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Conference Overview and Summary of Proceedings

1. Introduction

The financial crisis that emerged in 2007 had many and varied causes, but one of its most consistent themes has been the disappearance of liquidity. Indeed, in one of the first manifestations of the crisis in August 2007, BNP Paribas announced that it would suspend redemptions from three hedge funds, noting that a "complete evaporation of liquidity in certain market segments of the U.S. securitization market" had made it impossible to value the funds' assets. Since then, much economic policymaking has been devoted to understanding and combating liquidity shortages.

Although the crisis began less than two years ago, a significant body of academic work has already attempted to understand and address its causes and symptoms. Indeed, in February 2009, the Federal Reserve Bank of New York organized a Central Bank Liquidity Tools Conference to bring together some of the world's leading experts on liquidity to present their work and discuss its relevance and significance in the context of the ongoing crisis. While the papers considered a variety of topics, three critical and related questions unified the discussions: How do we define and understand liquidity? What are the causes and consequences of illiquidity? And what is the proper regulatory response to issues of liquidity?

One goal was to set out a clear definition of liquidity and to distinguish between different interpretations of the term. In particular, there is "market liquidity," which involves the readiness with which firms can buy or sell assets; "funding liquidity," which involves the ability of firms to obtain funding quickly and easily; and "central bank liquidity," which involves the ability of banks to easily borrow and lend reserve balances at the central bank. Although each of these types of liquidity is distinct, they are closely linked, and problems with one can quickly cause problems with the others.

A second goal was to examine the causes and consequences of liquidity shortages. Shocks to liquidity can be exacerbated, perpetuated, and spread because of financial market frictions such as balance-sheet constraints and the maturity mismatch between assets and liabilities, potentially leading to difficulties in rolling over sources of funding. In examining the consequences of illiquidity, many academics have made reference to traditional models of bank runs, updating them to account for the greater complexities of the modern financial system. Another common thread in the recent literature is the issue of systemic risk, whereby financial market illiquidity can turn firm-specific problems quickly into system-wide problems.

A third goal was to determine how central banks can best respond to these problems. Common issues of concern included the relative merits and effectiveness of ex ante policy (addressing causes) and ex post policy (addressing consequences), the need to define and measure policy goals in the absence of a single clear target such as the overnight rate, and the proper scope of financial regulation in a system where there are many major players outside the traditional banking sector.

Ultimately, all of the papers presented sought to answer a common question: What is the new "normal"? There is a broad consensus that the post-crisis financial system will not look like the pre-crisis system, as market participants and regulators adjust to the issues raised by the present crisis. Because illiquidity has played a key role in the crisis, an answer to this

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question requires us to develop a better understanding of the nature of illiquidity, the role of illiquidity in the financial system, and the most effective policy responses to illiquidity.

2. Session 1: Overview of Recent Problems in Liquidity Provision

Paper:
"Central Bank Tools and Liquidity Shortages"
Stephen G. Cecchetti, Bank for International Settlements
Piti Disyatat, Bank for International Settlements

Discussant:
Bengt Holmstrom, Massachusetts Institute of Technology

Cecchetti and Disyatat examine the role of central banks as lenders of last resort. They distinguish three types of liquidity: central bank liquidity, market liquidity, and funding liquidity. Central bank liquidity consists of deposits from financial institutions at a central bank, which are often called reserve or settlement balances. Market liquidity is the ability of market participants to buy and sell assets in relatively large quantities without significantly influencing their market price. Funding liquidity is the ability of an individual or institution to raise cash by selling assets or borrowing.

Motivated by the definitions of liquidity, the authors describe three kinds of liquidity shortages. The first is a shortage of central bank liquidity, which occurs when institutions find themselves short of the reserve balances that they wish to hold. This shortage can be caused either by insufficient aggregate supply of reserves or by problems related to their distribution, and is not directly related to the solvency of individual institutions. The second type is an acute shortage of funding liquidity at a specific institution. This occurs when an institution is unable to raise funds to meet its short-term obligations, and is typically associated with solvency concerns. The third type of liquidity shortage is a systemic shortage of funding and market liquidity. This is potentially the most harmful kind of liquidity shortage, and it arises when coordination failures and an evaporation of confidence among market participants lead to a breakdown of key financial markets that affect many institutions simultaneously.

As a lender of last resort, a central bank has two main liquidity tools: open market operations and institution-specific transactions. In open market operations, a central bank lends and borrows or buys and sells assets outright in the open market. In addition, a central bank may also deal with specific institutions in order to channel liquidity directly to them.

The authors go on to examine the use of the two main liquidity tools to address each type of liquidity shortage. If there is a shortage of central bank liquidity, the primary aim of central bank intervention is to maintain the smooth functioning of the payments system and keep interest rates near their targets. This is generally accomplished by open market operations when aggregate supply shortages occur and through discount window lending directly to specific institutions when distribution problems arise. When a central bank is confronted with an acute shortage of funding liquidity at a specific institution, central bank support is designed to contain potential contagion and spillover effects to the rest of the financial system, hence forestalling an institution-specific problem from becoming a systemic one. The response typically takes the form of bridge financing in order to allow the institution time for restructuring. In such situations, the central bank must tactfully handle communication challenges to support confidence while staving off panic. Finally, in the face of a systemic shortage of funding and market liquidity, the immediate objective of central bank intervention is to restore market functioning and shore up confidence in the financial system as a whole. This is likely to entail the broad provision of liquidity to institutions as well as to specific markets.

In the current crisis, central banks have taken four major steps to stem systemic shortages of funding and market liquidity. First, they are providing backstop financing to financial institutions. Second, central banks are supporting term funding by lengthening the maturity on refinancing operations and establishing swap lines between central banks. Third, they are lending high-quality liquid securities against lower quality, less liquid securities in an effort to bolster markets for the latter and ease collateral constraints more generally. Fourth, central banks are supplying credit to the nonbank sector directly. These actions have significantly increased the size of the balance sheets at many central banks, including the Federal Reserve, the Bank of England, and the European Central Bank (ECB).

Overall, Cecchetti and Disyatat conclude that the traditional view of lender of last resort, as originally expounded by Walter Bagehot, requires modification. Significantly, the appropriate principles of lender-of-last-resort support by central banks must be conditioned on the particular type of liquidity shortage that is taking place. Moreover, given the complexities of the modern financial system, with large interdependencies between financial institutions and markets, the lender of last resort may need to act to support not only institutions, but certain markets as well.

Holmstrom—Cecchetti and Disyatat's discussant—drew lessons from the crisis on the relative merits of liquidity provision and risk sharing. He motivated his remarks by discussing issues of

aggregate risk sharing, high demand for secure, liquid debt, and the role of government in supplying and managing liquidity. He began by noting that even though the originate-and-distribute model may have led to weaker incentives to supervise lending standards and tranching of mortgages, where risk is spread to many investors, one should not jump to the conclusion that the model is fundamentally flawed.

Holmstrom argued that lack of transparency is a significant problem now, but that it is a standard, even essential, feature of liquidity provision. A traditional bank has never been transparent; there is no mark-to-market accounting and the balance sheet is quite opaque. In analyzing the nature of liquidity provision, it is important to recognize the high velocity of credit markets, a feature that prevents investors from evaluating the creditworthiness of investments. Such an evaluation requires that agents have symmetric information about the value of the instruments they are trading. The natural way to achieve this is to create information-insensitive instruments, such as debt, where agents rely on coarse ratings rather than detailed information about the assets supporting the debt. Securitization and limited transparency are logical steps to reduce information intensity.

The current crisis has been spurred by the symbiotic relationship between excess foreign demand for savings and demand for subprime loans. However, while the originate-and-distribute model has the ability to distribute systemic risk, it is now apparent that this risk was not always distributed to those who wanted to bear it and was in many cases held by liquidity providers. The distribution of systemic tail risk is the major flaw in the system, and it arises because systemic risk is not appropriately priced into liquidity-providing markets. This is a major challenge going forward. The government also has a role in providing insurance against systemic risk by injecting liquidity when there are large negative aggregate shocks. Public insurance is more efficient than private insurance for rare events, since the government can insure ex post, while private markets have to arrange insurance ex ante.

Holmstrom concluded by observing that, in an ideal world, all idiosyncratic risk would be eliminated through diversification and systemic risk would be borne by everyone in proportion to their risk tolerance. No crisis would ever occur in that case. The reality is far from this ideal, because information and incentive problems lead to an enormous demand for riskless debt. Though the originate-and-distribute model could be a step toward the ideal, and it has been useful in the industry, the problem with systemic tail risk needs to be resolved. As part of the solution, there should be a greater focus on regulation of leverage, as well as maturity mismatches.

