Introduction

In the beginning of the 1900s academics became interested in how they analytically could construct mathematical models for trading in options. The entering of academics on the stock market became a reality in 1997 when Robert C. Merton and Myron S. Scholes were awarded the Swedish central bank's Price in Memory of Alfred Nobel "*for a new method to determine the value of derivatives*". By using dynamic hedging they claimed to eliminate the risk, the model came to use by a commercial company called Long-Term Capital Management (LTCM) who hired academics, including two Nobel Prize winners, to implement mathematical models. What seemed to be a success story with a 40% increase in value per year turned, after four years, into a nightmare with the hit of the East Asian financial crisis and later the Russian default. LTCM never recovered and the New York Federal Reserve pushed banks to invest in LTCM to avoid a worldwide crisis. Merton and Scholes theories were trashed, more or less fair, in the public domain.

Background

This section covers information that is needed to understand the rise and fall of LTCM.

Mathematical models

The French mathematician Louis Bachelier was the first person who used a stochastic process, now recognized by the name Brownian motion for an analytical valuation for stock options[1]. This was a part of his PhD thesis "*The theory of Speculation*" where he discussed how Brownian motion could be used to evaluate stock options and the thesis is considered to be the first paper using advanced mathematics in the finance field. Applying Brownian motion on the fluctuations of the stock market means that the price of a stock either increases or decreases with a predefined fix probability at each instant.

      Samuelson, Kendall, Roberts and Osborne modified the Bachelier model by assuming that the return rates followed a Brownian motion instead of the stock prices. This led to that the stock prices followed a lognormal distribution instead of a normal distribution.

      Based on these previous theories, 1973 Black and Scholes invented a new equation and a few years later Robert Merton justified it and it became extremely successful. This new equation applied to the oldest and simplest derivative – the option. It relates the recommended price of the option to four quantities whereof three you directly could determine; time, the price of the asset upon which the option is secured and the risk-free interest rate. The volatility of the asset is the fourth quantity and it is a measure of how unstable and unforeseeable the market value is. This quantity is assumed to be constant during the lifetime of the option and does not need to be adjusted once put into the equation. One cannot measure this value exactly but it could be estimated from statistical analysis on price movements. (1)

Hedge Funds

A hedge fund is a private partnership that is not as regulated and monitored as other funds are. *Hedging* means reducing risks and since return is a function of risk, an investor in a hedge fund

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[1] An option is an agreement or contract that gives the owner the right to buy an asset at a determined price at, or before, a specified date. This means that the holder can buy the asset if they want, but they are not obliged to by the agreement.

expects a higher return with the same risk taken in an ordinary fund. The fund does not need to register with the U.S. Securities and Exchange Commission (SEC) as long as they only take in accredited or qualified investors i.e. investors with a net worth minimum $1 million or investors with at least $5 million in investable assets. The reason why the fund only take in these investors is that in order for a manager of a hedge fund to succeed with the high returns, he might need to use techniques that an ordinary investor are not allowed to use because of the high risk and one assumes that wealthy people understand the investment risk better.

One example of a technique a hedge fund can use is short-selling which means that they buy securities that they think are undervalued. They also borrow securities that they think are overvalued from investors and then sells them in order to buy them back when the value of the security has decreased. Another example is leverage, which means that the fund borrows money to invest and thereby increase their returns. This technique can multiply the risk and therefore it is most commonly only used for low-risk investment strategies.

East Asian Financial Crisis
During the 1990 the Asian markets attracted foreign credits, which lead to new channels opening for foreign capital to enter the Asian economies. This lead to a rapid expansion of bank lending which in turn caused increased vulnerability to a reversal in capital flows. When the capital inflows waned in 1996-1997 a financial panic broke out which due to mistakes by the Asian governments, market participants and the International Monetary Fund (IMF)[2] lead to a financial crisis. In 1997 problems began to arise in Korea and Thailand. When Hanbo Steel declared bankruptcy in Korea, they left the country with a $6 billion debt. Further down the road Sammi Steel and Kia Motors faced the same difficulties, this putting pressure on merchant banks. The problems in Thailand arose with the fall of property prices in 1996, which caused Somprason Land to not being able to meet their foreign debt payment. This showed evidence that financing companies on the Bangkok property market were in trouble. When later the baht came under attack the fragile condition of the property sector and the financial institutions became evident. The evident problems in Thailand and Korea lead to the withdrawal of capital from foreign creditors, this caused pressure on the exchange rates. The currency of four of the Southeast Asian countries had fallen by 20% or by early September 1996. When the currencies fell and capital flows reversed creditors assumed that if Thailand was in trouble then the countries around Thailand would soon after join them, also the exchange rates depreciated and the domestic currency costs of servicing foreign debts rose. This caused the foreign creditors to reluctant to extend new loans and roll over existing ones. Also foreign debtors started to purchase foreign exchange to try to keep their positions. Furthermore rating agencies would downgrade countries in the region, which lead to further withdrawal of foreign creditors.

In December 1996 Korea was on the brink of default, therefore the US government started pressing foreign commercial banks to roll over the short-term credits and by the end of January the Korean government and the banks decided upon converting $24 billion of short-term debt into claims of maturities between 1 and 3 years. This lead to a decline in the Stock Markets of Thailand, Indonesia and Korea, also the currencies in Thailand and Indonesia continued to depreciate. The effects of the crisis spread in the area affecting the Philippines, Malaysia and China as well.

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[2] Organization of 188 countries, working to foster global monetary cooperation, secure financial stability, facilitate international trade, promote high employment and sustainable economic growth, and reduce poverty around the world.

