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# Three Liquidity Crises in Retrospective: Implications for Central Banking Today

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## Abstract

Liquidity problems lie at the heart of crises on financial markets as demonstrated in this paper by detailed descriptions of the stock market crash in 1987, the LTCM-crisis in 1998 and the financial market consequences of 11 September 2001. The events also demonstrate that modern central banks, in particular the U.S. Federal Reserve under Alan Greenspan, provided emergency liquidity to limit the negative effects of such crises. However, the anecdotal and empirical evidence from the three crises shows that such emergency liquidity assistance implies risks to goods price stability if it is not focused on the interbank market and quickly sterilised.

*Keywords:* Liquidity Crises, Financial Stability, Monetary Policy.

*JEL classification:* E58, E44, G10.

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# 1 Introduction

Crises have been a recurring element of the modern financial system.<sup>1</sup> Liquidity problems lie at the heart of many of these crises on financial markets because market participants may not be able to sell their assets as quickly and costlessly as in more ordinary times.

This review looks at three major crises on financial markets in the United States during the chairmanship of Alan Greenspan at the Federal Reserve (Fed) from 1987 to 2006. The focus is twofold: First, I consider the role of liquidity as the (non-)ability to sell assets in the course of the stock market crash in 1987, the LTCM-crisis in 1998 and the aftermath of the terrorist attacks on 11 September 2001. This represents the microeconomic perspective of liquidity as discussed in the finance literature. Second, I examine the emergency liquidity provision by central banks, in particular by the Fed, in response to these crises. In this case, liquidity refers to a generally accepted medium of exchange or, in brief, money, which represents the macroeconomic perspective of liquidity. Since money does not need to be converted into anything else in order to make purchases of real goods or other assets, it is the most liquid asset and valuable in both perspectives.

The following section provides detailed descriptions of the events during each crisis. Section 3 compares the reaction of the Federal Reserve under Greenspan in response to the different crises and its implications for goods price stability. After a brief description of the model in Sauer (2007) that captures the relevant trade-offs of central bank interventions during liquidity crises, section 5 provides lessons from these liquidity crises for central banking in the modern market based financial system and concludes.

## 2 Chronologies of the crises

There is a lot of empirical evidence for the role of liquidity in asset pricing.<sup>2</sup> In particular, Chordia, Sarkar and Subrahmanyam (2005) establish an empirical link between the macro- and the micro-perspective of liquidity. The authors find that ‘money flows (...) account for part of the commonality in stock and bond market liquidity.’ Furthermore, they use vector autoregressions to provide evidence that a loose monetary policy, measured as a decrease in net borrowed reserves or a negative interest rate surprise,<sup>3</sup> is associated with lower

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<sup>1</sup>See e.g. Kindleberger (1978) for a number of historic financial crises.

<sup>2</sup>See, e.g., Amihud and Mendelson (1986), Pastor and Stambaugh (2003), Acharya and Pedersen (2005) and the discussion of these papers in Sauer (2007).

<sup>3</sup>Net borrowed reserves represent the difference between the amount of reserves banks need to have to satisfy their reserve requirements and the amount which the Fed is willing to supply. A negative interest rate surprise is defined as a drop of the federal funds target rate below market expectations (Chordia et al., 2005, pp. 112-113).

bid-ask spreads, i.e. increased liquidity, in times of crises.

Besides such empirical studies, there is also a lot of anecdotal evidence how central banks reacted to liquidity crises since the last decades have shown a number of such crises on financial markets. For example, Davis (1994) describes five severe liquidity crises in international markets: The Penn Central Bankruptcy in 1970, the crisis in the floating-rate notes market in the UK in 1986, the failure of the US-High Yield bond market in 1989, the Swedish Commercial Paper crisis in 1990 and the collapse of the ECU bond market in 1992. Greenspan (2004) highlights three crises during his chairmanship at the Federal Reserve (Fed), in which market participants wanted to convert illiquid medium to long-term assets into cash because they favoured safety and liquidity over uncertainty: The stock market crash in 1987, the LTCM-crisis 1998 and the terrorist attacks of 11 September 2001. This section provides a brief review of these three events and the central banks', in particular the Fed's, reactions to them.

## **2.1 Stock market crash in October 1987**

### **2.1.1 Black Monday 1987**

On 19 October 1987 ('Black Monday'), the Dow Jones Index dropped by 22.6%. The summer 1988 issue of the *Journal of Economic Perspectives* provides a nice symposium of the events in October 1987. Many commentators blamed institutional investors that followed a portfolio insurance investment strategy for the dramatic crash in prices. Similar to stop-loss-orders, portfolio insurance implies automatic sell orders when the value of a portfolio or single shares falls below a certain threshold. If the absorption capacity of the market is limited, portfolio insurance can cause a vicious circle of price falls and further sell orders. For example, Gammill and Marsh (1988) report official statistics that show that institutional investors who followed a portfolio insurance investment strategy were the heaviest net sellers on the New York Stock Exchange and in the S&P 500 index futures market.

Furthermore, a number of traders such as arbitrageurs who traded in shares involved in takeovers or recapitalisations faced margin calls that forced them to sell shares into the falling market (Laderman, 1987, p. 28). Neely (2004, p. 32) reports enormous problems for brokerage houses and market makers as they had accumulated unusually large inventories and banks were reluctant to provide them with further credit. Garcia (1989) notes that futures, options and stock markets differed in the timing of settlement obligations, which created additional liquidity problems for investors trading off-setting positions across markets.