One participant asked if it was logical for central banks to charge lower haircuts than the market does. Holmstrom responded that his presentation focused on redistribution of aggregate risk and did not incorporate information on haircuts.

Another asked how to overcome issues of adverse selection in the securities markets. Holmstrom noted that new innovation has failed to get beyond this problem. Cecchetti mentioned that the originate-and-distribute model allows the provider to keep good assets while selling off bad ones. The same participant observed that private providers are not ideal for offering insurance for catastrophic events. Holmstrom indicated that there is some scope for private insurance, but also for government insurance. Cecchetti added that this insurance cannot be supplied by private entities at a reasonable price.

The last question related to why over-the-counter markets have been disrupted. Cecchetti said he felt that most securities should be forced onto exchanges. A standardized market structure would be much more resilient.

3. Session 2: Funding Liquidity and Market Liquidity

Papers:
"Leverage, Moral Hazard, and Liquidity"
  Viral V. Acharya, New York University
    and London Business School
  S. "Vish" Viswanathan, Duke University

  Discussant:
  Patrick Bolton, Columbia University

"Interbank Market Liquidity and Central Bank Intervention"
  Franklin Allen, University of Pennsylvania
  Elena Carletti, European University Institute
  Douglas Gale, New York University

  Discussant:
  Adriano A. Rampini, Duke University

"Bank Liquidity, Interbank Markets, and Monetary Policy"
  Xavier Freixas, Universitat Pompeu Fabra
  Antoine Martin, Federal Reserve Bank of New York
  David Skeie, Federal Reserve Bank of New York

  Discussant:
  Franklin Allen, University of Pennsylvania

3.1 Acharya and Viswanathan

Acharya and Viswanathan address a phenomenon that appears during times of financial shock: the evaporation of liquidity. Liquidity was plentiful prior to the crisis, and the problem was not one of hoarding cash, but rather, which asset class would absorb the demand from yield-seeking investors. With the onset of the crisis, however, risk aversion swept through the financial sector. The authors argue that the short-term debt with which balance sheets had been financed was a possible contributor to the market freeze. Firms were dependent on the ability to raise or roll over short-term debt collateralized by assets, as well as short-term unsecured commercial paper. If firms faced liquidation risk, these assets would have to be sold at "fire-sale" prices that would be much lower than the assets' fair value. Moreover, the inability of firms to roll over their existing debt would place a high burden on their ability to cover liabilities, necessitating fire sales.

Acharya and Viswanathan present two possible explanations for the increasing amount of leverage firms carried. The first holds that the downward trend in volatility prior to the crisis—a phenomenon that has been called the "Great Moderation"—led to rapid growth and increased issuance of inexpensive debt. The second explanation centers on the notion of a "credit bubble" characterized by light regulation and risk taking among financiers. The paper provides a model capturing the first theory.

In the model, short-term rollover debt is an optimal form of financing and the risk-shifting problem tied to leverage limits the funding of financial institutions that are reliant upon trading. The model revolves around one parameter: the maximum borrowing allowable as a result of the ex post risk shifting.

The key result attempts to explain why adverse shocks preceded by a prosperous economy tend to be much more severe. The authors state that when times are good, borrowing is inexpensive and even firms with low capitalization levels can leverage themselves in the market. Thus, ex ante there are more firms that are highly leveraged in the financial sector when times are good, and as a result there is not much spare debt capacity ex post in the event of a financial crisis. Only firms that are not highly leveraged during prosperous economic times have enough spare debt capacity to buy debt from other firms. Margin borrowing is usually very high during a prosperous economy, and as a result, prices are much lower during a subsequent crisis because once the adverse shocks materialize, there is a much deeper deleveraging in the economy. The asset substitution problem plays a key role, because it potentially rations firms when they are faced with the burden of raising

cash. In such an environment, the only feasible option is to sell assets. The authors endogenize both the debt market and asset market and examine the implications for prices. They also argue that hard debt contracts and collateral requirements give lenders higher recoveries and raise prices, outcomes that make raising debt desirable ex ante.

In his discussion, Bolton related this topic to the theory of lending booms and liquidity crises. He summarized the Acharya-Viswanathan paper as follows: the main premise is that firms may engage in asset sales to meet debt obligations. The buyers of the assets, however, have limited purchasing power because of the liquidity shock. The prices are determined by supply and demand and by the distribution of leverage in the industry. In a boom, increasing profitability leads to lower demand for outside liquidity, which is followed by higher asset prices. Because of greater entry into the market of lower quality assets, however, there is a larger collapse in asset prices when a negative shock occurs. Bolton also commented on the fact that the model does not have any losers ex ante, and that liquidity crises involve no inefficiencies ex post.

3.2 Allen, Carletti, and Gale

Allen, Carletti, and Gale focus on the interbank market. They begin by explaining that under normal circumstances, the interbank market works smoothly. Under some circumstances, however, it ceases to function properly. As a result, central banks intervene in the market in an attempt to stabilize prices and correct market inefficiencies.

The paper develops a simple theoretical framework for analyzing interbank markets and how central banks should intervene through open market operations. Banks use the interbank market to hedge against idiosyncratic and aggregate liquidity shocks. Hedging opportunities are, however, limited and markets are incomplete. This implies that market allocations are inefficient, as they entail excess price volatility and thus consumption volatility across banks. This is the only market failure in the model. The authors show that, by conducting open market operations and fixing the interest rate in the interbank market, the central bank can implement the constrained optimal allocation, where all banks can offer the same consumption to their late depositors irrespective of the idiosyncratic liquidity shock they face. The central bank is coupled with a fiscal authority that imposes lump-sum taxes on (or provides transfers to) depositors to acquire the short (or long) asset at the initial date and can give a lump-sum transfer to (or impose a tax on) the later consumers at the final date. Allen, Carletti, and Gale show that the exact nature of central

bank intervention depends on the type of shocks banks face and on the initial contract that banks promise to their depositors.

Discussant Rampini observed that "market freezes" in the context of the paper manifest themselves through a lack of trade when all banks have excess liquidity and the central bank drains excess liquidity by selling the long asset. He considered this an interesting, albeit somewhat unconventional, notion of a market freeze. Rampini also argued that the central bank policy proposed encompasses aspects of fiscal policy, and that the paper might thus provide a guide to the possibility of monetary and fiscal policy working in conjunction during a financial crisis.

3.3 Freixas, Martin, and Skeie

The final paper, by Freixas, Martin, and Skeie, begins by examining the role of central bank policy in the face of crisis. One view maintains that the central bank should focus on inflation and output in the medium and long run and not respond to the crisis directly. However, in the past, central banks have aggressively lowered interest rates during crises.

During financial disruptions, banks usually face considerable uncertainty with regard to their demand for liquid assets. A state-dependent interest rate, which is low during times of shock and high during a strong economy, can help mitigate the risks associated with idiosyncratic shocks. The paper argues that monetary policy plays a crucial role in setting low interest rates to facilitate the redistribution of liquidity during a crisis.

In the authors' model, the interest rate in the interbank market plays an important role in two ways. Ex ante, high interest rates are beneficial because they ensure that banks hold enough liquid assets, as it is expensive to acquire such assets in the interbank market. Ex post, however, interest rates need to be low when an idiosyncratic shock hits to facilitate trading in the interbank market. Redistribution of liquidity and high levels of interbank risk sharing are now necessary for the banking sector. The main challenge for a central bank is to set the right balance between high expected rates ex ante and low rates ex post in times of crisis.

Allen's discussion first reviewed the authors' model and then showed its relationship to the traditional model of Diamond and Dybvig (1983). Allen also pinpointed the innovative addition to the new model: having two states with different idiosyncratic bank shocks. An important point was also raised on the issue of how the central bank should set interest rates. According to Allen, these models are very

important because they are a building block for understanding the complexities surrounding both market failures and stability. In light of the crisis, these models can provide clarity and a possible course of government intervention.

4. Session 3: Policy Responses to Illiquidity

Papers:
"Illiquidity and Interest Rate Policy"
   Douglas W. Diamond, University of Chicago
      and National Bureau of Economic Research
   Raghuram G. Rajan, University of Chicago
      and National Bureau of Economic Research

   Discussant:
   Guido Lorenzoni, Massachusetts Institute of Technology

"Liquidity Hoarding and Interbank Market Spreads:
      The Role of Counterparty Risk"
   Florian Heider, European Central Bank
   Marie Hoerova, European Central Bank
   Cornelia Holthausen, European Central Bank

   Discussant:
   Gaetano Antinolfi, Washington University

4.1 Diamond and Rajan

Diamond and Rajan investigate the relationship between interest rates and the incentives facing banks regarding illiquid investments. Their work contributes to the longstanding debate between those who believe, like Alan Greenspan, that the Federal Reserve cannot prevent asset price bubbles, only mitigate their consequences, and those who believe that asymmetric interest rate policy can encourage behavior that makes booms and busts more likely.

