however, selling assets caused more marked-to-market losses because the sales lowered the value of its remaining assets. Additional margin calls resulted. This downward spiral eventually caused Barings Bank's failure.

2. The option position's profits depended on a temporary quantity impact on the price due to his massive trading of options. When Leeson stopped selling, his option positions lost value.

3. Leeson had a massive position in Nikkei 225 futures. When liquidated quickly, the value of this position diminished considerably (this occurred when SIMEX liquidated Barings Bank's futures position).

18.2.6 Operational Risk

Operational risk to the bank existed because the trading strategy was not adequately monitored by senior management. This occurred for two reasons. One, Leeson managed both the trading and settlement process, hence he could manipulate the observed profits via this joint responsibility. Two, his access to capital was unrestricted and not monitored. This enabled Leeson to accumulate large losses, directly reducing Barings Bank's capital.

18.3 Conclusion

The losses to Barings Bank were due to inadequate risk management controls and a fraudulent trader. Senior management did not understand the source of Leeson's positive returns.

Chapter 19

Long Term Capital Management (1998)

The references for this Chapter are Lowenstein [50], Edwards [17], and Jorion [47].

19.1 Summary

Long Term Capital Management (LTCM) was a hedge fund created in 1994 by a group of former Solomon Brothers' bond traders and quantitatively inclined academics, most of whom had a strong connection to the Massachusetts Institute of Technology (MIT). The initial capital in the fund was $1.3 billion. LTCM was a quantitative hedge fund. Their management fee was 2% of capital plus 25% of profits, which was higher than the norm of 1% and 20%. Their primary trading strategy was betting on the mean-reversion of various spreads, based on historical relationships. They traded on spreads across different fixed income securities: bonds (governments, private), mortgage backed securities; and to a lesser extent spreads across different equities. Using options, they also placed speculative bets that the market's volatility was mean reverting (see Lowenstein [50], p. 234). Because their trading strategies could lose value before finally generating profits, investors in LTCM were required to lock-up their invested funds for three years.

A key component of their trading strategy was leverage. Based on the convergence of abnormal spreads, their trading strategies generated small (but positive) expected profits. To increase the magnitude of their returns, they highly levered their positions. A typical leverage ratio was 25 to 1

(see Jorion [47], Fig. 3). The majority of their financing was done using repurchase agreements and interest rate swaps. Increasing leverage typically increases the variance of a portfolio. LTCM allegedly controlled the portfolio's variance using diversification and quantitative methods based on historical correlations in market prices.

In the beginning LTCM was very successful. From 1994 - 1997 their returns were (after fees) 19.9%, 42.8%, 40.8%, 17.1%, respectively. Capital under management increased to $7 billion by 1997. Problems started in the spring and summer of 1997. In the spring of 1997, mortgage-backed securities prices declined, causing a 16% loss to LTCM's capital. In August 1997, Russia defaulted on is debt, causing LTCM's cumulative capital loss to reach 52%. These losses dramatically increased LTCM's leverage ratio, increasing the severity and magnitude of additional shocks to its capital.

As LTCM lost capital, it received margin and collateral calls on its exchange traded and OTC positions. To fulfill these calls, it liquidated its assets. As it liquidated its assets, the quantity impacts from the trades caused prices to fall further, cascading and accelerating the loss in the value of its positions. This is funding risk. By September 1998 only $400 million in LTCM's capital remained. LTCM was on the verge of failure. LTCM reached out to private investors for additional capital, but negotiations failed.

LTCM's continued forced liquidations, in conjunction with the market turmoil caused by the Russian debt default, created the possibility of a financial market failure. To avoid such a calamity, on September 23rd the New York Federal Reserve organized a bailout of LTCM consisting of a $3.6 billion capital infusion by 14 banks for a 90% position in the firm (see Jorion [47], p. 283). The bailout avoided a market failure. In early 1999 LTCM was dissolved and the bailout investors departed earning a reasonable return on their capital.