Grossman and Miller (1988) describe the events on 19 and 20 October against

the background of their model in which market liquidity is determined by the demand and supply of 'immediacy', i.e. the willingness to trade immediately rather than to wait some time for a possibly better price. They argue that order imbalances were so great<sup>4</sup> that market makers became incapable of supplying further immediacy. Market illiquidity materialised as delays in the execution and confirmation of trades and as the virtual impossibility of executing market sell orders at the quoted prices at the time of order entry.

### **2.1.2 The Fed's response**

As chairman of the Fed, Alan Greenspan managed to improve the confidence of investors and the liquidity of the market by issuing the following statement at 9 am on 20 October 1987:<sup>5</sup>

The Federal Reserve, consistent with its responsibilities as the Nation's central bank, affirmed today its readiness to serve as a source of liquidity to support the economic and financial system (Greenspan, 1987).

The Dow Jones regained 5.9% and 10.1% on this and the following day, respectively. Garcia (1989) discusses the different tools the Fed used to limit the extent of the stock market crash. These included, besides communication via the quoted statement, mainly open market operations and the use of the discount window to provide liquidity in the form of additional money to the market as well as the 'persuasion' (Bernanke, 1990, p. 148) of banks to lend freely to their customers at Wall Street. The handling of the crisis by Alan Greenspan, who had been appointed as Fed Chairman only two months earlier, laid the foundations for the belief in an insurance against stock market losses, termed 'Greenspan put' in the popular press. Taylor (2005) refers to this approach as Greenspan's 'liquidity provision principle'.

## **2.2 LTCM crisis in 1998**

### **2.2.1 Summary**

In September 1998, the near-collapse of the hedge fund Long-term Capital Management (LTCM) caused severe turmoil on financial markets.<sup>6</sup> After years of extraordinary performance, LTCM experienced below-average returns in 1997 and even losses in the first half of 1998. In response, LTCM increased its lever-

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<sup>4</sup>After a more than 10% decline of the Dow Jones between Wednesday, 14 October, and Friday, 16 October, Gammill and Marsh (1988) note an 'overhang of incomplete portfolio selling' by portfolio insurers which caused additional selling pressure on the morning of Black Monday.

<sup>5</sup>Note that the Fed did not intervene on 19 October when the market crashed.

<sup>6</sup>For a more detailed analysis of the LTCM-crisis, see e.g. IMF (1998), Jorion (2000) or Sauer (2002).

age, i.e. its debt/equity ratio, and focused even more on investments in relatively illiquid assets. The Russian default in August 1998 caused a flight to quality into liquid government bonds, while the prices of more illiquid assets fell dramatically. Margin calls forced LTCM to sell its assets into the falling market, which exacerbated the crisis. Other market participants could not (and some did not want to, see Brunnermeier and Pedersen, 2005) step in and buy assets, not least because they had copied LTCM's trading strategies and were constrained in their available funds. LTCM's supposedly sophisticated risk management system had not taken this endogeneity of risk sufficiently into account and its imminent collapse threatened the functioning of the Treasury bond market because of LTCM's large short-positions on this market.

On 23 September, the New York Fed organised a private bailout of LTCM by 14 banks that had lent to the fund. In the following weeks, the Fed lowered its policy rate three times by 25 basis points in order to provide sufficient liquidity to financial markets. Both Greenspan (2004) and Meyer (2004), who was on the Fed's Board of Governors at that time, admit that the purpose of these rate cuts was to calm financial markets rather than to stimulate the still expanding real economy. Indeed, the second cut boosted financial markets<sup>7</sup> and, for example, considerably lowered spreads on repos, swaps, corporate bonds and off-the-run treasuries, which all had increased dramatically after the Russian default (IMF, 1998, p. 39). Nevertheless, the Fed still feared the downside risks and lowered its policy rate a third time on 17 November despite lingering positive GDP data. Given the subsequent rise in inflation and equity prices until 2000, Meyer (2004, p. 121) later regretted this last cut.

### 2.2.2 Buildup of the crisis

LTCM's strategy for 1998 rested mainly on a narrowing of spreads between risky bonds and safe government bonds of western industrialised countries. These spreads had widened in the course of the Asian crisis in 1997. Figure 1 shows that LTCM failed to achieve its expected annual returns of 25%<sup>8</sup> already in the first months of 1998. Major losses of about 700 million U.S. \$ followed in May and June as a consequence of turbulences on the market for mortgage-backed securities (MBS). In order to balance these losses, LTCM sold liquid and therefore low-yielding assets instead of dissolving illiquid positions or raising new capital. Jorion (2000, p. 288) and LTCM itself in Kolman (1999) identify this decision as a 'major' and 'critical mistake', respectively, because it made the fund even more vulnerable to margin calls on loss-generating derivative activities. In July followed the closure of Meriwether's and his colleagues' for-

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<sup>7</sup>The cut was implemented between two scheduled meetings of the Federal Open Market Committee on 15 October 1998, a very rare step by the Fed under Alan Greenspan.

