Knowledge and Liquidity

Patrick Bolton
Columbia University

Tano Santos
Columbia University

Jose Scheinkman
Princeton University

December 2008

As the record of Fed interventions over the past year, from December 2007 to December 2008, makes abundantly clear a foremost concern of monetary authorities in responding to the financial crisis has been to avoid a repeat of the great depression, and especially a repeat of the monetary contraction that Friedman and Schwartz (1963) have identified as the major cause of the 1930s depression. The Fed has shown tremendous resourcefulness and inventiveness in its liquidity injections, considerably widening the collateral eligible under the discount window and the term auction facility, and setting up new programs targeted at primary dealers, the commercial paper market and money market funds. At the same time it has stepped in to offer guarantees on assets held by Bear Stearns and Citigroup in an effort to avoid bankruptcy for these institutions. In the fall of 2008 the US Congress also authorized the Treasury department to inject up to $700 billion to recapitalize US banks, with about half of these funds used up to inject new equity capital in the major US banks.

This unprecedented intervention has had the intended effect of averting a major systemic financial meltdown and it has kept the most critical financial institutions afloat. Yet, until now banks have mostly responded by cutting new lending and hoarding liquidity, so that the ultimate goal of forestalling a credit crunch has not been achieved. For the most part banks also are still holding most of the toxic assets that have undermined the market's confidence in the soundness of the banking system. Moreover, the Fed has put its balance sheet at risk, increasing the assets it holds from $851 billion in the summer of 2007 to $2.245 trillion at the end of 2008. Finally, the massive public liquidity injection has also had the effect of crowding out private liquidity and private capital as an alternative source of funding for banks.

These side effects of the public liquidity injection may undermine the effectiveness of public policy and may also impose substantial costs on the real economy. It is therefore important to explore with the benefit of hindsight whether less costly approaches to public liquidity injections aren't available. This is what we intend to do in this paper, by relying on the analytical framework we developed in Bolton, Santos and Scheinkman (2008) (BSS). The model we have developed in BSS is set up do address two issues that have been at the core of the current crisis. The first issue is the *originate-and-distribute* model of financial intermediation, what the underlying economic rationale for this model might be (if there is any), and how it might affects optimal liquidity provision. We propose a new explanation for origination and *contingent* distribution based on maturity shocks and the optimal allocation of long-term assets in the hands of long term investors. The second issue concerns the dynamics of liquidity crises and the optimal timing of public liquidity. At what point in a liquidity crisis is public liquidity most desirable?

Although, recent economic research provides a better understanding of the benefits of public intervention in credit markets during aggregate liquidity crises (Holmstrom and Tirole, 1998 and Bolton and Rosenthal, 2002) it does not touch on the issue of the optimal timing of liquidity in a dynamically unfolding liquidity crisis. Also, the monetary authorities did not have a blueprint they could rely on when the crisis broke out, and have essentially had to improvise their policy response as events unfolded.

The model in BSS only provides a most rudimentary dynamic structure, but it is sufficient to be able to frame the issue of the timing of public liquidity. We briefly outline the main building blocks of the model in the next section and in a subsequent section characterize equilibria using a numerical example. We then proceed to a discussion of the effects of public liquidity in our model.

Three main observations emerge from our analysis. First, lack of knowledge and opaqueness about asset-quality of institutions in need of liquidity, while it can facilitate liquidity trading (as Holmstrom and Tirole (2008) observe) also tends to induce inefficient liquidity provision by the market. Institutions who are faced with a liquidity shortage may trade assets for cash too soon in an effort to avoid future adverse selection problems, which undermine the liquidity of future secondary markets. By choosing to trade sooner these institutions forego a valuable option not to trade assets at fire-sale prices at all should their liquidity needs prove to be temporary.

