(1-\eta_0)Z-(1-f)D\right]+(1-q)\left[(1-\eta_0)Z+\eta_0 P_0 Z-D\right]$$

$$=q\left[(1-\frac{fD}{ZP_0})Z-(1-f)D\right]+(1-q)\left[(1-\frac{fD}{ZP_0})Z+\frac{fD}{ZP_0}P_0 Z-D\right]$$

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

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

$P_0^{Ask} = \frac{1}{q\frac{1}{P_1}+(1-q)}$. 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 $P_0 \le 1$, 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 and if $Z - D - (\frac{1}{P^{ask}{}_0} - 1) fD \ge (1-q)(Z-D)$, 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 $\frac{1}{P^{ask}{}_0} \le 1 + \frac{q(Z-D)}{fD}$, which simplifies to $P_0^{Ask} \ge \frac{1}{1+q(\frac{Z-D}{fD})}$. 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

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[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.

condition is $fD > P_1\left[Z-(1-f)D\right]$, which is satisfied if the bank is insolvent conditional on the liquidity shock at date 1 and not having sold assets at date 0. 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 not from uncertain fundamental values but from the potentially low future (and low current) fire sale prices at which illiquid assets will have to be sold.[7]

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,

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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.

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 will 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. The timeline is

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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 $P_1 Z$. This means the total value of cash generated this way is $\frac{1}{Z}\int_{P_1 Z}^{Z} x dx = \frac{Z}{2}\left(1-\left(P_1\right)^2\right)$. 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

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

Also, we know that in equilibrium, $P_0 = \dfrac{1}{q\dfrac{1}{P_1}+(1-q)}$. 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

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

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) If there is a* $f = f^R$ *at which all sales of the long dated asset Z cease at date 0, then ceteris paribus, there will be no sales for any* $f > f^R$ *. If there is a* $D = D^R$ *at which all sales of the long dated asset Z cease at date 0, then ceteris paribus, there will be no sales for any* $D > D^R$ *. If there is a* $\theta = \theta^R$ *at which all sales of the long dated asset Z cease at date 0, then ceteris paribus, there will be no sales for any* $\theta < \theta^R$ *.*

Proof*:* We sketch the proof when the change in parameters does not cause a change in whether the bank defaults or not. Incorporating such a change is straightforward. (i) Totally differentiating (1.3), we get $\frac{dP_1}{df} = \frac{D}{-(1-\beta)ZP_1 + I'\left(\frac{1}{P_0^{\,2}}\right)\frac{\partial P_0}{\partial P_1}}$ which is negative since the denominator is negative. Similarly, we can show $\frac{dP_1}{dD} < 0$ and $\frac{dP_1}{d\theta} > 0$. Since $P_0 = \frac{1}{q\frac{1}{P_1} + (1-q)}$, lemma 2 (i) follows. (ii) Ceteris paribus, an increase in *q* leads to a decrease in P_0. From (1.3), this must imply that P_1 will increase in equilibrium, since liquid buyers will lend less and store more cash. (iii) The condition for all sales to cease is that the bank ceases to be solvent. The solvency condition is given by (1.4), which on simplifying is $P_1\left[(1-\beta)\left(\frac{Z}{2}\right)P_1 + \beta Z - D\right] > fD(1-P_1) - (1-\beta)\left(\frac{Z}{2}\right)$. This is clearly satisfied if $P_1 = 1$, so long as $D < Z$. As f increases, P_1 falls, from lemma 2 (i). So the right hand side of the inequality increases, while the left hand side falls. Hence provided the bank fails for some f^R, it should fail for all $f > f^R$. The other conditions follow similarly. Q.E.D.

The intuition behind 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: Lending increases in P_0. P_0 decreases in f, D, and q and increases in θ from lemma 2. Hence the proposition. Q.E.D.