The authors create a model in which entrepreneurs who invest in long-term projects must borrow from banks that in turn borrow from risk-averse households. In the model, there is no uncertainty about the profitability of projects, which are predetermined, but there is uncertainty about the households' income in each period. Liquidity problems can emerge if households have an unexpectedly high need to withdraw deposits. This, they assert, can occur either because of an unexpected decrease in present income or an increase in expected future income. With a decrease in present income,

households face a higher marginal utility of consumption and may want to spend their financial assets in order to consume more today. If, however, households expect significantly higher income in the future, they may spend their assets today in order to smooth lifetime consumption.

In either case, unanticipated demand for funds can force banks to call in loans for long-term projects early. As a result, the real interest rate must rise in order to equalize household demand for consumption goods and the supply of consumption goods from terminated projects whose loans have been called in. This in turn decreases bank net worth, since a bank's loans, which pay off only in the long run, fall in value as the real interest rate rises, but the bank's liabilities of demandable deposits do not have a corresponding fall in value. If the bank's net worth becomes negative, the bank can experience runs, which can be highly inefficient when they cause the terminations of otherwise profitable projects financed by bank loans. Thus, an increase in households' withdrawals, owing either to a current decrease in income or to a future increase in income, can create fragility in the banking system that harms the real economy.

One solution to this problem would be to change the structure of banks so that they were less reliant on demandable deposits for funding. However, such a change would be very difficult, as Diamond and Rajan, citing their past work, note. The authors assert that demandable debt is the cheapest form of financing available to banks, and that using more long-term liabilities that are not demandable would reduce the efficiency of intermediation substantially. Changing the sources of banks' funds is therefore not viewed as a viable option to reduce fragility in the banking system.

Another option is to use government intervention to attempt to stabilize the banking system and prevent bank runs. As a first possibility, governments can intervene by taxing households and giving the proceeds directly to banks. But while such a bailout scenario could certainly be effective in preventing bank runs and might be necessary in times of crisis such as the present, Diamond and Rajan argue that the severity with which property rights are violated under these policies makes them unsuitable for frequent use.

Instead, they consider an alternative policy measure in which the government lends or borrows in the market in an attempt to alter interest rates, and apply this type of policy to their model. Diamond and Rajan first note that since government action must be financed by tax revenues, there are potential issues of Ricardian equivalence. If the government seeks to lower interest rates by lending funds, it must raise these funds by increasing taxes. When a household's taxes are raised, however, the household is likely to increase its withdrawals in order to make up for the

current decline in income, as mentioned earlier, which would counterproductively push interest rates back up.

The authors' model shows that as long as the government finances its lending by taxing only households with deposits, with the level of deposits exceeding the size of the tax, there is zero effect on the interest rate. As a result, government intervention is likely to be ineffective when most or all households hold large amounts of demandable deposits relative to the size of the tax. However, if there are households that do not hold deposits, or if the level of the tax exceeds the amount of the households' deposit holdings, then the government action does have a marginal effect in the model, lowering the real interest rate and increasing banks' net worth. Thus, although households' actions in response to a government intervention may reduce its effectiveness, the intervention should still be effective, provided that it is large enough.

Next, Diamond and Rajan note while there can be benefits to influencing household and bank behavior if it prevents bank runs, it is also likely that altering these decisions can have negative effects. In the model, the authors consider both an "entrepreneur-friendly" central bank that seeks to lower interest rates as much as possible and a "household-friendly" central bank that seeks to raise interest rates as much as possible. They demonstrate that each type of central bank can have negative effects when its action is anticipated, even on the group that it attempted to benefit, owing to the distortions in behavior that it creates.

Finally, the authors argue that when government policy is anticipated, it can have an important impact on how banks choose to allocate their portfolios between liquid and illiquid investments. In the model, they assume that the government commits to lowering interest rates in case of liquidity problems and find that this encourages banks to take on more deposits and to finance more illiquid projects, making liquidity shortages more likely. As a result, they claim that commitment to a "one-sided" policy to intervene only to lower interest rates when they are too high can lead to distortions in bank decisions that can have a strongly counterproductive effect and make liquidity crises much more likely.

For this reason, Diamond and Rajan assert that an optimal interest rate policy must not only prevent bank runs by lowering interest rates in times of crisis, but also encourage banks to make more liquid loans to prevent distortion. To this end, the central bank should pursue a "two-sided" policy of interventions, in which the bank not only acts to lower interest rates to prevent runs when rates are too high, but also pushes interest rates up when the interest rate would otherwise be low. This type of intervention would punish illiquid banks, forcing them to call in loans and decreasing their net worth, but would not raise rates so much as to cause bank runs. Appropriately

implemented, this incentive against illiquidity could balance out the incentive in favor of illiquidity caused by the central bank's commitment to lower interest rates in times of crisis. Such a two-sided policy could therefore prevent distortions and allow banks to make an efficient allocation between liquid and illiquid investments while still allowing the central bank to intervene in order to prevent harmful bank runs.

Lorenzoni, in his discussion, offered an adaptation of the basic model presented by Diamond and Rajan. In the original model, a bank choosing to liquidate an entrepreneur's project must liquidate it entirely. Lorenzoni presented a model of partial liquidation, in which the bank can choose to terminate only part of a project early for an immediate payoff, leaving the rest to mature in the final period.

In this variation, the payoff that the bank gets for a project that is not completely liquidated is assumed to be a concave function that represents diminishing returns to the proportion of the original loan still invested in the project (that is, the proportion *not* liquidated). When this payoff is combined with terms representing the returns from liquidation and the cost of paying interest on deposits, a profit function for banks can be formed. First-order conditions can then be taken to find a bank's optimal policy with regard to liquidation. Lorenzoni found three possible regimes, depending on the interest rate: a no-liquidation regime at a low interest rate, a complete-liquidation regime at a high interest rate, and a partial-liquidation regime at an interest rate between the two extremes.

The discussant then created a supply function by optimizing consumers' utility with respect to the amount of funds loaned over the two periods and combines it with the demand function to find the market equilibrium. The result is that in an "exuberant" state, in which consumers' second-period endowments turn out to be very high, the equilibrium interest rate is also high, because consumers require larger incentives to transfer consumption from the first period to the second. If the equilibrium rate is high enough in this scenario, it can lead to a regime in which no lending takes place and banks go bankrupt and default on their debt as a result.

Lorenzoni incorporated the government into the modified model. The government taxes consumers and lends out tax revenues to banks. Once the loans are repaid, the government returns the tax revenues, plus interest, to the consumers. If consumers are free to optimize over any quantity of lending, including negative quantities (meaning that the consumers borrow from the banks), then households will simply adjust their lending to offset the tax. Government intervention therefore has no effect on the net supply of funds, which is independent of the size of the tax, and Ricardian equivalence holds. However, if a constraint is imposed that households may lend but may not borrow (that is, the amount of lending must

be non-negative), then government intervention may have an effect on the interest rate. Specifically, if the size of the tax is larger than the supply of loans under the initial equilibrium so that consumers cannot simply decrease their lending to offset the tax, then such a policy will reduce market interest rates.

Lorenzoni then turned to the issue of the optimal choice of banks' initial short-term debt, from the standpoint of maximizing expected payment to customers. More debt increases the probability of inefficient bankruptcy, but also increases the payment to consumers in nonbankruptcy states. The optimal level of debt must therefore find an equilibrium that balances these two opposing forces in favor of the consumer.

The issue of moral hazard was also considered. Lorenzoni assumed that the government intervenes ex post to protect banks in the "exuberant" state. But if this can be expected ahead of time, the level of debt that banks will take on increases endogenously. It is also possible, Lorenzoni asserted, for this distortion to make all parties worse off, reinforcing the potential problems of government intervention posed by Diamond and Rajan in their original model.

Overall, the partial-liquidation version of the model adapted by Lorenzoni is consistent with the main findings of Diamond and Rajan. This is especially true regarding the benefits and dangers of interest rate interventions not driven by cyclical conditions. Therefore, the powerful ex ante effects of moral hazard and reverse moral hazard present in the initial version of the model are maintained under the assumption of partial liquidation.