Second, if the monetary authorities wrongly time their injection of liquidity they risk crowding out private liquidity that may be available outside the banking sector (mainly in hedge funds, pension funds and sovereign wealth funds). At the same time, if liquidity is injected in the form of a collateralized lending facility, public liquidity will undermine financial institutions' incentives to obtain liquidity outside the banking sector by selling (problem) assets for cash.

Third, public liquidity injections while alleviating the liquidity needs of solvent institutions, may also provide a life-line to insolvent banks and thus slow down the resolution of an insolvency crisis. Unfortunately, the monetary authorities may not have the knowledge required to be able to optimally time their liquidity injections and to be able to discriminate liquidity from solvency crises. To be able to improve the monetary authorities' knowledge in a crisis it may thus be desirable to give the authorities greater powers to monitor the financial system and the financial institutions that may one day have to rely on its liquidity facility.

The BSS model

In BSS we consider a model with two types of investors, long-run (LR) and short-run (SR) investors. The latter invest in assets that mature early, while the former invest in higher return long-duration assets. Assets that mature early are risky and expose their holders to both maturity and return risk. The other assets are riskless. There are gains from trade between LR and SR investors when the risky asset matures late. In this case SR investors prefer to sell the asset to LR investors as long as the price is at least as high as the future value of the asset's returns discounted at their higher discount factor. If SRs anticipate to be able to sell in these contingencies they are more willing to invest in the risky asset. Similarly, if LRs anticipate to be able to buy risky assets at marked down prices in these events they are willing to hold more cash. In sum, there is a natural complementarity between LR and SR investors. SRs sell assets in states where they value them the least and LRs provide cash when SRs value cash the most.

In a frictionless financial system it is efficient for SRs to rely on this source of outside liquidity. This mechanism allows SRs to originate a larger volume of valuable assets and to distribute them to the highest-value holders. However, in reality there are at least two frictions that may disrupt this financing model. First, the originator may have private information about the underlying value of the asset. Second, both sides of the market must coordinate their portfolio composition decisions and the timing of their trades to generate maximum gains from trade. Indeed, the secondary market for assets can completely dry up at any moment if SRs expect LRs not to carry much cash, or if LRs expect to be able to purchase these assets at even more marked down prices in the future.

More formally, the BSS model allows for four periods. At date 0, LRs choose the amount M to hold in cash and the amount $(\kappa - M)$ of their endowment κ to invest in a long-term decreasing returns-to-scale project that yields a return $\varphi(\kappa - M) > \kappa - M$

at date 3. Similarly, SRs choose the fraction $(1-m)$ of their unit endowment to invest in an *i.i.d* risky project that they originate and that can be scaled up to at most one unit; the remainder m is held in cash. Both LR and SR investors are assumed to be risk neutral. They differ only in their time preferences, with SR investors discounting date 3 consumption with discount factor $\delta < 1$ but not LR investors.

Risky projects are likely to mature early: they pay an amount $\widetilde{\rho}_t$ at either dates $t = 1, 2, 3$, where $\widetilde{\rho}_t \in \{0, \rho\}$ and $\rho > 1$. At date 1 risky assets yield ρ with probability λ, and with probability $(1-\lambda)$ they only yield a positive return at either dates 2 or 3. The date 1 shock to cash-flows is an aggregate publicly observable shock. Subsequent cash-flow shocks, however are *i.i.d.* idiosyncratic shocks: (i) the asset matures with probability θ at date 2 and with probability $(1-\theta)$ at date 3; (ii) when it matures it yields $\widetilde{\rho}_t = \rho$ with probability η and $\widetilde{\rho}_t = 0$ with probability $(1-\eta)$. Only the originators of a risky asset are able to observe the realization of the idiosyncratic shocks. This informational asymmetry introduces a key friction in the secondary market for risky assets at both dates 1 and 2.

Finally we assume that there is a unit mass of both LR and SR investors and we assume that the law of large numbers applies, so that θ is also the proportion of risky assets that matures at date 2 and η is the proportion of risky assets that pay off ρ.