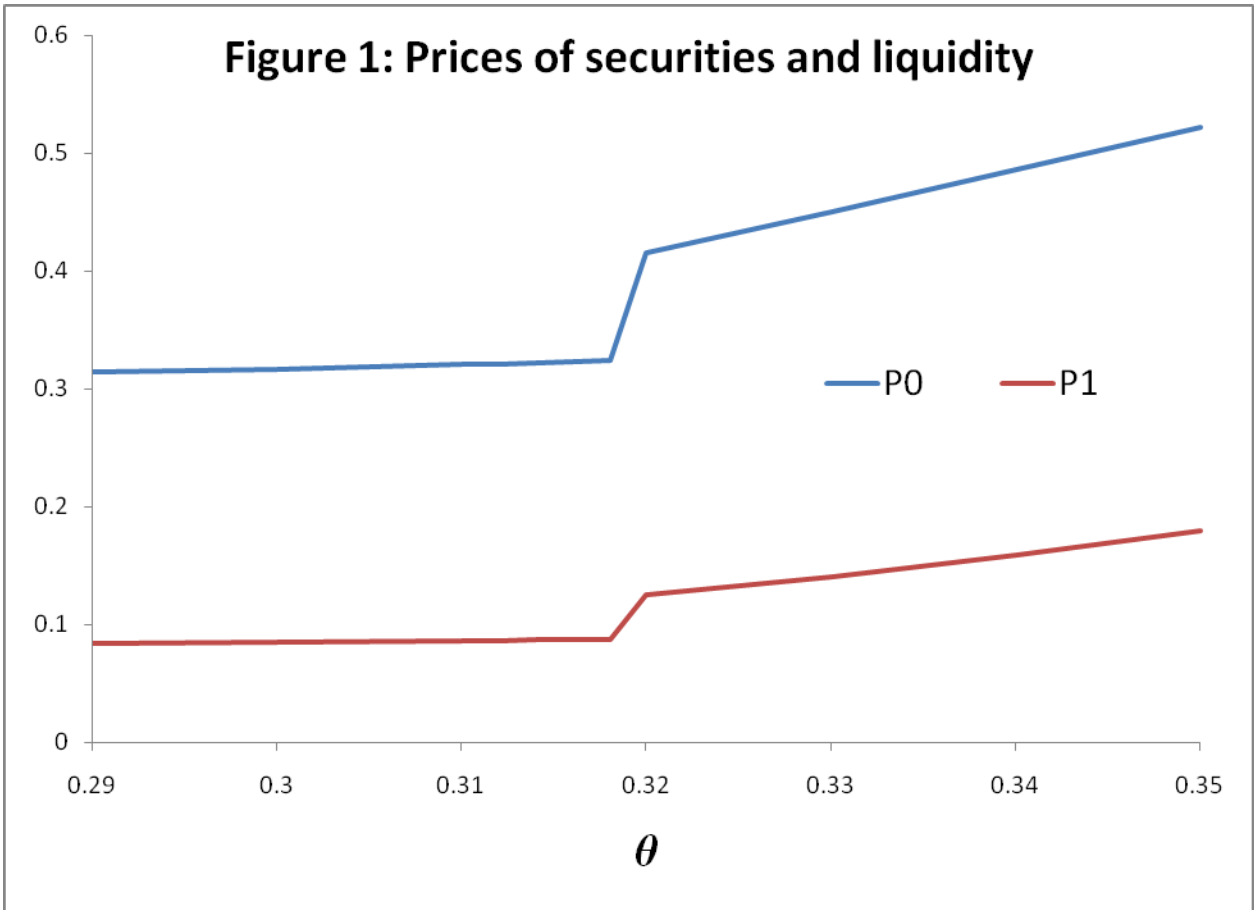
As the returns to buying illiquid assets increases, date-0 lending slows. Indeed, if date-0 trading in the long dated asset halts, liquid buyers may have plenty of cash on their balance sheet which is not being lent, in anticipation of buying assets cheaply at a date-1 fire sale. To the outsider politician, 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 a rational equilibrium phenomenon.