4.2 Heider, Hoerova, and Holthausen

The session's second paper sought to explain the recent tensions and eventual breakdown in the unsecured interbank lending market in a number of countries around the world. Much more so than in the past, banks have been keeping liquidity on their accounts rather than lending excess funds on the interbank market. Authors Heider, Hoerova, and Holthausen identify this phenomenon as a clear failure of the interbank market to efficiently redistribute liquidity.

To explain these developments, they present a three-period model based on adverse selection caused by the asymmetric information between banks regarding the risk of illiquid assets. In the first period, banks must allocate their funds between a risk-free liquid asset and a risky illiquid asset. The liquid asset pays off in the next period exactly what was put into it, and is essentially a form of storage. The illiquid asset will either have a high return R if it succeeds, or a return of zero if it fails. The size of the return R is known and is the same for all banks. The

probability of success varies across banks, but is unknown to banks in the first period. It is assumed that the expected return from the illiquid asset is greater than 1, making it larger than the return to the liquid asset.

In the second period, banks face a "liquidity shock" in which either a small or large amount of deposits is withdrawn by consumers, which the banks must pay. Banks with a shortage of liquidity (large withdrawals) can borrow from other banks that have excess liquidity (small withdrawals), thus forming an interbank market. However, banks also receive private information as to whether their illiquid assets are riskier (with a lower probability of success) or safer (with a higher probability of success) than expected. If banks have a shortage of liquidity to pay depositors, they may drop out of the unsecured interbank market and convert their illiquid assets into liquidity at a cost. Riskier assets are more illiquid, so banks with safer assets have better opportunities to obtain (costly) funding outside the unsecured market.

In the third period, the illiquid assets either succeed or fail, and interbank loans are repaid when possible. Since the illiquid asset has zero return when it fails, interbank loans are not repaid when the borrower's illiquid asset does not succeed. This potential for default leads to counterparty risk in the interbank market.

The study focuses on the role of asymmetric information about counterparty risk in the functioning of the unsecured interbank market. Banks with a liquidity shortage have a choice between borrowing and converting their illiquid assets into liquidity at a cost. Since safer assets are more liquid than riskier assets, banks with safe assets will require a lower interbank interest rate than banks with risky assets to be willing to stay in the unsecured interbank market. If the interest rate is higher than what the safe borrowers are willing to pay, they will drop out of the market. However, the risky borrowers may still be willing to pay this higher interest rate, leading to a scenario of adverse selection.

Depending on parameters, reflecting in particular the level and distribution of counterparty risk among banks, three different equilibrium "regimes" can arise in the interbank market. Under the first regime, there is full participation in the interbank market, and banks do not need to resort to converting their illiquid assets into liquidity. This is typically the case when there are low levels of counterparty risk and thus low interbank interest rates, preventing adverse selection. Under the second regime, the interbank interest rate is high enough that the safe borrowers are no longer willing to participate. However, there is still a market to provide unsecured loans to risky borrowers willing to pay a higher interest rate. This is the regime in which adverse selection takes place.

In the third regime, the interbank market breaks down. This can occur for one of two reasons. In the first case, the banks with excess liquidity can refuse to lend, and "hoard" their liquidity instead. A necessary condition for this to occur is that the illiquid asset that turns out to be riskier than expected is unprofitable in expected value. Still, the ex ante expected return on the illiquid asset is positive and dominates the rate of return on the liquid asset. In the second case, banks with excess liquidity may be willing to make loans to the banks with risky assets, but the market interest rate may be so high that even the risky banks prefer to drop out of the unsecured interbank market.

Heider, Hoerova, and Holthausen then compare the results of their model with empirical evidence from the three-month unsecured interbank market in the euro area from July 2006 and January 2009. They argue that the interbank market did in fact exhibit the three regimes described above as both the perceived level and dispersion of risk associated with banks' illiquid assets rose. The authors first examine the spread between the three-month unsecured interbank rate in the euro area (Euribor) and the overnight index swap (OIS) in three months' time to show changes in the interbank interest rate. They also look at the use of the ECB's deposit facility, where banks can place their excess funds, but which offers a lower interest rate than does the interbank market, to demonstrate liquidity hoarding.

In the first phase, beginning in July 2006, the authors note both a very low spread and an insignificant utilization of the deposit facility, consistent with a "full-participation" regime. In the second phase, beginning in August 2007, the spread rises significantly, but the deposit facility is still used very rarely, which they argue is consistent with an "adverse selection" regime, in which only the "riskier" banks, lacking good-quality collateral to borrow in the repo market, are willing to pay such high interest rates in the unsecured interbank market. In the third phase, beginning in September 2008, the interest rate increases further, and use of the deposit facility increases dramatically, showing a breakdown of the interbank lending market and large amounts of hoarding behavior. The authors also show that a similar pattern of the three-month interbank market spread can be observed in the United States in the aforementioned time period.

Heider, Hoerova, and Holthausen conclude by identifying policy interventions that could reduce or prevent adverse selection and thereby increase the efficiency of the interbank market. These are divided into two types of interventions: ex ante policies to prevent a dropping out of the good risks from the unsecured market, and ex post policies to restore the effectiveness of the interbank market after an unexpected increase in counterparty risk.

On the ex ante side, the study offers two options: liquidity requirements and improved transparency. Under the liquidity requirements option, there would be a limit on the amount of illiquid assets that banks would be permitted to hold at any given time. This would generally provide banks with more liquidity, reducing the demand for liquidity in the interbank market. As a result, the interbank interest rate would fall, which would make all banks, particularly banks with safe assets, more willing to borrow. This outcome in turn would ensure the full participation of banks in the unsecured market and, consequently, its smooth functioning. The downside of such a policy is that with less of the illiquid assets held, banks would receive lower returns on average from their investments, because of distortions in banks' optimal portfolio allocation.

Under the improved transparency option, the government would work to make banks' private information about their portfolios more public. This could allow for banks with excess liquidity to distinguish between safe and risky lenders, and potentially offer different lending terms to each. It would prevent adverse selection, as safe banks with a liquidity shortage would no longer be pooled with riskier banks and could instead pay a lower rate that reflects the reduced counterparty risk taken on by the lending bank. Therefore, improved transparency could also facilitate interbank lending and reduce early liquidations.

On the ex post side, the authors present three policy alternatives for situations when interbank market functioning has already been impaired. First, the central bank can directly provide liquidity to banks. This, they argue, can be profitable for all parties involved, since the central bank can raise liquidity at a unit cost by "printing money," in contrast to the private supply of liquidity that must compete with the returns offered by the illiquid asset. By supplying liquidity to banks in need, the central bank could crowd out the private supply of liquidity. Heider, Hoerova, and Holthausen argue that as a result, the central bank could offer to take on liquidity from the banks with excess liquidity. In this case, the central bank would act as an intermediary in the interbank market.

A second option is for the central bank to guarantee interbank loans. This would reduce or eliminate counterparty risk and make banks with excess liquidity more willing to lend in the interbank market. It would in turn reduce the interbank interest rate, which would increase borrowing and potentially reduce adverse selection in the interbank market. However, such guarantees are costly and must be designed optimally to minimize the overall costs to the guarantor.

The third option is asset purchases, in which the government directly purchases illiquid assets from banks. Since the government can afford to purchase the assets at their

expected value, this would prevent banks from having to sell at fire-sale prices, which occurs when the amount of illiquid assets being sold in order to convert them into liquidity exceeds the amount of liquidity available to purchase them. Such a measure would not increase interbank lending, and would in fact likely discourage it, but the measure would reduce the losses faced by banks that would otherwise have to sell assets at a price significantly below their expected value.

Antinolfi's discussion offered a number of avenues for further inquiry using Heider, Hoerova, and Holthausen's model. First, he examined the issue of the deposit arrangement within the model. The question was posed as to whether the deposit contract as specified is actually optimal, or if a better arrangement could be found. Antinolfi also considered the issue of deposit insurance. Whether deposit insurance is provided, how much is provided, and who pays for it could all have an important impact on outcomes in the model.

Next, Antinolfi considered the informational aspect of the model. The adverse selection in the model is entirely driven by private information held by banks about their assets that is not available to the public. Therefore, it is important to make sure that it is reasonable to assume that banks can in fact ascertain their own "type" while keeping it unknown to potential lenders.

Finally, the discussant suggested that the authors or future researchers look into the structure of the banking sector. The model assumes perfect competition, but it might yield different results under another arrangement, such as monopoly or oligopoly.