An Example

Most of our analysis can be illustrated with the help of the following example, where all but one parameter value is fixed as follows:

$$\lambda = .85 \qquad \eta = .4 \qquad \rho = 1.13 \qquad \kappa = .2 \qquad \delta = .1920 \qquad \varphi(x) = x^{\gamma} \quad \text{with} \quad \gamma = .4$$

The only free parameter is θ, which we allow to vary between 0 and $\overline{\theta} = .4834$. This free parameter plays a central role in the analysis as it is simultaneously a measure of the expected maturity of the asset and of the informational rent of the originators of the asset. As θ increases the risky asset is more attractive to SR investors, since the probability $(\lambda + (1-\lambda)\theta)$ that the asset matures before date 3 is then higher. It is straightforward to verify that for any value $\theta \leq \overline{\theta}$ SR investors prefer to only hold cash under autarchy.

Note also that in this example $\varphi'(\kappa) > 1$ so that LR investors must be able to purchase risky assets in secondary markets at marked down prices to compensate for the opportunity cost of holding cash. In other words, in this example equilibrium secondary market prices must be *cash-in-the-market* prices, a term first coined by Allen and Gale (1998).

Equilibrium

BSS solve for symmetric, competitive, rational expectations equilibria in which LR and SR investors choose their optimal portfolio and asset trades taking prices as given. They solve for two types of equilibria, an *immediate-trading equilibrium* in which secondary markets are active only at date 1, and a *delayed-trading equilibrium* in which secondary markets are active only at date 2.

The immediate-trading equilibrium exists for all $\theta \in [0, \overline{\theta}]$ and is such that :

$$M_i^* > 0,\ m_i^* \geq 0, \text{ and } q^*(\omega_{1L}) = Q^*(\omega_{1L}) = 1 - m_i^*,$$

where $q^*(\omega_{1L})$ and $Q^*(\omega_{1L})$ respectively denote the SR asset supply and LR asset demand in the event ω_{1L} at date 1 where risky assets do not mature at date 1.

This equilibrium is supported by *on-the-equilibrium-path* market-clearing prices such that:

$$P_{1i}^* = \frac{M_i^*}{1 - m_i^*} = \frac{1 - \lambda\rho}{1 - \lambda},$$

and *off-the-equilibrium-path* prices at date 2, P_{2i}^*, such that neither SRs nor LRs have an incentive to trade at date 2. SRs prefer to sell assets at date 1 for a price P_{1i}^* rather than wait to trade at date 2 if necessary at price P_{2i}^* if the following condition holds:

$$P_{1i}^* \geq \theta\eta\rho + (1 - \theta\eta) P_{2i}^*.$$

As for LRs, they also prefer to trade at date 1 if their off-the-equilibrium-path beliefs are such that they expect to buy only *lemons*, so that the conditional expected return of the risky asset at date 2 is $\mathbf{E}[\widetilde{\rho}_3|\mathcal{F}] = 0$.

The equilibrium portfolio policies $[m_i^*, M_i^*]$ are obtained by solving respectively the SR and LR optimization problems at date 0 given the equilibrium price P_{1i}^*. An SR's payoff function at date 0 is linear in m and given by

$$\pi_i(m) = m + (1 - m)[\lambda\rho + (1 - \lambda) P_{1i}^*],$$

so that SRs are indifferent between any cash holding $m \in [0, 1]$ if $P_{1i}^* = \frac{1-\lambda\rho}{1-\lambda}$. Similarly, an LR investor's payoff function at date 0 is given by:

$$\Pi_i(M) = \varphi(\kappa - M) + \lambda M + (1 - \lambda) \frac{\eta\rho}{P_{1i}^*} M,$$

so that M_i^* is given by

$$\varphi'(\kappa - M_i^*) = \lambda + (1 - \lambda)^2 \frac{\eta\rho}{1 - \lambda\rho}.$$

Then, setting m such that

$$\frac{M_i^*}{1-m} = \frac{1-\lambda\rho}{1-\lambda}$$

completes the characterization of the immediate-trading equilibrium.