An Example

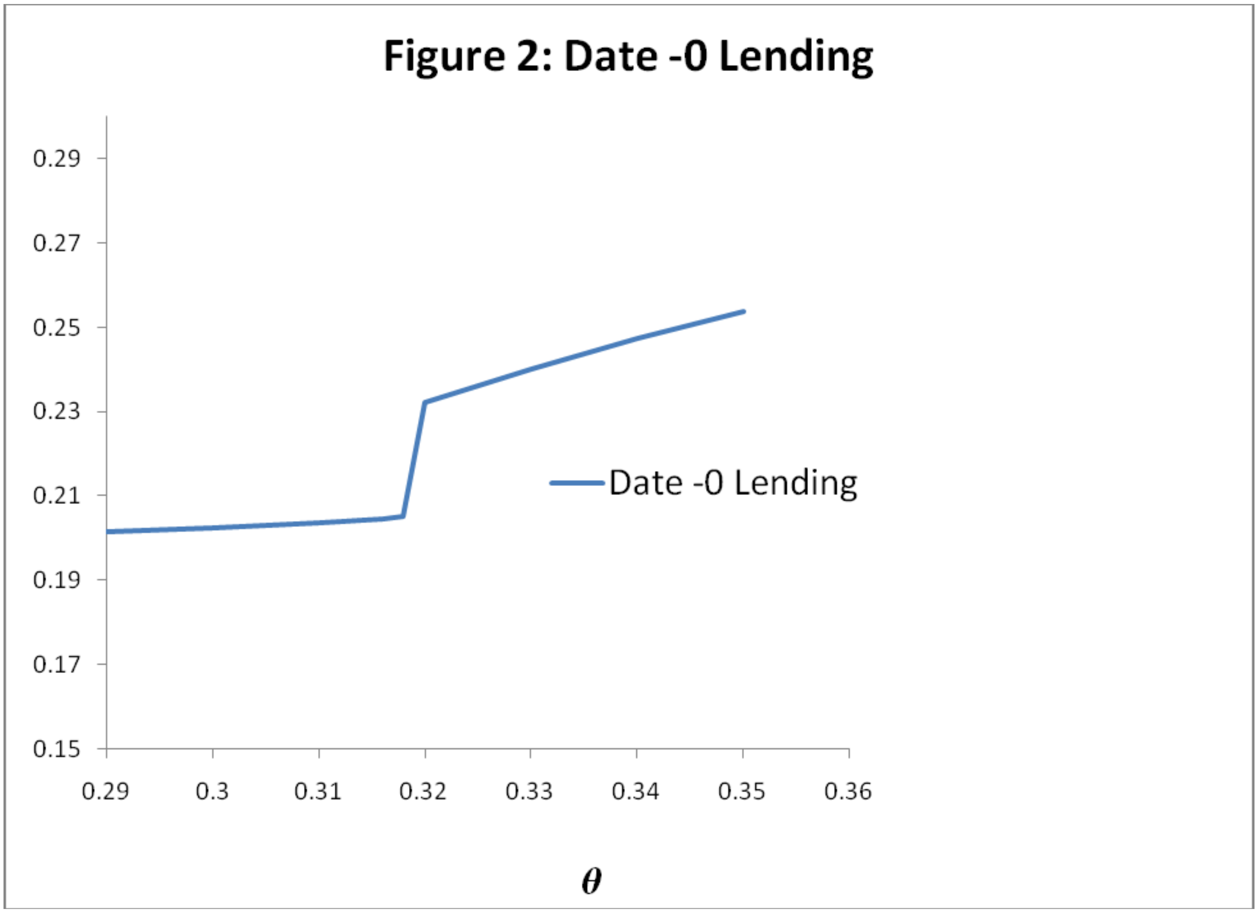
Let the base case be Z=2, θ=0.3, f=0.58, q =0.2, β=0.5, $I(1/P_0) = 0.3*1.2^{1-\left(\frac{1}{P_0}\right)}$. Given these parameters, P_0=0.354, P_1=0.0988 and the amount of date 0 lending is 0.215. The bank could sell just 24% of its securities holdings at date 0, not sell any securities at date 1, and 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 0.32, 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.

[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.

Furthermore, term lending (as opposed to overnight lending) would be curtailed so long as such lending is done by *either* the illiquid banks or the potential buyers of their assets. In other words, it is because of the future high expected cost of capital/rate of return for entities that suffer the liquidity shock, or can buy the illiquid assets, that today's required rate of return is high and lending is depressed. For firms that can borrow from institutions outside this group (such as small firms borrowing from local financiers, who have no capacity to understand, and hence buy, the illiquid assets), lending would be less constrained (though, of course, there are many channels through which illiquidity can spill into the rest of the economy).

Finally, we assume banks 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, we assume that 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

There are several reasons that government regulators or central banks might consider intervening to eliminate the market freeze. First, they may need a market price to help determine if the banks are solvent. Banks and expert buyers know the long-run value of assets, Z, but we assume that the regulators may not know or may not have a way of verifying the value (we will discuss the implications of making Z unknown and random in section IV). Ask prices will depend on the selling bank's probability of a liquidity shock as well as the extent of the shock. Bid prices at date 0 depend on (in addition to Z) the probability and extent of liquidity pricing as well as the elevated return available to buyers who wait for the liquidity event. Therefore, useful valuation information can be obtained by unfreezing the market. In addition, the number of banks that will ultimately fail can be reduced if some sell assets earlier. Furthermore, because bank runs and failures can cause all assets to be sold immediately, it can be desirable to focus the available liquidity on a subset of the banks (even if this makes the remaining banks more insolvent). Finally, if there is an intervention that reduces the fire sale pricing, it can allow banks to survive and increase the flow of credit today, both from potential sellers and buyers.