<sup>8</sup>See Kolman (1999) for this number.

mer place of work, Salomon's arbitrage trading desk in New York, due to the merger of Salomon Brothers and Travelers Group. Since this group had followed strategies similar to LTCM, the rapid liquidation of its positions caused losses for LTCM. Putman (1998, p. 46) calls this the 'proximate cause' of the imminent disaster, especially as Salomon Brothers decided to close its London arbitrage desk in September.

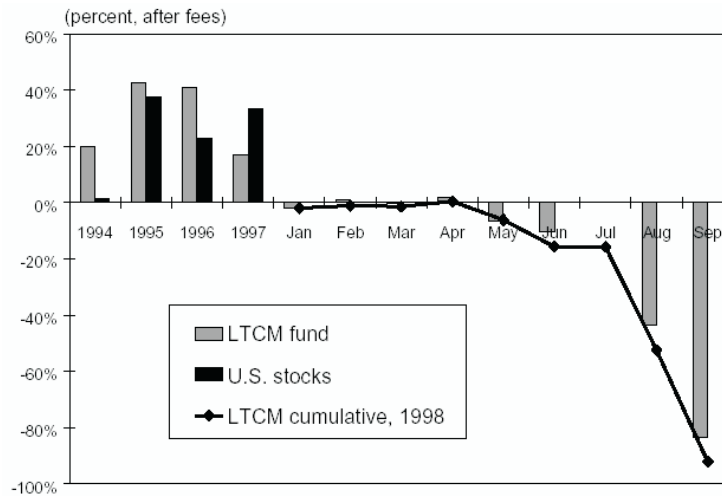


Figure 1: LTCM's returns.

Source: Jorion (2000, p. 281).

Eventually, on 17 August, Russia defaulted on its domestic government bonds (GKOs) and devalued its currency, taking the market by surprise as the West, lead by the IMF, had provided 22.5 billion U.S. \$ a month before. This unexpected event caused a fundamental revaluation of risk premia on less liquid bonds and led to a flight-to-quality in liquid assets such as US or German government bonds. The associated increase of spreads sharply contradicted LTCM's expectations. The fund could not sell its positions in the market which was characterised by severe illiquidity as the significant size of the positions affected the price. After a loss of 2.5 billion U.S. \$ in August alone, LTCM's survival came into question while the fund had 60,000 trading positions on its books, a balance sheet of 125 billion U.S. \$ and derivatives with a notional principal amount of more than 1.4 trillion U.S. \$.<sup>9</sup>

<sup>9</sup>A lot of the futures contracts of more than 500 billion U.S. \$, the swap contracts of more than 750 billion and other derivative contracts of more than 150 billion U.S. \$ cancelled each other such that the net position lay considerably below the 1.4 trillion. Nevertheless, the risk of default was surely sizable for many of LTCM's trading partners. For the figures, see PWG (1999, pp. 11).

### 2.2.3 The Fed's response

When the fund tried to raise new capital to avoid bankruptcy on 2 September, it failed. After further formidable losses in September, LTCM was on the brink of bankruptcy on 21 September. Its precautionary measures against liquidity shortages, e.g. the minimum investment duration of three years or its internal risk management, had proven to be insufficient under these extreme market conditions. The size of LTCM as well as the significant amount of copycats of LTCM's previously successful strategies at the trading desks of many banks threatened the smooth functioning of the US treasuries market. Bill Clinton expressed the dimension of the problem when he declared that the 'world faces its biggest financial challenge in 50 years' (Economist, 1998, p. 83). Due to the threat to the whole financial system, the New York Fed under its Chairman William J. McDonough deemed it necessary to organise a private bail-out of LTCM. It arranged a consortium of 14 banks that were involved with LTCM to invest 3.625 billion U.S. \$ for a 90% stake in the fund. Before that deal, Meriwether had rejected the offer of a complete takeover of LTCM by a group around Warren Buffet's Berkshire Hathaway for 250 million U.S. \$ plus an investment of 3.75 billion U.S. \$.<sup>10</sup>

The Fed lowered its target rate three times during the following weeks in order to provide sufficient liquidity to the markets. The cuts by a quarter percentage point each took place on 29 September, 15 October (between two regular meetings, a very rare event) and 17 November, after the target rate had stayed at 5.5% for more one and a half years. An international aid package for Brazil under IMF leadership further calmed the markets. After a loss of 92% in the first nine months of 1998, LTCM's portfolio regained 13% under its old management subject to the control of the banks' consortium. Its positions were completely dissolved until the end of 1999 (Jorion, 2000, p. 284). Even the banks in the consortium, whose market value had suffered disproportionately during the crisis, profited strongly from the market recovery. Figure 2 includes an index that summarises the market capitalisation of the banks in the consortium.<sup>11</sup> The development of the index shows not only how drastically the share prices of the consortium banks dropped during the crisis relative to the total market

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<sup>10</sup>According to Edwards (1999, p. 200), Meriwether claimed that he was unable to accept the Buffet offer because it did not allow sufficient time for him to obtain the needed approvals. The official report by the IMF (1998, p. 56) explains the failure to reach an agreement with a shortage of time, too. The true reason could also be a strategic game with the Fed since the offer of the consortium left a 10%-stake in LTCM, worth about 400 million U.S. \$ at the time, plus expected management fees with the partners instead of 250 million offered by Buffett (see Dowd, 1999, pp. 4). Since the achievement of a private bailout at the time of the rejection of the Buffett offer was not certain, a further reason for the rejection could also be a personal antipathy of Meriwether against Warren Buffett because he had already caused Meriwether's departure from Salomon Brothers in 1991. Besides, members of the Buffett group, the investment bank Goldman Sachs and the insurer American International Group (AIG), had exploited and corroborated LTCM's distress by strategic trades (see Lowenstein, 2000).