A *delayed-trading equilibrium* may also exist for a subset $\theta \in [0, \tilde{\theta}]$, where $\tilde{\theta} = .4628 < \overline{\theta} = .4834$. This equilibrium is such that:

$$m_d^* \in [0,1), M_d^* \in (0,\kappa), \text{ and } q^*(\omega_{20},\omega_{2L}) = Q^*(\omega_{20},\omega_{2L}) = (1-\theta\eta)(1-m_d^*),$$

where $q^*(\omega_{20},\omega_{2L})$ and $Q^*(\omega_{20},\omega_{2L})$ respectively denote the SR asset supply and LR asset demand at date 2 in either (idiosyncratic) event ω_{20} when the risky asset is known to be worthless to SR or, event ω_{2L} when the risky asset is known to mature at date 3.

This equilibrium is supported by *on-the-equilibrium-path* market-clearing prices such that:

$$P_{2d}^* = \frac{M_d^*}{(1-\theta\eta)(1-m_d^*)}.$$

Under delayed trading, the total cash in the market is M_d^* and the total supply of risky assets is given by the fraction of SRs who want to trade $(1-\theta\eta)$ times the total amount of assets they each have available to trade $(1-m_d^*)$. Equilibrium prices are then simply given by the aggregate cash-to-asset ratio at date 2.

The equilibrium portfolio policies $[m_d^*, M_d^*]$ are again obtained by solving the SR and LR optimization problems at date 0 under the assumption that trade takes place only at date 2. The SRs' payoff function at date 0 is again linear in m and is given by

$$\pi_d(m) = m + (1-m)[\lambda\rho + (1-\lambda)(\theta\eta\rho + (1-\eta\theta)P_{2d}^*)].$$

And an LR investor's payoff function at date 0 is given by:

$$\Pi_d(M) = \varphi(\kappa - M) + \lambda M + (1-\lambda)\left(\frac{(1-\theta)\eta\rho}{(1-\theta\eta)P_{2d}^*}\right)M,$$

so that

$$\varphi'(\kappa - M_d^*) = \lambda + (1-\lambda)\frac{(1-\theta)\eta\rho}{(1-\theta\eta)P_{2d}^*}. \tag{1}$$

For $\theta \in [0, \widehat{\theta})$ the equilibrium is such that $m_d^* > 0$ and the equilibrium price is such that SRs' are indifferent between any $m \in [0,1]$:

$$P_{2d}^* = (1-\lambda)\rho + \frac{1-\rho}{1-\theta\eta} = \frac{M_d^*}{(1-\theta\eta)(1-m_d^*)}. \tag{2}$$

The equilibrium value of M_d^* is then obtained by substituting for P_{2d}^* in equation (1), and m_d^* is obtained from equation (2). For $\theta \in [\widehat{\theta}, \tilde{\theta}]$ the equilibrium is such that $m_d^* = 0$ and M_d^* is given by

$$\varphi'(\kappa - M_d^*) = \lambda + (1-\lambda)\,\frac{(1-\theta)\eta\rho}{M_d^*}.$$

The *off-the-equilibrium-path* prices at date 1, P_{1d}^*, must also be such that neither SRs nor LRs have an incentive to trade at date 1, or:

$$\text{(3)} \qquad P_{1d}^* \leq \theta\eta\rho + (1-\theta\eta)\,P_{2d}^* \qquad \text{and} \qquad \frac{\eta\rho}{P_{1d}^*} \leq \frac{(1-\theta)\eta\rho}{(1-\theta\eta)P_{2d}^*}.$$

The first inequality ensures that SRs are better off trading at date 2, and the second that LRs also prefer to trade at date 2. If LRs trade at date 1 their net return is given by the total expected return of the risky asset at date 1, $\eta\rho$, divided by the price of the asset P_{1d}^*. Similarly at date 2 the conditional expected return on the asset is $(1-\theta)\eta\rho/(1-\theta\eta)$, as SRs don't trade with probability $\theta\eta$ and are expected to trade lemons with probability $\theta(1-\eta)$ at date 2. It is straightforward to verify that for our parameter values it is always possible to find a price P_{1d}^* that satisfies these inequalities.