Let us now turn to the 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? The authorities can reduce the possibility of a fire sale by getting the illiquid assets off weak bank balance sheets at date 0 (including by closing them), by boosting available liquidity to purchase assets at date 1, and by strengthening weak banks so that they are not run.

Typically (though not always), this will mean that the authorities will have to infuse resources into the system, either directly to banks or indirectly via the liquid buyers. One immediate issue is that the authorities may not have the expertise to value the illiquid asset, and hence any security that depends directly or indirectly on it, 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. Unlike the private market, though, the authorities may be willing to tolerate some losses because they internalize the economy-wide positive spillovers from having a healthy, functioning, financial sector. These losses could take the form of rents needed to ensure incentive-compatibility for buyers that can acquire the asset on their behalf, subsidies to induce banks to sell and partly reveal the value of assets, or losses made in buying the illiquid assets or claims on the illiquid assets that the authorities do not have great expertise in.

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 either need to generate a market price or it will have to hire experts.[9] 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

[9] A market price will be sufficient to value assets held on the books so long as there are easily observable and verifiable characteristics that put the traded assets in the same equivalence class as the book assets – e.g., mortgage backed securities based on sub-prime mortgages originated by A in new development B in city C. If, however, if there are still intrinsic differences between assets that require expertise (mortgages originated in the south-side of the development have different default characteristics than those originated in the north side, and only south side mortgages are traded), then there is no alternative to hiring experts.

return, but it does not absolve them of the need to value assets or pump in resources (to finance the holding entity).

The problem comes when the banks appear 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.

Injecting government resources.

Let us now turn to more direct injections of resources. 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, or to lend directly to banks. 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). The equity claims could be worth less than the value of bonds provided, implying a subsidy. 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.

Liquidity Infusion 1: Direct asset purchases at Date 0

The authorities can offer to buy assets at at date 0 so as to drive up their price and drive down anticipated returns to buyers, and to establish the value of assets. 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 $P_0^{Ask} = \dfrac{1}{1+q(\dfrac{Z-D}{fD})}$. This will, for example, be the price that banks would have set in a reverse auction, originally considered in the initial TARP program. This will provide a price, but if authorities are unsure of the motivation for the lack of selling (and do not know q or f), it will not reveal the value of Z to them. Note that the reverse auction price 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 $P_0^{Bid} = \dfrac{1}{q\dfrac{1}{P_1}+(1-q)}$, 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 voluntary 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. Of course, the political support for paying bankers more in the midst of a crisis is small.

Liquidity infusion 2: Lend to liquid buyers at date 0 or date 1.

An alternative to the government buying assets directly is for it to lend to liquid buyers at date 0 or date 1, thus augmenting θ and boosting prices (see lemma 2). Buyers certainly have the expertise to value the assets, the real issue being whether they have the incentives to use government financing in a reasonable way. Some rents/subsidies may have to be offered to them to give them the incentive to use their expertise on behalf of the government.[10]

Liquidity infusion 3: Lend to the banks at date 1

An apparently straightforward solution to the problem of a fire sale at date 1 is to lend freely to the banks experiencing liquidity withdrawals. If the government could commit to do this on a sufficiently large scale, which would require it to value the banks' assets at date 1, the illiquid pricing would be eliminated as would be the date 0 market freeze. However, if as we argue in the next section, regulators are unsure about the asset values (Z), they would be unsure if they were providing liquidity or participating in a bail out. If the public believed, rightly or wrongly, that lending was a bail out, it might be unwilling to support it. As a result, it might be difficult for the authorities to commit to unconditional date-1 liquidity support at date 0, preventing them from ending the freeze.

Note that infusing liquidity (buying at the market price or lending to potential buyers or to the banks that would otherwise need to sell) is different from targeting a particular asset price. The problem in targeting asset prices is the difficulty authorities have 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.