5. Session 4: Collateral and Haircuts

Papers:
"Rollover Risk and Market Freezes"
　　Viral V. Acharya, New York University
　　 and London Business School
　　Douglas Gale, New York University
　　Tanju Yorulmazer, Federal Reserve Bank of New York

　　Discussant:
　　Michael Manove, Boston University

"Central Bank Haircut Policy"
　　James Chapman, Bank of Canada
　　Jonathan Chiu, Bank of Canada
　　Miguel Molico, Bank of Canada

　　Discussant:
　　Mitchell Berlin, Federal Reserve Bank of Philadelphia

5.1 Overview

A conference session on collateral and haircuts featured two papers examining the theoretical underpinnings of the market for secured short-term debt.[2] Many financial institutions rely on overnight or short-term secured lending to meet their liquidity needs and finance longer maturity assets. The counterparty in these loans is often a central bank or market participant such as a bank, a money market mutual fund, or an institutional investor. Collateral used to secure these loans can vary from Treasury and agency debt securities to corporate bonds, equities, and bank loans. To protect the lender from changes in the collateral's value, an initial discount, or "haircut," is applied to the value of the asset that can be borrowed against, hereafter referred to as the asset's debt capacity. The optimal choice of haircuts for central banks is the topic of the paper by Chapman, Chiu, and Molico while Acharya, Gale, and Yorulmazer explore changes in an asset's debt capacity when the debt must be rolled over.[3]

In the interbank market, secured lending takes the form of repurchase agreements, or repos.[4] Repos typically have a maturity ranging from overnight to fourteen days. A central bank can provide intraday liquidity to financial institutions through repos and, as Chapman, Chiu, and Molico suggest, affect the supply of liquidity in the market through its choice of haircuts. The authors develop a general equilibrium formulation for the optimal level of haircuts in the presence of agent liquidity constraints, liquidity shocks, and asset price volatility. Their model stipulates that haircuts are higher when a central bank cannot exclusively lend to agents with liquidity constraints, and that a sudden, temporary increase in haircuts can be welfare-improving.

Acharya, Gale, and Yorulmazer attempt to explain how markets for collateralized lending can fail as a result of rollover risk, the risk that short-term debt cannot be rolled over and the sponsoring institution will have to sell the underlying asset in a fire sale. By constructing a regime-switching model for how investors perceive expectations on news, the authors demonstrate how an asset's debt capacity can decline without a change in its fundamental value and raise the issuing firm's counterparty credit risk. This adverse event is equivalent to an increase in haircuts and can help explain the market dislocation observed in the asset-backed commercial paper market during the subprime mortgage crisis beginning in 2007.

As the discussion following each presentation highlighted, the issues of liquidity and risk management arising from maturity mismatch and market shocks in secured lending are nontrivial. Short-term financing ex ante with loans secured by assets whose fundamental value is not resolved until ex post creates uncertainty over ultimate payoffs endogenous to default and counterparty credit risk. Since the debt capacity of an asset can change over time, it is important to understand what drives these changes and how to manage the risks from both the borrower's and the lender's perspective. The inability to sufficiently manage these risks can lead to depreciation of both liquid and illiquid assets, unforeseen liquidity constraints, and catastrophic market failure. The papers presented draw attention to important considerations for regulators with regard to participation and intervention in these markets.

5.2 Acharya, Gale, and Yorulmazer

Acharya, Gale, and Yorulmazer examine how changes in investor expectations in secured short-term lending markets can lead to market freezes. The authors focus on the market for asset-backed commercial paper, where debt must be rolled over several times before the underlying asset matures and its value is realized. They construct a regime-switching model for two possible states of the world, denoted as the "optimistic" and "pessimistic" states (defined later), and explore how the debt capacity of an asset changes as debt is rolled over in each state. The study concludes that the debt capacity of an asset is determined by the terminal state, where it tends to its fundamental value if the state of the world is optimistic and zero if the state of the world is pessimistic. This last result can explain how short-term debt markets can freeze regardless of the credit risk of the underlying asset.

The authors interpret their model in the context of a special investment vehicle that finances an asset-backed security by issuing short-term debt that must be rolled over a finite number of times before the asset matures. There exist two states of the world for investor expectations: an optimistic state where "no news is good news" and a pessimistic state where "no news is bad news," which can switch with a fixed probability each period. In the optimistic state, by backward induction, the debt capacity increases with each rollover to match the asset's fundamental value. In the pessimistic state, similarly, the debt capacity tends to zero and leads to a market

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[2] Secured lending differs from unsecured lending in that an asset with low credit risk is pledged by the borrower as collateral to be seized in the event of default. This form of lending allows an institution to borrow at more attractive interest rates with a debt ceiling not limited by its own credit risk.

[3] Since the maturity of short-term debt in commercial paper markets is often less than the maturity of the asset being financed, the debt must be reissued, or "rolled over," to new investors until the asset matures.

[4] In a repurchase agreement, the lender purchases the posted collateral at a discount and agrees to sell it back at a later date at a higher price that includes the interest on the loan.

freeze, wherein the sponsoring bank takes the asset back onto its balance sheet and sells it in a fire sale.

 Based upon these results, the authors propose an explicit formula for collateral haircuts by solving for the pledged asset's debt capacity. As the number of rollovers becomes unbounded in the pessimistic state, haircuts tend to reach 100 percent as long as the recovery rate on the asset is less than full recovery. One policy implication of these results is that firm failure from market freezes can potentially be avoided if regulators monitor firm capital structure for excessive reliance on short-term debt that entails rollover risk. Another implication is that regulators could help thaw market freezes by lending against the asset as collateral based on its value if held to maturity without risk of liquidation.

The ensuing discussion centered on the results of the model's pessimistic state. As Manove observed, one implication is that removing risk of default in one period will not prevent default in future periods once the asset's debt capacity is on the default trajectory. While the paper showed that mismatching maturities by financing long-term investments with short-term debt can lead to market failure, Manove noted that using long-term debt to finance long-term investments lacked the benefits described in the Diamond-Dybvig (1983) model. In addition, reducing rollover risk by financing with more unleveraged equity would be less profitable than debt financing.

Examining the policy implications of the paper, participants discussed whether regulators could reduce liquidation costs by swapping assets for more liquid instruments in addition to lending against them at their value if held to maturity. Regulators could also limit leverage by requiring firms to maintain a minimum level of equity financing. Drawing parallels with the Diamond-Dybvig model, Manove also compared the market freezes described in the paper with bank runs. When one views short-term lenders as depositors and long-term assets as bank loans, a situation such as a market freeze in secured lending markets can be seen as analogous to a bank run. Consequently, if creating deposit insurance through the Federal Deposit Insurance Corporation (FDIC) helped prevent bank runs, establishing similar insurance in the secured lending markets could perhaps prevent market freezes.

5.3 Chapman, Chiu, and Molico

Chapman, Chiu, and Molico examine the optimal central bank haircut policy for the Canadian Large-Value Payment System. The authors develop a discrete-time three-market model for an illiquid and a liquid asset with anonymous agents that face portfolio allocation uncertainty. They find that central bank liquidity facilities provide insurance against both liquidity and downside asset risk, and that setting a haircut involves a trade-off between satisfying agent liquidity constraints and depreciation of the liquid asset. This depreciation can lead to portfolio distortions and increased probability of default on collateralized loans.

In the first subperiod of each period of the model, agents choose portfolios of the two assets in an asset market based on a signal as to whether they will be buyers or sellers in the second subperiod. In the second subperiod, agents reform portfolios based on the realization of their type in a decentralized market. This reformation can lead to liquidity constraints that agents satisfy with collateralized loans from the central bank. In the third subperiod, the illiquid asset's value is resolved and agents choose whether or not to settle their loans or default in a centralized market. The optimal choice for central bank haircuts on collateralized loans minimizes the incidence of default while providing financing to constrained agents.

The results of this model suggest that haircuts are higher when a central bank cannot identify which agents actually need liquidity. In addition, a relationship is established between collateral haircuts and the nominal interest rate, which is affected by the injection of the liquid asset into the market through collateralized loans. As haircuts are lowered, defaults create inflationary pressure by making this injection permanent. Lowering haircuts relative to the interest rate also erodes the liquid asset's value by making the illiquid asset less costly to hold.

Chapman, Chiu, and Molico's paper elicited discussion about the topic's relevance in the context of recent changes in central bank collateral policies brought on by the crisis. This included the expansion of the Federal Reserve's range of lending facilities and the European Central Bank's concern about accepting too wide a range of collateral. Berlin, leading the discussion, emphasized providing more empirical interpretation of the paper's assumptions and conclusion. He stipulated methods for measuring the relevant quantities in determining haircuts and reconsidering the assumption of endogenous default probability that can lead to strategic default.