Figure 1 illustrates the two equilibria for $\theta = .35$. In the immediate trading equilibrium the isoprofit curves $\pi_i(m) = \overline{\pi}$ and $\Pi_i(M) = \overline{\Pi}$ are tangent at $(M_i^*, m_i^*) = (.0169, .9358))$ and in the delayed trading equilibrium the isoprofit curves $\pi_d(m) = \overline{\pi}$ and $\Pi_d(M) = \overline{\Pi}$ are tangent at $(M_d^*, m_d^*) = (.0540, 4860)$. Note that the SRs' isoprofit line $\pi_i(m) = \overline{\pi}$ is *flatter* than line $\pi_d(m) = \overline{\pi}$, reflecting the fact that SRs require more outside liquidity to compensate for a reduction in inside liquidity under immediate than under delayed trading. The reason is that when they choose to trade only at date 2, SRs need to trade less often at marked down prices as the risky asset is more likely to mature before they need to trade. As a result, in the immediate trading equilibrium most of the liquidity is *inside liquidity* held by SRs, while in the delayed-trading equilibrium there is more *outside* and less *inside* liquidity.

As Figure 1 highlights both equilibria are *interim efficient*. However as the figure also highlights, the delayed trading equilibrium (weakly) *Pareto dominates* the immediate trading equilibrium. This is actually a general result. The reason is that under delayed trading the risky asset is more valuable to SRs as it is more likely to mature before trading is required. As the risky asset is more valuable, SRs invest more in the risky asset, thus generating a higher return for the economy as a whole. In the example, all the benefit from higher investment in the risky asset goes to LRs, but this is generally not the case.

Although delaying trading to date 2 is ex-ante efficient, the delayed trading equilibrium may fail to exists due to adverse selection problems at that date. This occurs whenever

$$P_d(\omega_{20}, \omega_{2L}) < \delta\eta\rho, \tag{4}$$

where $P_d(\omega_{20}, \omega_{2L})$ is the expected value of the risky asset at date 2 from the perspective of uninformed LR buyers. In that case SRs' who have assets that mature at date 3 prefer to hold onto those assets rather than trade at highly dilutive prices at date 2. As can readily be verified, in our example both the immediate and delayed trading equilibria exist for $\theta \in [0, .4628]$, but for $\theta \in (.4628, .4834]$ the delayed trading equilibrium fails to exist, as in this range the price of risky assets in the secondary market is too low.

Figure 2 exhibits the comparative statics with respect to θ for the cash positions, m_d^* and M_d^*. The amount of cash carried by SRs is a decreasing function of θ, and $m_d^* = 0$ for $\theta \geq \widehat{\theta} = .4196$. Surprisingly, the amount of cash carried by LRs is an increasing function of θ. There are two effects at work. First, although an increase in θ does worsen the adverse selection problem at date 2 there is a second countervailing effect, which is that an increase in θ also results in a higher investment in the risky asset by the SRs. This latter effect dominates the former, which explains the comparative statics of M_d^* with respect to θ.

Knowledge and the Timing of Public Liquidity

When θ is higher the average asset quality of SRs, conditional on trading at date 2, is lower. That is, the market expects SRs to trade a higher proportion of lemons. As a result, valuable assets traded by SRs demanding liquidity, trade at lower fire-sale prices. At some point (when $\theta \in (.4628, .4834]$) it becomes unattractive to sell valuable assets at fire-sale prices and the market breaks down, so that the delayed trading equilibrium fails to exist. In such a situation, knowledge of asset values by SRs undermines the liquidity of the market. If SRs were as ignorant about asset values as LRs, they would trade. In other words, if assets were so opaque that no-one could ascertain their value there would be efficient liquidity trading. Indeed, the immediate trading equilibrium always exists precisely because SRs don't have an informational advantage over LRs at date 1. However, note that liquidity trading at date 1 is inefficient. Thus, while asset-opaqueness underpins liquidity trading, it also may induce inefficiently early liquidity trading, in liquidity crises where the originators of assets gain an informational advantage over time.