19.2 The Trading Strategy

This section describes the trading strategy in a simplified fashion to highlight the economics involved.

Let X_t and Y_t denote the market prices of two closely related assets (e.g. a government and corporate bond of 10 years to maturity).

Let $S_t = X_t - Y_t$ be the spread in market prices. Although spreads are normally described in terms of yields, for simplicity (and without loss of generality), we illustrate the trading strategy with price spreads.

Suppose that based on historical relationships, the spread satisfies the following evolution over the time interval $[t, t + \Delta t]$:

$$\triangle S_t = \kappa(\mu - S_t)\triangle t + \triangle M_t$$

where $\kappa > 0$, $\mu > 0$, $\Delta M_t = M_{t+\Delta t} - M_t$, and M_t is a martingale (hence, $E_t(\triangle M_t) = 0$).

This implies that the spread S_t follows a mean-reverting process with its long-term value equal to μ. The expected change in the spread is:

$$E_t(\triangle S_t) = \kappa(\mu - S_t)\triangle t.$$

If $S_t > \mu$, then S_t is expected to decline. If $S_t < \mu$, then S_t is expected to increase.

The trading strategy consists of three steps. Step 1 is the spread position, step 2 is the leveraging, and step 3 is diversification.

19.2.1 Step 1 (The Spread Trade)

1. If $S_t > \mu$, then sell the spread, i.e. sell X_t and buy Y_t. Hold this position until $S_t = \mu$, then liquidate. At this time either X_t will have declined, Y_t will have increased, or both will have occurred generating a profit.

2. If $S_t < \mu$, then buy the spread, i.e. buy X_t and sell Y_t. Hold this position until $S_t = \mu$, then liquidate. At this time either X_t will have increased, Y_t will have decreased, or both will have occurred generating a profit.

Note that this is not an arbitrage opportunity because there is a positive probability that the spread may never converge, due to the random component $\triangle M_t$. It is also important to observe that the trading strategy can lose value before convergence occurs. Hence, the ability to fund the losses must be part of the trading strategy.

19.2.2 Step 2 (The Leveraging)

This section explains how leveraging increases the risk of an investment portfolio.

Let C_t be the capital invested at time t.

Let α represent the shares in the spread trade S_t at time t.

Let B_t be the dollars borrowed at the rate r at time t.

Then, an accounting identity gives:

$$C_t = \alpha S_t - B_t.$$

The percentage of the portfolio in the spread S_t is $w = \frac{\alpha S_t}{C_t} > 1$ and the percentage of the portfolio in borrowings is $1 - w = -\frac{B_t}{C_t} < 0$.

The return on the capital over $[t, t + \triangle t]$ is determined as follows:

$$C_{t+\triangle} = \alpha S_{t+\triangle} - (1 + r)B_t,$$

$$\frac{C_{t+\triangle} - C_t}{C_t} = \frac{\alpha S_t}{C_t}\left(\frac{S_{t+\triangle} - S_t}{S_t}\right) - \frac{B_t}{C_t}r = w\left(\frac{S_{t+\triangle} - S_t}{S_t}\right) + (1 - w)r.$$

Letting $R_C = \frac{C_{t+\triangle} - C_t}{C_t}$ and $R_S = \frac{S_{t+\triangle} - S_t}{S_t}$, we have in return form:

$$R_C = wR_S + (1 - w)r.$$

Note that

$$E_t(R_C) = wE_t(R_S) + (1 - w)r, \text{ and}$$
$$\sqrt{Var_t}(R_C) = w\sqrt{Var_t}(R_S)$$

where $Var_t(\cdot)$ is the variance computed at time t.

The leverage ratio in this trading strategy is $\frac{B_t}{C_t} = -(1 - w)$. Consequently, the return on the spread is multiplied by $w = 1 + \frac{B_t}{C_t} > 1$. For example, if LTCM's average leverage ratio was 25, then the expected return and standard deviation of the spread was multiplied by a factor of 26. To illustrate, if $E_t(R_S) = .001$, then $wE_t(R_S) = 26(.001) = .026$.