From a policy perspective, participants discussed methods for refining collateral policies in light of the results of the paper. Berlin, for instance, suggested that discriminating between potential borrowers based on measures of liquidity or balance-sheet signals could potentially lead to a better outcome by effectively providing liquidity to constrained agents. He also introduced the possibility of charging higher borrowing rates to banks with more illiquid balance sheets and making loan payments contingent on investment returns to mitigate the impact of the liquidity injected into the system when defaulted assets are sold. Participants highlighted the paper's practical

implications in quantifying the impact of market forces driving haircut policy calibration.

6. Session 5: Empirical Evaluation of Central Bank Liquidity Programs—Part 1

PAPERS:
"Do Central Bank Liquidity Facilities Affect Interbank Lending Rates?"
Jens H. E. Christensen, Federal Reserve Bank of San Francisco
Jose A. Lopez, Federal Reserve Bank of San Francisco
Glenn D. Rudebusch, Federal Reserve Bank of San Francisco

DISCUSSANT:
Pierre Collin-Dufresne, Columbia University

"Repo Market Effects of the Term Securities Lending Facility"
Michael Fleming, Federal Reserve Bank of New York
Warren Hrung, Federal Reserve Bank of New York
Frank Keane, Federal Reserve Bank of New York

DISCUSSANT:
Lasse H. Pedersen, New York University

6.1 Christensen, Lopez, and Rudebusch

Lopez, presenting on behalf of coauthors Christensen and Rudebusch, examines the effects of central bank liquidity operations on interbank lending rates using an arbitrage-free term structure model that controls for fluctuations in the U.S. Treasury yield curve and the term structure of risk in financial corporate bond yields. The paper concludes that central bank liquidity operations at the close of 2007 helped to lower term interbank lending rates.

Motivating this paper were the large fluctuations in spreads of the three-month Libor (London interbank offered rate) over Treasury yields in mid-December 2007, when the Federal Reserve introduced two major liquidity operations: reciprocal swap lines with the European Central Bank and the Swiss National Bank, and the Term Auction Facility (TAF) program, whereby the Federal Reserve auctions collateralized loans to banks facing liquidity constraints. The goal of the Christensen, Lopez, and Rudebusch paper was to determine if these central bank policy actions helped increase bank liquidity, reduce liquidity risk premiums, and thus lower Libor rates.

Fluctuations in the spread of the three-month Libor over Treasuries are commonly attributed to movements in credit and liquidity risk premiums. The authors account for credit risk premiums by using the entire Treasury curve to control for risk-free rates and the term structure of financial corporate debt to control for credit risk premiums. In practice, Treasury bonds are considered free from credit risk and the most liquid debt instrument available. The key assumption for the latter is that Libor rates have credit risk characteristics similar to senior, unsecured AA-rated debt issued by U.S. financial firms. Controlling for credit risk allows the authors to isolate movements attributable to liquidity risk premia in interbank lending rates.

The authors use a six-factor affine arbitrage-free joint model of Treasury yields, financial bond yields, and Libor rates. The Treasury yield curve accounts for three factors: the level, slope, and curvature. Since movements in Treasury, bank bond, and Libor rates all share common elements, two of the remaining factors account for differences between bank debt yields and Treasuries (levels, slope). The last factor captures the idiosyncratic nature of term Libor rates, which the authors assume is independent of the other five factors.

The model specification draws on four major assumptions. The first is that the Libor-specific factor is independent of the other factors. The second is that the Treasury level factor is independent and has no dynamic interaction with the two credit spread risk factors. The third assumption allows the Treasury level and curvature factors to individually affect the Treasury slope factor, but not each other. The fourth posits that there is no feedback from the credit risk level factor to the Treasury curvature factor or from the credit risk slope factor to the Treasury slope factor. The likelihood ratio test on the specification with the independent Libor factor results in a failure to reject the null hypothesis that these additional zero restrictions are reasonable.

The paper presents three major results from the preferred model specification. First, the persistence of shocks was generally quite high, although much less for the Libor-specific factor. Second, the effects of Treasury factors on credit risk factors seem limited. Third, credit risk factors do have an influence on Treasury slope and curvature factors.

The presentation focuses on results that had implications for the interbank market. The estimated Libor-specific factor had been relatively stable around its historical mean in the pre-crisis period, but dropped more than two standard deviations below its mean after the first TAF auction on December 17, 2007. To test the hypothesis that this drop represented a structural break in the Libor factor, the authors use the Kalman filter and impose different parameters in the pre and post periods, at December 21, 2007. The likelihood ratio test rejects

the null hypothesis that no break occurred. The authors find that the data support the conclusion that central bank liquidity operations had an effect on the Libor-specific factor after the first TAF auction had taken place.

Lastly, the authors consider the counterfactual situation—what if the central bank effects on the Libor-specific factor were "turned off"?—to determine the magnitude of the effect of central bank liquidity operations. They generate a counterfactual Libor path by setting the Libor-specific factor constant at its mean after December 21, 2007. The average difference between the observed and counterfactual three-month Libor spread to Treasuries in the post-crisis period is more than 70 basis points. This provides additional evidence suggesting that central bank liquidity operations lowered interbank lending rates.

In conclusion, the authors find that the results from their six-factor model demonstrated that the TAF auctions significantly affected the dynamics of the interbank market via the structural break in the behavior of the model-implied Libor factor, and that these operations kept the Libor rate roughly 70 basis points lower than it could have been in their absence.

Discussant Collin-Dufresne questioned the assumptions and methodology of the paper. He wondered what was driving the difference between Libor and AA-rated bank yields and how various possible explanations would influence interpretation of the results.

Collin-Dufresne also questioned whether an affine model was well suited for a regime shift since affine models tend to need a lot of data. Given that much of the activity was found in the second half of the sample, he wondered if the model would have picked up a structural break at any point in the second half, and how intrinsically significant the post-TAF date was compared with other dates in the post-crisis period (that is, if causality could be established between the TAF and the regime shift). In addition, he conjectured a regime shift in the underlying Treasury rates, implying that the graph of the agency-Treasury spread may represent anticipation in the market.

6.2 Fleming, Hrung, and Keane

Fleming presented on behalf of coauthors Hrung and Keane. The presentation focused on the effects of the Term Securities Lending Facility (TSLF), introduced by the Federal Reserve in March 2008 to improve liquidity in the financing markets for Treasury and other collateral. In particular, the paper examines the supply effects of the program on rates and spreads in the repurchase agreement (repo) market. The authors find that the TSLF led to a significant narrowing of spreads between Treasury (higher quality) collateral and lower quality collateral.

The Federal Reserve introduced the TSLF in the midst of turbulent financial markets to help promote the liquidity of secured funding markets. The program auctions loans of Treasury securities to primary dealers for a period of twenty-eight days in exchange for lower quality collateral that, owing to stressed market conditions, would otherwise be difficult or unattractive to finance. The TSLF thereby increases the ability of dealers to obtain financing, especially dealers relying on the repo market for financing of less liquid collateral.

In addition to improving dealers' financing capacity, the TSLF can potentially affect rates in the repo market by altering collateral supplies. By allowing dealers to swap lower quality collateral for Treasury securities, the TSLF increases the supply of Treasury collateral in the market and decreases the supply of lower quality collateral. The additional Treasury collateral available to the market is hypothesized to put upward pressure on Treasury general collateral repo rates while the reduction in lower quality collateral is hypothesized to put downward pressure on repo rates for such collateral.

The data examined by the authors cover all thirty-seven TSLF operations from March 27, 2008, to October 30, 2008. The authors also use repo rates for Treasury securities, agency debt securities, and agency mortgage-backed securities (MBS) from the Federal Reserve Bank of New York's Trading Desk and Bloomberg. Additional data employed include Treasury issuances/redemptions and corporate yield spreads.

Fleming, Hrung, and Keane regress changes in overnight repo rates and spreads on changes in the amount outstanding under the TSLF. They focus on settlement days because TSLF-induced changes in the supply of securities should affect overnight repo rates on those days. The dependent variable, changes in the amount outstanding under the TSLF, is calculated as the amount awarded in the operation settling that day less the amount maturing that day. Dummy variables are also included for the last and first days of the quarter, on which repo spreads typically widen and narrow, respectively.