Consider next the implications of our analysis for public liquidity provision. There is a welfare-improving role for public liquidity in the BSS model in situations when the delayed trading equilibrium fails to exist. In such situations, the monetary or fiscal authorities could intervene by providing price support in the secondary market at date 2 and thus restore existence of the delayed-trading equilibrium. Another, related welfare improving intervention is to ensure that the economy coordinates on the efficient equilibrium by providing price support at date 2, so as to put a price floor on *off-the-equilibrium prices* at date 2 and thus ensure that an immediate-trading equilibrium cannot exist.

Note that either forms of intervention are market-making interventions similar to those initially envisaged under TARP, that aim to support outside liquidity by facilitating the *transfer* of (troubled) assets from SRs to LRs. Thus, our analysis suggests that rather than the government playing a role of lender of last resort it should play a role of *market-maker of last resort*. By inducing SRs to obtain liquidity through asset sales, the government makes optimal use of market liquidity and helps maintain the efficiency of origination and distribution of risky assets under the delayed-trading equilibrium. To the extent that monetary authorities may not be legally authorized to play such a market-making role of last resort, fiscal authorities need to intervene in this capacity as had been envisaged under Paulson's reverse-auction plan.

In the absence of such an offsetting intervention, public liquidity provision through collateralized lending has the perverse effect of encouraging hoarding and crowding out market liquidity, thus undermining the efficient distribution of risky assets originated by SRs. More precisely in our model such an intervention has the effect of raising δ and thus encouraging SRs to inefficiently hold risky assets until they mature at date 3. Another unintended effect of central banks' collateralized lending is that it worsens the lemons problem in secondary markets, as only the worst assets, those that cannot serve as collateral, will be traded in secondary markets. This may help explain why the LIBOR did not fall following the large interventions by central banks.

Our analysis, thus highlights an important concern with Fed interventions over the past year that other commentators have also emphasized: namely that it does not do much more than provide a life-line to financial institutions. It does not induce them to engage in new lending. On the contrary, it encourages zombie lending by helping banks maintain non-performing assets on their balance sheet. What is more, it transfers a potentially major asset risk to the Fed.

An even more efficient intervention could be envisaged if the authorities were able to identify institutions in states ω_{20} and ω_{2L}. In that case, liquidity could be granted to the solvent SRs who need liquidity and not to the insolvent SRs in state ω_{20}. To be able to pull this off, however, the monetary authorities would need a much more detailed knowledge of financial institutions' assets and liabilities than they currently have. In sum the efficient provision of public liquidity requires detailed knowledge by monetary authorities to be able to time the intervention optimally and to be able to sort solvency from liquidity problems.

References

Allen, Franklin and Douglas Gale (1998) "Optimal Financial Crises," *Journal of Finance*, 53, 1245-1284.

Bolton, Patrick, and Howard Rosenthal (2002) "Political Intervention in Debt Contracts", *Journal of Political Economy*, 110, 1103-34.

Bolton, Patrick, Tano Santos and Jose Scheinkman (2008) "Inside and Outside Liquidity", mimeo, Columbia University

Friedman, Milton and Anna Schwartz (1963) *Monetary History of the United States, 1867-1960*

Holmstron, Bengt and Jean Tirole (1998) "Private and Public Supply of Liquidity" *Journal of Political Economy,* vol. 106 no. 1, 1-40.

Holmstrom, Bengt and Jean Tirole (2008) "Inside and Outside Liquidity" Wicksell Lectures, http://idei.fr/doc/by/tirole/wicksell_lectures.pdf