<sup>11</sup>Appendix A describes the construction of the index.

and the banking sector after an extraordinary performance until July 1997, but also how quickly their market values recovered after the second interest rate cut by the Fed.

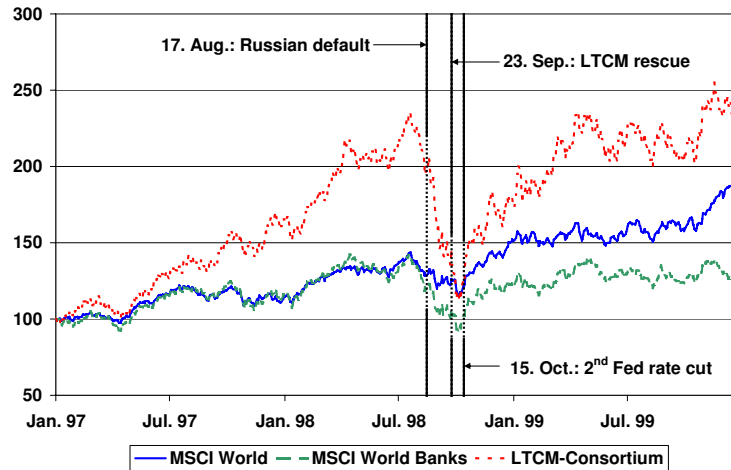


Figure 2: Performance of different share indices from 1997 to 1999.  
Data source: Thomson Financial Datastream, author's calculations.

## 2.3 11 September 2001

### 2.3.1 Summary

The terrorist attacks in the morning of 11 September 2001 represented a very different form of a liquidity shock to financial markets. Liquidity evaporated from the financial system not because of margin calls, portfolio insurance strategies or a preference shock, but rather because large parts of the communication system and a lot of back offices in lower Manhattan were physically destroyed. One immediate response of the authorities was to leave the New York Stock Exchange, the American Stock Exchange and NASDAQ closed until 17 September. Hence, liquidity problems concentrated in the payments and settlement systems and did not affect the stock market immediately. In that sense, the effects were limited and the Fed as well as the ECB could quickly withdraw the additional liquidity they had supplied to banks until 13 September within a couple of days.

Just before U.S. stock markets reopened on the morning of Monday 17 Sep-

tember, the Fed cut its target rate by 50 basis points. The ECB followed suit and also lowered its key interest rates by the same amount. The Fed continued to cut rates on 2 October, 6 November and 11 December, while the ECB reduced its rates only on 9 November. The contemporaneous action of central banks worldwide (see figure 4 below) on 17 September hints that this move was aimed at rebuilding confidence and signalling that central banks would continue to provide liquidity if necessary. Indeed, on 17 September the Dow Jones opened only 3.2% below the closing value on 10 September. Until 21 September, the Dow lost 14.3% compared to 10 September, but regained quickly in the following weeks and reached the pre-terrorist level already in October. Hence, one can agree with Lacker (2004, p. 961) that ‘the [Fed] interest rate cuts following September 11 are probably best viewed as addressing the medium- and longer-term macroeconomic consequences’ rather than a necessary response to a continuing liquidity crisis.

### **2.3.2 Financial market consequences of the terrorist attacks**

The first plane hit the World Trade Center at 8:46 am local time on Tuesday, 11 September 2001, the second one at 9:02 am. The immediate effects differed for the various financial markets mainly due to different trading times. For example, U.S. stock markets were not directly affected because trading hours at the New York Stock Exchange, the Nasdaq and the American Stock Exchange begin at 9:30 am and the authorities quickly decided not to open the equity markets and kept them closed for the rest of the week.

Other markets like the money market<sup>12</sup> and the one for government bonds were severely disrupted due to the breakdown of large parts of the communication system and the direct effects on several relevant market participants, in particular interdealer brokers and the Bank of New York, with offices in the World Trade Center or close-by. Lacker (2004) notes that repo trading begins at 7 am and trading in government securities at 8 am with most trading taking place before 9 am. Hence, 11 September was close to a full trading day which caused severe problems for the clearing of the trades in the aftermath of the attacks. GAO (2003) reports that the number of failed transactions in the government securities markets, i.e. trades whose settlement was not completed, increased dramatically, rising from around 500 million U.S. \$ per day to over 450 billion U.S. \$ on 12 September and staying high at about 100 billion U.S. \$ daily through September 28. The same happened in the repo market and caused liquidity problems for firms that relied on this market as a funding source. Overall, the physical disruptions prevented the markets from an efficient allocation of the available reserves in the financial system.

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<sup>12</sup>Money market instruments are short-term instruments that include federal funds, foreign exchange transactions, commercial paper and repurchasing agreements (repos) (GAO, 2003).