The authors find that the TSLF does in fact narrow financing spreads between Treasury collateral and lower quality collateral. Further, the observed narrowing is driven by an increase in Treasury repo rates as opposed to a decrease in rates on lower quality collateral. Financing spreads also widen and narrow on the last and first days of the quarter, as expected.

Additional results show that the effects of the TSLF are driven by "Schedule 2" operations, in which dealers can pledge a wide range of collateral, as opposed to "Schedule 1" operations, in which eligible collateral is limited to Treasury securities, agency debt securities, and agency MBS. The results suggest that that agency debt and agency MBS collateral may be considered substitutes for Treasury collateral to a large degree,

whereas the lower quality collateral that can be pledged in Schedule 2 operations is not.

A final set of results shows that the effects of the TSLF on repo rates and spreads increase with the spread between the fed funds rate and the Treasury general collateral repo rate. That is, changes in the amount of collateral made available to the market have more of an effect when the Treasury repo rate is far below the fed funds rate rather than when it is close to the rate.

Pedersen's discussion highlighted the statistical significance of Schedule 2 collateral and the statistical insignificance of Schedule 1 collateral, which led him to posit that agency and agency MBS behave more like Treasuries than the other lower quality collateral in Schedule 2.

Pedersen maintained that repo spreads are generally mean reverting, and thus controls are necessary for the level of repos and repo spreads. He also questioned whether the quantity of Treasury securities provided by the TSLF is endogenous to the repo rates and spreads: Do high repo spreads lead to a large TSLF amount? Is the large reduction in repo spreads due to general mean reversion or to the TSLF auction? Fleming responded that he and his coauthors consider their results robust.

Lastly, Pedersen addressed what he thought was the big question: Does the TSLF help solve the banks' funding problems and break liquidity spirals? He questioned whether the results of increased repo rates under the TSLF alleviated liquidity problems.

The question-and-answer session centered on Pedersen's "big question" of whether the TSLF effectively achieved its program goals. One participant asked whether the Federal Reserve can effectively work only with primary dealers and banks to reduce haircuts in the repo market, or whether it should consider dealing with investors. Other participants observed that the TSLF is about switching good and bad collateral, as opposed to reducing haircuts, and urged that the intent of the program be kept in mind. Pedersen, by contrast, argued that the program is directly about reducing haircuts, and that the question is whether or not the Federal Reserve has been successful in doing that.

7. Session 6: Empirical Evaluation of Central Bank Liquidity Programs—Part 2

Papers:
"Funding Liquidity Risk: Definition and Measurement"
  Mathias Drehmann, Bank for International Settlements
  Kleopatra Nikolaou, European Central Bank

Discussant:
Marie Hoerova, European Central Bank

"Provision of Liquidity through the Primary Credit Facility during the Financial Crisis: A Structural Analysis"
  Erhan Artuç, Koc University
  Selva Demiralp, Koc University

Discussant:
Carolyn Wilkins, Bank of Canada

7.1 Drehmann and Nikolaou

Throughout the current crisis, central banks have introduced facilities aimed at addressing liquidity shortages in financial markets. Despite liquidity's centrality to the crisis policy response, however, a debate continues on the term's precise definition. Drehmann, presenting on behalf of coauthor Nikolaou, set out to define one aspect of liquidity: funding liquidity risk. His presentation focused on providing and testing a definition of funding liquidity risk that could be constructed from public information by central banks.

Drehmann and Nikolaou define funding liquidity as the "ability to satisfy demand for money with immediacy." Consequently, funding liquidity risk reflects the potential inability of a bank to meet money demand over some future period. With this definition in hand, they laid out the theory and construction of a publicly available proxy for funding liquidity risk based on information available from open market operations in the euro area. The measure is based on the theory that, in turbulent times (that is, in the presence of market frictions potentially resulting from asymmetric information, incomplete markets, and issues of market power), a bank with a greater need for liquidity will bid more aggressively for liquidity at the central bank auctions. By looking at the spread between a bank's average bid rate and the policy rate weighted by the volume in a price-discriminating auction, the authors argue that central bankers can easily construct a measure of liquidity risk for each bank or for the system as a whole.

To test their measure of funding liquidity risk, Drehmann and Nikolaou exploit the theoretical relationship between market liquidity and funding liquidity. Some financial theory shows that as funding liquidity risk rises and market frictions become important, downward spirals of funding and market liquidity can occur. Using an average of liquidity proxies for market liquidity in various markets as a proxy for overall market liquidity, Drehmann and Nikolaou demonstrate that their measure of funding liquidity risk does have the negative relationship with market liquidity suggested by theory.

Hoerova's comments on Drehmann and Nikolaou's measure focused on data issues and alternative theoretical considerations. Hoerova pointed out that the measure

proposed by Drehmann and Nikolaou suffers from a number of potential biases, including selection issues and problems related to construction. Selection bias could occur because the choice by banks to participate in the auctions is nonrandom and likely influenced by liquidity conditions. Furthermore, by summing across the value-weighted spread for all banks, the proposed measure could overstate the influence of outliers. The theoretical concerns focused on factors driving bank bidding behavior. A bank could potentially increase its bid rate for a number of reasons unrelated to liquidity risk, such as risk aversion, differences in the personal value of collateral, and the need for "window dressing" around important regulatory dates. Finally, Hoerova suggested that the authors look at alternative measures of market liquidity when documenting their downward liquidity spirals.

7.2 Artuç and Demiralp

Alongside the need for new data to evaluate central bank facilities, another critical issue is the construction of counterfactuals. What would the world have looked like in the absence of certain policies or if the credit crisis had manifested itself in alternative ways? The Federal Reserve made a number of changes to the discount window during the crisis, including reductions in the penalty rate and an increase in borrowing terms. Artuç and Demiralp use model-based counterfactual estimation to examine the impact of these policy changes.

From the data, it is clear that banks responded to the discount window changes by increasing their borrowing substantially, but it is also clear that some cost or stigma was still associated with discount window borrowing because many banks were seeking funds in the interbank market at rates above the discount rate. These trends lead one to wonder how effective the policy changes were in reducing market stress during the credit crisis. Using a structural model of the fed funds market based on each bank's desire to hold certain daily and maintenance-period–wide levels of reserves, Artuç and Demiralp estimate the impact of aggregate shocks to, and changes in, borrowing terms at the discount window. They compare these estimates with simulations in which the cost of borrowing remained unchanged during the crisis period.

Based on the difference between these two models, Artuç and Demiralp find that the Federal Reserve's changes to the discount window were generally, though not universally, effective. Namely, the most effective policy changes were the lengthening of the term of discount window loans and the addition of new eligible collateral. Less effective were the

reductions in the spread between the target fed funds rate and the primary credit rate.

In her discussion, Wilkins pointed out three potential shortcomings of this approach to assessing the Federal Reserve policy changes. First, although the structural model helps clarify assumptions and allows for the construction of a counterfactual, some changes remained potentially conflated. In particular, the implicit cost of borrowing from the discount window could come from many sources aside from the stigma cited by Artuç and Demiralp, and certain assumptions such as the static nature of the model might not hold in reality. Second, Wilkins questioned the estimation used to calibrate the model. From the charts presented by Artuç and Demiralp, it appears that some discrepancies exist between the in-sample estimation and the observed data. Also, alternative estimation strategies were not compared with the one used by the authors. Third, Wilkins wondered if other changes were occurring aside from a simple doubling of aggregate shocks that should be included in a model of the crisis period. Most notably, collateral costs were likely changing over the period and other Federal Reserve programs, such as the Term Auction Facility, were introduced to offer additional nonmarket funds to banks. Overall, however, Wilkins emphasized the importance of the policy questions raised by Artuç and Demiralp.

8. Panel Discussion

Chair:
    Patricia C. Mosser, Federal Reserve Bank of New York

Panelists:
    Louis Crandall, Wrightson ICAP
    Andrew W. Lo, Massachusetts Institute of Technology
    Paul Mercier, European Central Bank
    Lasse H. Pedersen, New York University
    W. Alexander Roever, J.P. Morgan Chase

The final event of the conference brought together participants from the private sector, academia, and central banking to discuss the crisis and the policy response. Mosser, moderating the panel, gave participants the freedom to choose topics of interest, but she began the session by posing the overarching question: What are the key policy lessons learned from the crisis so far?

The panelists represented a broad cross section of perspectives on the financial world: Louis Crandall, chief economist at broker Wrightson ICAP; Andrew W. Lo, a professor at MIT's Sloan School of Business; Paul Mercier,

deputy director general of market operations at the European Central Bank; Lasse H. Pedersen, a professor at NYU's Stern School of Business; and W. Alexander Roever, a debt strategist at J.P. Morgan Chase's short-term fixed-income sales and trading desk. Each panelist gave a presentation with his perspective on Mosser's initial question; the panel then opened itself to questions from the audience.