19.2.3 Step 3 (Diversification)

To reduce the variance of the balance sheet, LTCM diversified its position by investing in a collection of spreads $S_1, \ldots, S_n$.

The return on the spread portfolio is

$$R_C = \sum_{j=1}^{n} w_j R_{S_j} + (1 - w)r$$

where

$$w \equiv \sum_{j=1}^{n} w_j > 1.$$

LTCM choose $(w_1, \ldots, w_n)$ such that the variance of the portfolio was set to equal that of the market portfolio, i.e.

$$Var_t(R_C) = \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j cov_t(R_{S_i}, R_{S_j}) = \sigma^2_{market}$$

where σ^2_{market} is the variance of the equity market portfolio.

19.2.4 Market Risk

This trading strategy is subject to the price risks inherent in the evolution of the spreads.

19.2.5 Credit Risk

The trading strategy used fixed income securities, some of which could default. Credit risk was a component of LTCM's trading strategy.

19.2.6 Liquidity Risk

First, since the trading strategy involved buying and selling assets when spreads deviated from their norms, liquidity risk played a role in the profits earned. Indeed, spreads often deviate from their norms when markets are less liquid than typical. Second, using a highly levered trading strategy, a "cash flow crisis" occurred due to funding risk, which is the conjunction of liquidity risk and borrowing constraints being binding. Indeed, when LTCM sold assets to cover margin and collateral calls, the impact of the sales caused more marked-to-market losses, generating additional margin calls. Borrowing constraints were binding, inhibiting the ability to obtain outside funding without selling assets. This cash flow crisis only stopped when a bailout plan was created, which provided outside funding.

19.2.7 Operational Risk

The operational risk existed in this hedging strategy to the extent that LTCM's management incorrectly: (i) determined the market and credit risk and (ii) accounted for funding risk.

19.3 Conclusion

It has been argued by LTCM's management that their methodology was correct, but they suffered from extreme bad luck in the occurrence of a 3.7 sigma event in their market and credit risk exposures (see Jorion [47], p. 289). Others disagree with this conclusion. For example, Jorion [47], p. 287 argues that LTCM did not adequately take into account changing asset correlations across healthy and distressed markets. There seems to be no debate that LTCM did not understand or adequately account for liquidity

risk and binding borrowing/margin requirements - funding risk - in their risk management procedures.

In summary, the evidence support's the following:

1) Market and credit risk were not correctly modeled by LTCM.

2) Funding risk was not properly anticipated by the management team.

Chapter 20

The Credit Crisis (2007)

The references for this Chapter are Lewis [49], Crouhy, Jarrow, Turnbull [12], and Jarrow [33]. Studying the 2007 credit crisis is important because it illustrates the economy wide risks encountered in risk management of a firm's or individual's balance sheet.

20.1 Summary

The genesis of the credit crisis was a healthy U. S. economy in the late 1990s and early 2000s with a nation-wide sustained growth in residential home values, now widely believed to have been a price bubble. In conjunction, interest rates were low from a historical perspective in the early 2000s and the equity market was in the midst of a sustained bull market. We argue below that the financial markets prior to 2007 were in the midst of an economy-wide Ponzi scheme, based on the continued growth in housing prices. When the alleged housing price bubble burst, the Ponzi scheme collapsed. This collapse was the 2007 credit crisis.

20.1.1 The Ponzi Scheme

The housing price expansion was fueled, in fact, accelerated by an enormous supply of capital available for home mortgages, especially to low income households. This capital was available from two sources: (i) government agencies (Fannie Mae and Freddie Mac), and (ii) financial institutions: commercial banks, investment banks, hedge funds, mutual funds, insurance companies, and pension funds. It was available from government agencies partly because of government legislation promoting an increase