In the payments system, the Federal Reserve's Fedwire securities and payments transfer systems and the private Clearing House Interbank Payments System (CHIPS) continued processing transactions but McAndrews and Potter (2002) show that Fedwire transfer volume decreased by more than 40% on 11 September and payment processing was delayed at many banks. On Monday, 17 September, however, the transfer systems had returned to normal levels. The severest problem for the retail payments systems was the grounding of airplanes until that was only partly lifted on 13 September, which delayed the transportation and thus the clearing of checks significantly.

### 2.3.3 Central banks' response

On 11 September, one of the first measures of the Fed was to communicate in the spirit of the statement in October 1987 (see section 2.1) its readiness to provide liquidity to the markets:

The Federal Reserve System is open and operating. The discount window is available to meet liquidity needs.  
(<http://www.federalreserve.gov/boarddocs/press/all/2001/>)

Besides, it extended the provision of credits related to the clearing of checks, called 'floats'. Further immediate measures included substantial repurchase agreements by the New York desk of the Federal Reserve, direct lending through the discount window<sup>13</sup> and swap lines to permit foreign central banks to meet liquidity needs in U.S. dollars (Neely, 2004; Lacker, 2004, see).

These interventions prevented interest rates from rising and stabilised the money market within a couple of days, as banks quickly regained confidence in the ability of other banks to meet their payment obligations.<sup>14</sup> In that sense, the effects were limited and the Fed could quickly withdraw the additional 108 billion U.S. \$ in discount window credits, overnight repos and check floats it had supplied to banks until 13 September already by 20 September. Table 1 summarises the development of deposits of depository institutions with the Federal Reserve Banks from 10 September to 21 September.

Nevertheless, the money market showed significant volatility for some time as can be seen from the wide trading range of federal funds in figure 3 for almost three weeks.<sup>15</sup> Rates fell even considerably below the target rate from 17 to

<sup>13</sup>Lacker (2004, p. 942) also points out that some banks may have preferred to borrow from the discount window rather than from the market since the discount rate was 50 basis points below the prevailing funds rate target and the Fed statements had signalled a more liberal regulation of discount window lending than usual.

<sup>14</sup>McAndrews and Potter (2002) emphasise the interdependence of a bank's willingness to make payments and its receipts of payments from other banks, i.e. the presence of strategic complementarity in the payment system. Central bank liquidity provision can help to overcome possible coordination failures.

<sup>15</sup>The effective federal funds rate is the weighted average of this rate across all banks.

Table 1: Cumulative change of deposits of depository institutions with the Federal Reserve Banks from 10 September, billion U.S. \$.

10 Sep	11 Sep	12 Sep	13 Sep	14 Sep	17 Sep	18 Sep	19 Sep	20 Sep	21 Sep
0	33	95	108	98	32	6	2	0	-1

Source: Lacker (2004, p. 946). Deposits of depository institutions with the Federal Reserve Banks are the sum of repos, check floats, swap draws, currency, discount and overdraft overnight credit and the net effect of other Federal Reserve assets and liabilities, mainly the System's holdings of U.S. government securities.

19 September since the reserve requirement maintenance period ended on the 19th and banks had accumulated excess reserve positions in the previous days.

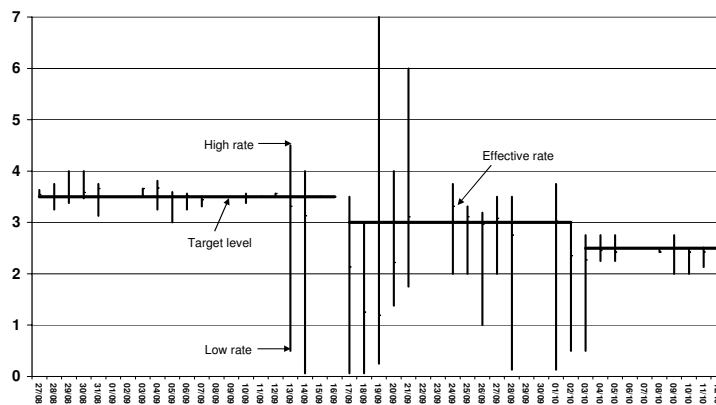


Figure 3: U.S. Federal funds rate around 11 September 2001: High, low and effective rates.

Data source: Bloomberg.

In Europe, the European Central Bank (ECB) immediately issued the following press statement on 11 September:

After the unprecedented and tragic events in the United States today, the Eurosystem stands ready to support the normal functioning of the markets. In particular, the Eurosystem will provide liquidity to the markets, if need be. (ECB, 2001a)

Furthermore, the ECB conducted two one-day fine-tuning operations on 12 and 13 September with a volume of 69.3 and 40.5 billion Euro, respectively, in which all bids were satisfied. It also entered into a swap agreement with the Fed over 50 billion U.S. \$ to provide dollar liquidity to European banks on 12 September (ECB, 2001b) and thus took over the task of dollar refinancing for European banks. However, the ECB left its key interest rates unchanged on its regular meeting on 13 September.