As a fixed-income strategist, Roever focused on the contribution of short-term debt markets to the crisis. He first demonstrated the massive growth in debt markets over the years leading up to the crisis, showing that the U.S. bond and money markets grew 2.5 times faster than GDP from 1998 to 2007. However, Roever said that the figures on money markets do not include debt issued at floating rates indexed to the Libor, which are a close substitute for money market funding, with many of the same characteristics. This development involved not only an increase in leverage on the part of financial firms issuing the debt, but also an increased reliance on a small set of firms, which Roever termed "liquidity investors," encompassing money market funds and other short-term investors with low risk appetites. Within this particular class of investors, Roever showed, assets are heavily concentrated in a very small number of the largest firms. Thus, the risk associated with high levels of leverage was magnified by borrowers' reliance on a narrow group of firms for funding. The crisis thus far has destroyed a large amount of these firms' assets under management, with Roever estimating the overall figure at $2 trillion. This decrease in wealth meant a sudden drop in the amount of money available to fund other financial firms through money markets, asset-backed securities, and other short-term debt, exacerbating the other problems of the crisis. Roever's primary conclusion from this narrative was that the scope of financial regulation has been too narrow, and should be expanded beyond banks to encompass a larger number of participants in the financial system.

Pedersen, whose research focuses on liquidity risk, spoke on the issue of systemic risk, and what central banks and other regulators could do to address it. He began by arguing that the recent crisis, for all its severity, was not a new kind of crisis—that the issues of market liquidity and funding liquidity that came to the fore during the last several months have always been important for financial stability. The key issue, he said, was the systemic component of risk, which he defined as "the joint failure of a significant part of the financial institutions." Among the drivers of this risk were liquidity spirals—the way declines in asset prices can increase the need of financial institutions for liquidity, causing massive simultaneous sales and further drops in asset prices. To highlight the difference between systemic and idiosyncratic risk, Pedersen contrasted the 2008 failure of Lehman Brothers, with all its systemic

consequences, with the 1995 failure of the London merchant bank Barings, which was a large institution, but which had relatively minor systemic consequences. The response of regulators, said Pedersen, should be to model and regulate systemic risk explicitly, treating it as a negative externality like pollution. He suggested that regulators run simulations of 1 percent systemic tail risk scenarios, gauging institutions' contributions to losses. Guided by these assessments, regulators should then impose a systemic capital requirement, systemic risk fees after the model of the FDIC, and required loss insurance policies that would be provided by a combination of the government and the private sector. This set of policies, Pedersen argued, would introduce incentives to limit systemic risk and reduce the cost and disruption of bailouts when they become necessary.

Mercier, whose position at the ECB affords him firsthand knowledge of the central bank's transactions with banks, commented primarily on the structure through which the ECB, and central banks in general, inject liquidity into the financial system. Mercier considered a precise concept of liquidity, defined simply as central bank credit. Under "normal" financial conditions, he said, the central bank relies on a small group of large and influential banks to further distribute central bank credit to the rest of the system. In the euro area, this group of banks is much larger than the Federal Reserve's set of primary dealers. With banks hoarding liquidity and the subsequent seizing up of interbank markets, however, Mercier noted that this standard practice started to lose its effectiveness, causing the ECB to lose some control over short-term interest rates. This led the ECB to implement a second regime, in which it made no net change to liquidity over its maintenance periods, but rather frontloaded its injections of liquidity to provide banks and, by extension, their counterparties with more certainty. As the crisis intensified after the collapse of Lehman Brothers, however, the ECB implemented a third regime, marked by fixed-rate tenders of unlimited quantity, which did in fact create a gross increase in liquidity in the system. In net terms, however, there was no increase in liquidity because net demand remained unchanged (except for the increase in banknotes in circulation). While some banks were borrowing more from the Eurosystem, others were increasing their deposits. Both sides of the balance sheet of the Eurosystem increased, leading to a wider exposure toward the banking system. In essence, the Eurosystem became a major intermediary between banks that were reluctant to lend to each other.

While this third regime has apparently been effective in providing financial institutions with needed liquidity, observed Mercier, it has come at the cost of reduced central bank influence over money market lending rates. Mercier pointed to two further lessons from the crisis: first, market psychology

plays a significant role and policymakers need to take it into account, and second, while it is important to consider what central banks' "exit policy" from the crisis should be, it is equally important to consider what a new stable equilibrium would look like—as he put it, "an exit to what?"

Lo based his presentation on the premise that financial crises are unavoidable because of two factors: first, fear and greed are natural parts of human behavior, and second, the economy is and should continue to be based on free markets. As a result of these unavoidable factors, policy efforts should focus on developing early warning systems for impending financial crises and developing measures to address them when they do occur. Much of Lo's recent work has focused on the role of hedge funds in the economy, and he noted that they, along with proprietary trading desks at other financial institutions, generally exhibit early warning signs of impending crises, and that regulators should look to glean information from their activities in the markets. On the question of what new measures regulators should develop to handle financial crises when they do occur, Lo emphasized the necessity of creating a different kind of regulation, rather than just more regulation. After all, he noted, banking and insurance are two of the most highly regulated sectors of the U.S. economy, yet they still played major roles in the recent financial crisis. A major problem with existing regulation, said Lo, is that the main language used for regulation is the language of accounting, which is not well-suited for talking about risk. Accounting, he argued, is fundamentally focused on backward-looking realizations, while financial regulation needs to be focused on risk, which is a fundamentally forward-looking concept.

Crandall, the final presenter, mainly addressed the issue of the currency composition of liquidity. He showed a graph demonstrating the enormous increase in U.S. dollar funds sent from U.S. branches of foreign banks to their home offices over the course of the crisis, as it became more and more difficult for the home offices to obtain U.S. dollar funding in the interbank market. He then showed how this large increase was significantly mitigated by the removal of size limitations on the Federal Reserve's reciprocal currency arrangements with four major foreign central banks, which provide a nonmarket channel through which foreign financial institutions can access U.S. dollar funding. The lesson from this example, according to Crandall, is that the currency composition of a bank's liquidity profile matters. He argued in favor of making the reciprocal currency arrangements permanent, saying that the fixed-rate unlimited-quantity auctions conducted by foreign central banks using the reciprocal currency arrangements had represented a crucial psychological change in financial markets, essentially giving every bank in the world access to a

"discount window" denominated in U.S. dollars. Second, Crandall identified one significant limitation facing policymakers: central banks only have the power to incentivize banks, rather than bankers themselves. He pointed out that within banks, profits are socialized (to the bank as a whole), whereas losses are privatized (putting the individual's job at risk). This makes bankers very risk-averse in the sense of being unwilling to learn about new things if they are not directly profitable. Crandall noted that liquidity facilities become more effective as market participants learn more, but that bankers are not paid to learn about these facilities. This poses a special challenge in short-term markets, where less attention may be paid to in-depth research and learning.

A short question-and-answer session concluded the conference. One topic of further discussion was the "exit strategy" that Mercier had brought up in his comments. The participants talked about how long the Federal Reserve and other central banks should wait before revoking current liquidity facilities, many of which are legally allowed to continue only as long as "unusual and exigent circumstances" persist. There was broad agreement that the facilities should remain in place for some time, even after circumstances appear to have stabilized. The panelists noted that many of the facilities are "self-liquidating" because they lend freely but at penalty rates, meaning that market participants will stop turning to them as conditions normalize. Crandall argued specifically that the facilities should remain in place through the period when the Federal Reserve begins to raise rates again. This would do much to instill confidence and remove uncertainty associated with monetary tightening.

The participants also went on to discuss the topic of "greed and fear" that Lo had raised, especially the extent to which such irrational motivations could play a role in creating financial crises. Pedersen suggested that the key shortcoming of the neoclassical model, which posits that irrational agents cannot move markets away from equilibrium as long as there are a small number of rational traders participating, is that agents have funding liquidity constraints. As evidence that funding constraints have recently been binding, he pointed out that covered interest rate parity has been failing for the major currencies because of limited availability of capital and limited willingness to lend, consistent with the idea that liquidity spirals are important drivers of the crisis. Lo cited Keynes' comment that "the market can stay irrational longer than you can stay solvent." More specifically, he pointed out that the neoclassical model requires the posited rational arbitrageurs to have infinite liquidity, which is a particularly unrealistic assumption during financial crises.

References

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