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[10] The initial Treasury structure for the Public Private Partnerships to buy toxic assets may have given private buyers a subsidy through easy financing terms. In addition, it may have given the partnership a put option of sufficient magnitude (given that it was to be funded by the FDIC with non-recourse debt) to pay for the put option the banks were giving up. Of course, all these put options are exercised at the expense of the taxpayer.

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 withdrawals, 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.

Forced Asset Sales

One stumbling block thus far has been the unwillingness of banks to sell illiquid assets. Of course, another alternative is for the authorities to force banks to sell assets – for example, by setting a date by which holdings of certain categories of illiquid assets have to be reduced by a certain percentage. Such fiat extinguishes banks' option to gamble for resurrection, while transferring a certain amount of bargaining power to buyers. For this to be a workable option that does not weaken already weak banks further, it is important that buyers be competitive and have sufficient buying capacity that an immediate sale does not render the banking system insolvent.[11]

Even if buying capacity is insufficient to keep the entire banking system afloat, the authorities may be able to intervene judiciously in forcing asset sales and thus keeping some banks and their borrowers afloat. 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,

[11] Note that an immediate forced sale makes the banks reliant on the available supply of liquidity amongst buyers. If however, they did not sell assets, they would not be reliant on liquidity in at least the future state of the world where there are no demands on them. So a forced sale will not just reduce bank equity values (by extinguishing the option to default on debt) but could also reduce bank asset values.

the amount of date-1 liquidity absorbed would be reduced, thus elevating prices and reducing date-0 lending.

IV. Risky vs Illiquid Assets

Thus far, we have assumed that the illiquid assets have a value Z with certainty. This simplifying assumption creates some expositional difficulty, for it is hard to imagine then why the asset is illiquid, since anyone with cash could buy the asset and hold it to maturity. In particular, there would be no cost to the government of liquidity intervention, so long as the market price per unit of face value is less than one.

One reason why the government could be reluctant to intervene is that the asset might require management (as with a bank loan), and the government may not have management capability. But this is not a plausible explanation for arm's length mortgage backed securities. Another reason, and one we have relied on so far, is that a fraction of the illiquid assets could be very poor in quality, so any casual buyer will end up with an adversely selected lot of securities (unless he buys the whole portfolio, which even the government may not have the funds to do). But a third reason, is there could be fundamental uncertainty about the asset's value, which overlays (and is partly responsible) for its illiquidity. To analyze this, let us start by examining an asset whose value is uncertain, ignoring illiquidity for the moment, then bring back illiquidity.

Risky assets

Suppose the date 2 value is not Z with certainty, but is Z with probability 1-q and $P_1 < Z$ with probably q, where the date 1 price, P_1 , is low because date 2 payments are expected to be low. In this case, the asset is liquid and the rate of return from buying it at the low price at date 1 is the normal expected rate of return (zero each period). Of course, because the asset is risky, a bank that would fail if the lower asset value were realized at date 1 might still ask for a price at date 0 that exceeds the fundamental value of the asset, because it values the option to shift risk to lenders, as in Allen and Gale (2000b).

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 the fundamental value of the asset, that is $qP_1 + (1-q)Z > P_o^{Bid}$). Because the hurdle rate for new lending by potential buyers is normal, their date-0 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 would be saved if they were forced to sell assets at date 0 if $qP_1 + (1-q)Z \geq D$, or all would be run conditional on the low valuation.

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.

Turning to interventions, 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 even over the long term. Thus if the asset price is not temporarily depressed due to illiquidity, there is no reason for the government to subsidize purchases even if were to bear the cost of bank failures because overpayment is simply a disguised form of a subsidized recapitalization. The latter is more direct and more transparent (unless the objective is obfuscation).

Illiquid and Risky Assets

If assets are risky as in the previous section, and illiquid because of the limited buying power of experts, then the earlier rationales for intervention hold. In addition, though, authorities cannot intervene blithely on their own, confident that the value of the asset is below fundamental value. Indeed, if there is sufficient fundamental risk, for a given amount of illiquidity, the ask price could exceed the fundamental long term value of the asset (because the bank's put option is so valuable), leading the buyer to make a loss.[12] In this case, there is a trade off for the government. One the one hand, illiquidity leads the asset to be underpriced relative to fundamentals. On the other, the put option leads asset to be overpriced.