Just before U.S. stock markets reopened on the morning of Monday 17 September, the Fed cut its target rate by 50 basis points. The ECB followed suit and also lowered its key interest rates by the same amount. The Fed continued to cut rates on 2 October, 6 November and 11 December, while the ECB reduced its rates only on 9 November. The contemporaneous action of central banks worldwide on 17 September hints that this move was at least partly aimed at rebuilding confidence and signalling that central banks would continue to provide liquidity if necessary (see figure 4 for the key interest rate in the Group of Seven (G7) countries around 11 September). Indeed, on 17 September the Dow Jones opened only 3.2% below the closing value on 10 September. Until 21 September, the Dow lost 14.3% compared to 10 September, but regained quickly in the following weeks and reached the pre-terrorist level already in October.

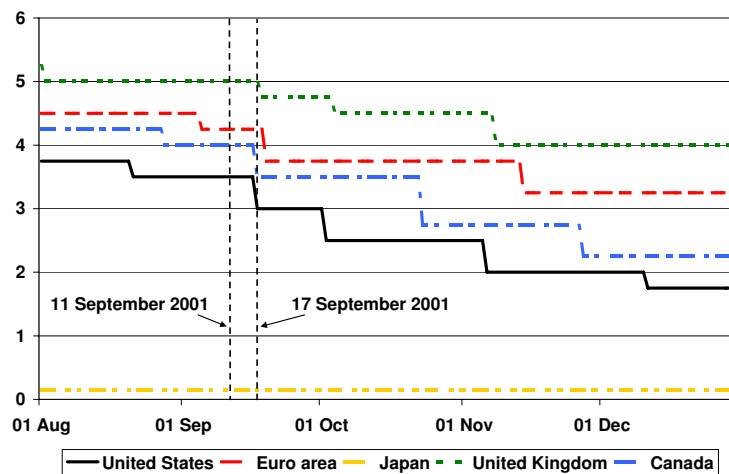


Figure 4: Key interest rates in Group of Seven countries around 11 September 2001.

Notes: The Euro area comprises Germany, France and Italy as members of the G7.  
Data source: Thomson Financial Datastream.

The U.S. economy had been in a recession since March 2001 according to the NBER. Correspondingly, the Fed had been decreasing the funds target rate from 6.5% in the beginning of 2001 to 3.5% in August 2001 as shown in figure 5. After the fourth post-September 11 rate cut in December, the target rate remained at 1.75% for almost a year. Given the previous development of the economy and the additional negative demand shock caused by the terrorist attacks on the one hand and the quick recovery of equity markets and the comparatively limited action of the ECB on the other, the extent of the rate cuts seems to be mainly driven by concerns of the Fed with respect to further macroeconomic developments in the U.S.<sup>16</sup>

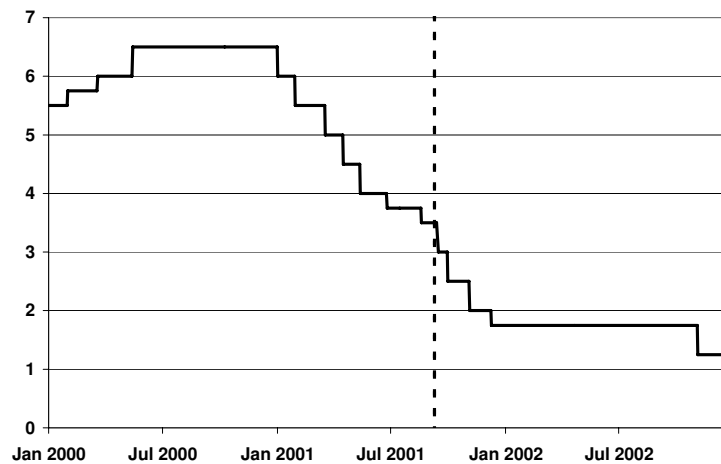


Figure 5: U.S. Federal Funds Target Rate.

Data source: Thomson Financial Datastream.

### 3 A comparison of the Fed's responses

A common feature of the crises in 1987, 1998 and 2001 is that the Fed lowered its interest rate to provide emergency liquidity to the market, although the mandate of the Fed in the Humphrey-Hawkins Act of 1978 focuses on price stability and full employment. Taylor (1993) suggested a simple interest rate

<sup>16</sup>For example, Lacker (2004, p. 961) and Neely (2004) hold this view as well.

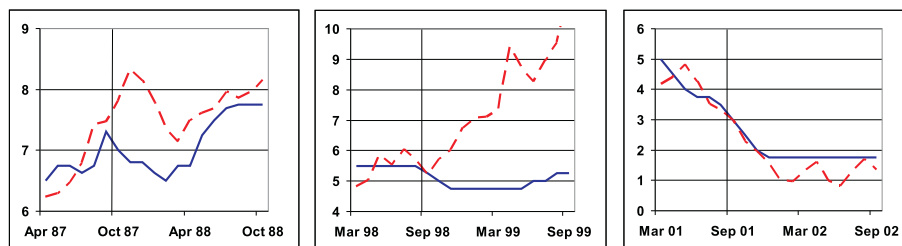


Figure 6: Federal funds target rate (solid line) and Taylor rule rate (dashed line) in the U.S. during the crises in 1987, 1998 and 2001.

Notes: The Taylor rule rate is based on equation (1) with  $\pi_t$  measured as the annual growth rate of the consumer price index and  $y_t$  measured as the quarterly OECD-output gap transformed into monthly data with a cubic spline. The Taylor rate is adjusted for time-varying  $r_t^*$  and  $\pi_t^*$  by matching the average Taylor rate in the six months prior to the respective crisis with the average Federal funds target rate over this period. Data source: Thomson Financial Datastream.

rule to capture these two goals monetary policy:

$$i_t = r_t^* + \pi_t + 0.5(\pi_t - \pi_t^*) + 0.5y_t. \quad (1)$$

The nominal interest rate  $i_t$  should rise with the natural real rate  $r_t^*$ , inflation  $\pi_t$  relative to its target rate  $\pi_t^*$  and the output gap  $y_t$ . The comparison of the actual Fed funds target rate with the recommendation from this Taylor rule provides a simple test for the liquidity provision principle, i.e. a temporary departure of interest rates from the Taylor rule during financial crises (Taylor, 2005) in order to avoid negative spillover effects from the asset to the goods market.

Figure 6 shows that the Fed decreased its policy rate in the months following all three crises as noted above. The Taylor rule, however, recommended a rise of the interest rate after the crises of 1987 and 1998 as the U.S. economy showed buoyant GDP growth and rising inflation. Furthermore, the Fed had to provide liquidity for a much longer time to calm the markets in 1987 and 1998 than in 2001. Hence, monetary policy appears expansionary for about six months until April 1988 and even more so after the LTCM-crisis 1998. In contrast, the Taylor rate matches the actual Fed funds rate after the terrorist attacks in 2001 quite closely. From the beginning of 2002, actual monetary policy looks even restrictive compared to the Taylor rule.

Figure 7 reveals considerable differences in the development of inflation in the aftermath of the crises. For comparison, inflation is measured as the annual growth rate of both the consumer price index (CPI) and the personal consumption expenditure index (PCE), but the differences appear to be negligible. The average inflation rate one and a half to two years after the crises compared to average inflation in the six months up to the crises increased by 0.8 percentage

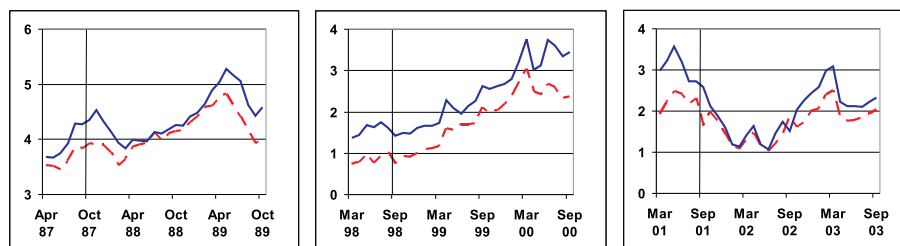


Figure 7: CPI (solid line) and PCE (dashed line) inflation rates in the U.S. after the crises in 1987, 1998 and 2001.

Notes: Inflation is measured as the annual growth rate of the consumer price index (CPI) and the personal consumption expenditure index (PCE). Data source: Thomson Financial Datastream.

points after 1987 and 1.7 points after 1998.<sup>17</sup> In contrast, inflation decreased by 0.4 (PCE) or 0.9 (CPI) points after 2001. Therefore, expansionary monetary policy via the liquidity provision principle appears to have contributed to price increases after 1987 and 1998, while a normal or even restrictive stance of monetary policy added to a decline of inflation after 2001.

All three historical episodes of liquidity crises demonstrate that central banks, and in particular the Fed under Alan Greenspan, stood ready to provide liquidity in times of financial crises. Greenspan (2004, p. 38) states that the ‘immediate response on the part of the central bank to such financial implosions must be to inject large quantities of liquidity,’ in line with the traditional Bagehot (1873) principle for a lender of last resort activity to ‘lend freely at a high rate against good collateral.’ But the events also indicate that not all financial crises are alike and central banks face a difficult task to decide on the optimal policy, which depends on the associated costs and benefits.

For example, liquidity shocks that are concentrated in the payments system allow the central bank to conduct liquidity provision in a very target-oriented manner and absorb (‘sterilise’) the additional liquidity quickly after the problems have disappeared. If the liquidity shock is a broader preference shock that affects financial markets in general, however, and volatility, bid-ask spreads and risk premia increase for a broad range of financial instruments, the central banks’ task is more complicated: Overcoming the disruptions in the financial markets and preventing fire sales requires sustained liquidity provision through interest rate decreases for some time in order to prevent fire sales of illiquid assets. Sterilisation of this additional liquidity becomes very difficult and therefore threatens the stability of goods prices. Sauer (2007) develops a stylised model of an asset market and a goods market which provides a framework to analyse the relevant trade-offs for the central bank. The next section

<sup>17</sup>Besides the rise in consumer prices, expansionary monetary policy may also have contributed to the boom and bust period of equity prices in the five years following the LTCM-crisis.

offers a brief summary of his model.

## 4 A theoretical model

The model in Sauer (2007) consists of two separate markets, an asset market and a goods market. The main focus is on developments on the asset market, but these developments have important implications for the goods market. Although the monetary authority only cares about deviations of goods prices and quantities from the optimal values, the spillover effects from the asset market may require a central bank intervention on this market.