In a voluntary subsidized sale, therefore, the buyers could risk losing money if they are not expert. Moreover, the voluntary price could well reflect q, f, and D (which go into determining the size of the bank's put as well as the illiquidity discount), and may thus not provide any guide to fundamental value.[13] For all these reasons, it might be better to collapse the put option by forcing banks to sell, even while financing buyers or even providing an element of subsidy so as to compensate sellers for absorbing the illiquidity discount. If there is sufficient

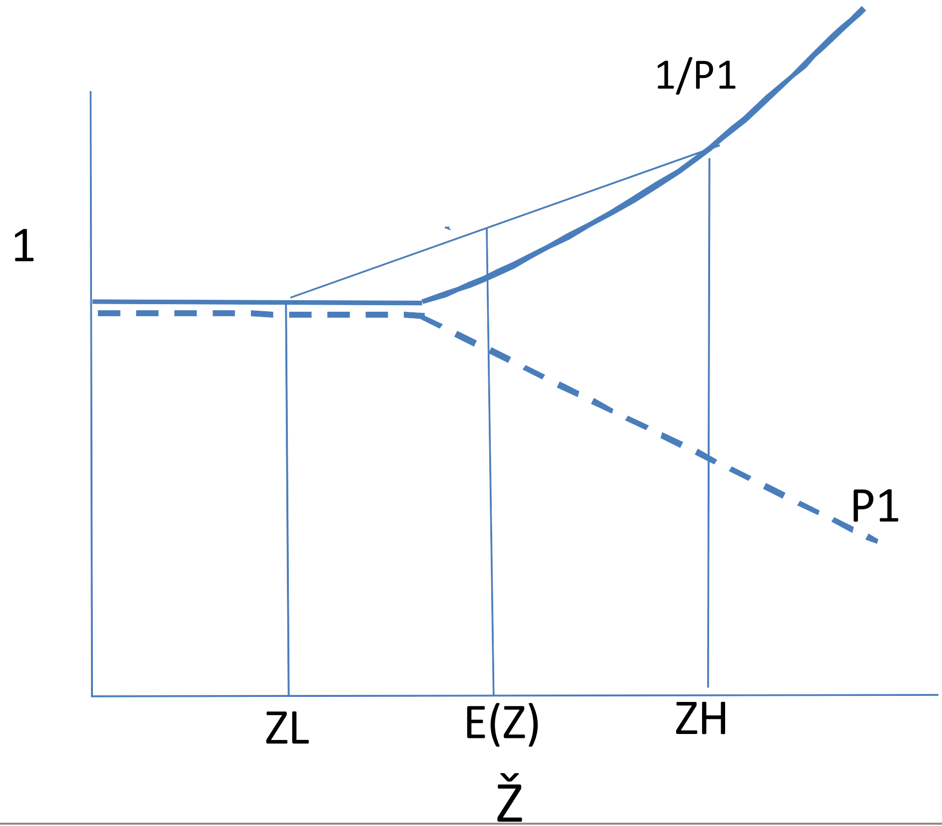
[12] This value from risk shifting could also explain why the banks held these assets initially, by an argument similar to that in Allen-Gale (2000b).

[13] This was not a problem in our earlier discussion where fundamental value was known.

liquidity amongst competitive buyers, and the sale is forced, the asset price will reflect only fundamentals (that is, Z), and not reflect q, f, and D.

There is a final but subtle consequence of considering both illiquidity and risk at the same time. Suppose the realization of $\tilde{Z}$ conditional on the liquidity shock is either low, Z_L, or high, Z_H, with expected value Z. At date 1 the available pool of liquidity will tend to bind more when asset prices are high – the departure from fundamental value will be greater because P_1 will be smaller, and the prospective returns, $\frac{1}{P_1}$, for investors from purchasing at that time will be higher. As a result, using Jensen's inequality, a mean preserving spread in the fundamental date-2 value of the asset, conditional on the liquidity shock, will result in an increase in the expected return to having cash in those states. Thus risk overlaid on illiquidity will further depress lending at date 0.

Figure 3: Risk, illiquidity, and Expected Returns



The point of introducing an overlay of risk on our basic model of illiquidity was to show how illiquidity is fundamental to the point we have made. The addition of risk does add richness to the model. There are interesting interactions between illiquidity and risk that deserve further exploration.

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 also dry up.

Allen, Carletti and Gale (2009) present a model of freezes 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. 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). This is related, yet somewhat different from the model of liquidity in Holmstrom-Tirole (1998), which relies on collateral value as the limit to liquidity of an asset, rather than limited purchasing power.

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 any financial market in a crisis. 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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