In the model, investors can invest on an asset market in liquid money and potentially illiquid, but productive assets, called shares, in order to optimally satisfy their uncertain consumption needs on the goods market over two periods. Two channels link the goods market to the asset market: First, the amount of money held by investors determines together with the size of a liquidity shock the aggregate demand of investors on the goods market which is subject to a cash-in-advance constraint. Second, a dramatic decrease of the asset price negatively influences the goods supply in the final period because it forces investors to costly liquidate their asset. Hence, the central bank faces a trade-off between inflating a demand shock today, which causes higher losses today, and limiting a negative supply shock tomorrow, which will cause higher losses tomorrow. Expectations of central bank intervention give rise to a moral hazard effect with additional investment in less liquid, but productive shares. If the central bank has the possibility to commit to some future policy, it should optimally weight these productivity gains against the expected intervention costs.

## 5 Conclusion

All three historical episodes of liquidity crises demonstrate that central banks, and in particular the Fed under Alan Greenspan, stand ready to provide liquidity in times of financial crises. Greenspan (2004, p. 38) states that the 'immediate response on the part of the central bank to such financial implosions must be to inject large quantities of liquidity,' in line with the traditional Bagehot (1873) principle for a lender of last resort activity to 'lend freely at a high rate against good collateral.' At first sight, this seems to be a simple panacea for central banks to respond to temporary liquidity crises on financial markets as central banks seem to provide liquidity at no costs.

However, liquidity provision is not costless and central banking is not that simple. Depending on the nature of the liquidity shock, it may take some time until market turmoils have seized and the central bank can withdraw its liquidity injections. The longer the additional liquidity circulates in the financial

system, the more it will spill over into the 'real' economy, fuel goods price inflation and thus raise the costs of the intervention. The aftermaths of the stock market crash in 1987 and the LTCM crisis in 1998 provide evidence for this mechanism, whereas the liquidity effects of the terrorist attacks on September 11, 2001, have been rather limited.

The events described in this review have highlighted a number of the relevant issues for the optimal response of monetary policy to liquidity crises. Sauer (2007) develops a model that includes the relevant trade-offs and provides further insights for optimal policy. The following questions offer a preliminary checklist that may help to determine the optimal response:

- In which markets does liquidity dry up?
- What causes the liquidity drain, i.e. is it really an issue of a (temporary) liquidity squeeze?
- How large is the extent of fire sales?
- How large are the possible spillover effects from the financial market to the rest of the economy in real (i.e. negative production effects) and nominal (i.e. goods price inflation) terms?

Looking at recent events in financial markets in the first half of August 2007, money market conditions were very volatile due to a number of defaults in the U.S. subprime mortgage backed securities markets that caused considerable losses for some banks. Central banks worldwide have provided substantial liquidity through open market operations that even exceeded the liquidity provision in September 2001 in the case of the ECB. So far, this liquidity provision was intended mainly to avoid disruptions in the money market, in line with the ECB's task to promote the smooth operation of payment systems,<sup>18</sup> and can be quickly sterilised.

While equity markets and other credit markets have experienced a noticeable increase in volatility and risk premia, losses have been relatively limited compared with the considerable increase of asset prices in recent years. If, however, the crisis dramatically spreads from the subprime market to other markets, the central banks face exactly the trade-offs described in this paper and in Sauer (2007). In particular, they should be aware of both possible spillover effects to the rest of the economy, risks to both the production and the prices of goods caused by the (non-)conduct of emergency liquidity provision.

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<sup>18</sup>See Art. 105 II, Treaty on European Union.

## Appendix

### A Description of the construction of the LTCM - consortium index

The computation of the index for the LTCM-consortium follows the construction of the FTSE-100 as described in Bain and Howells (2000, p. 217). The index abstracts from dividend payments and describes the development of the market values ( $MV$ ) of all banks involved in the private bailout of LTCM<sup>19</sup> according to the formula  $Indexvalue_t = (\sum_i MV_{i,t} / \sum_i MV_{i,0}) \cdot 100$ , where  $t = 0$  denotes the base date 1 January 1997 and 100 the base value of the index. Figure 2 uses the MSCI World - Index and the MSCI World Bank - Index, both normalised to the base value 100, as benchmarks. Several of the companies involved in the bailout merged in the course of the general consolidation in the banking sector. The computation of the index takes this into account.<sup>20</sup>

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<sup>19</sup>Banker's Trust, Barclays, Chase Manhattan, Credit Suisse First Boston, Deutsche Bank, J.P. Morgan, Goldman Sachs (not included in the index since not listed before May 1999), Lehman Brothers, Merrill Lynch, Morgan Stanley Dean Witter, Paribas, Société Générale, Travelers und Union Bank of Switzerland (vgl. IWF 1998, S. 56).

<sup>20</sup>On 26 June 1998, the Union Bank of Switzerland (UBS) merged with the Swiss Bank Corporation (SBC). Therefore, the market values of both previously traded share types of the old UBS and the shares of SBC have been added for the index up to this date. On 8 October 1998, Travelers and Citicorp joined forces as Citigroup, whereas only Travelers belonged to the consortium. Hence, the market value of Citigroup from 8 October is adjusted for the market value of Citicorp on 7 October. Furthermore, Deutsche Bank took over Banker's Trust and BNP took over Paribas in the early summer of 1999.

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