After the crisis international investors became reluctant to lend to developing countries, it also cause a reduction in the oil price affecting all the OPEC countries. The decline in oil revenue contributed to the Russian financial crisis. (2)

The Russian Default

A combination of incidents lead to the Russian default and the Russian financial crisis; the declination in productivity, their chronic fiscal deficit, the East Asian Financial crisis which lead to a drop in prices for Russia's major exports; energy and metal, but above all the artificial high fixed exchange rate for the ruble. During 1998 the ruble experienced a free fall due to the above stated facts. This lead to banks failing and a spike in inflation, 84% as opposed to the aim of the Government of 8%. An international package was determined to try to save the situation. The Russians tried to maintain market sentiment and access until fiscal structural reforms would deliver results. However the package did not succeed. The resources used to defend the ruble amounted to $30 billion and the currency debt of the federal government increased by 20.5 billion during this period. This lead to the floatation of the currency, which in turn lead to the devaluation of the ruble and Russia's default on their debt. August 13th the Russian stock, bond and currency markets collapsed. The stock market was actually closed down for 35 minutes due to the plummeted prices, worth noting is also the fact that the stock market lost more than 75% of its value from January 1998 until August 1998. The effects of the crash was the devaluation of the Ruble, trading band from 6.0-9.5 RUR/USD instead of 5.3-7.1 RUR/USD, the ruble debt would be restructured to prevent mass Russian bank default and a 90-day moratorium would be imposed on the payment of bank obligations.

This was one of the major factors to LTCMs downfall, because the U.S. stock market began to slip, first with financial crisis in Asia and furthermore due to the Russian default. The Dow Jones Industrial Average fell 984 points (11.5%) in three days at the end of August 1998. (3)

Long-Term Capital Management (LTCM)

This section describes the timeline during which LTCM was founded and fell.

The Founding

n 1994 John W. Meriwether (former employee of the Salomon brothers) founded a firm called Long-Term Capital Management who handled the hedge fund Long-Term Capital Portfolio. Robert Merton and Myron Scholes, who later got the Nobel Prize in Economics in 1997 for the Black-Scholes options pricing formula, also joined the firm to try their mathematical theories about finance in practice. The requirement for investors in the fund was that they had to have their money in the fund for at least three years and also the minimum amount of investment was $10 million. Even though these requirements were pretty high, they managed to gather over $1 billion because of the talented people on board.

The firm focused on using their mathematical computer models to do different kinds of trades where the risk were considered very low since they took advantage of bonds that had been wrongly prized. However, the investments made in these trades gave such low profit so in order for LTCM to leverage they had to borrow a lot of money to make these investments. In the first years they were very successful and they had annual returns of over 40% after fees.

The people in LTCM saw their financial models as almost risk free and it went really well for them the first years, but the models were based on a few critical assumptions that would lead

them to their downfall. The models were calculating risks based on historical data so when an event that has never happened before occurs: the model was no longer reliable. (4)

The LTCM fall

LTCM problems started with the East Asian financial crisis. Most investors became more cautious during this period and only bet on "safe cards". LTCM did the opposite; they followed their model blindly and trusted that fact that their model told them that the situation would change. But due to the stressed market LTCM's VaR models had been outplayed by the horribly correlated behavior of the market. The final hit came on the Friday after the Russian default. During this day LTCM lost $533 million, half of that was due to a short position in five-year equity options. Figure 1 shows the value of $1000 invested in LTCM, the Dow Jones Industrial Average and U.S. Treasury. (4)
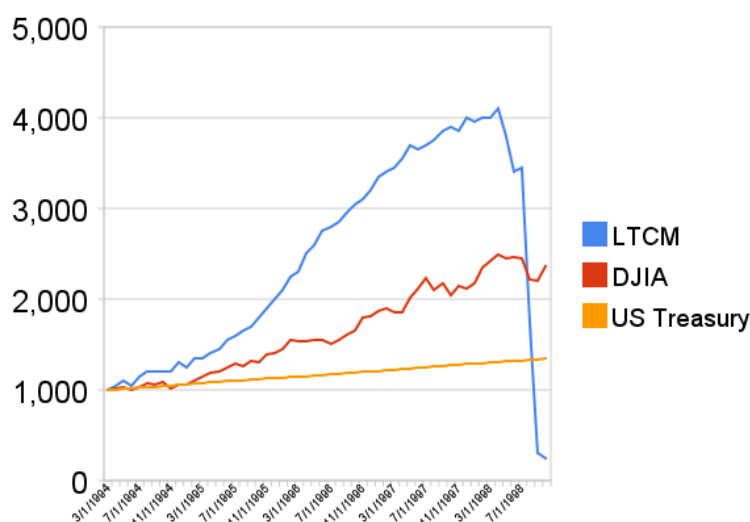

Figure 1; Shows the Rise and Fall of LTCM, source: www.investorsanthology.blogspot.se

The Bailout

Due to LTCM's high leverage they owed a lot of money to banks and financial institutions and when they were heading towards bankruptcy the New York Federal Reserve stepped in. The Federal Reserve feared how much the collapse of LTCM could disturb the whole financial system and therefore they organized a bailout for LTCM. After intense negotiations fourteen banks invested $3.5 billion in LTCM for a return of a 90% ownership. (4)

The Aftermath

The Fund has been liquidated by early 2000 and the banks that had financed the bailout had been paid back. However, the theories introduced by Merton and Scholes were trashed in the public domain. Merril Lynch[3] stated that mathematical risk models "*may provide a greater sense of security than warranted; therefore, reliance on these models should be limited*".

Conclusion

The greatest failure that LTCM did was to underestimate the credit risks and political risks in their mathematical model. The model calculated the level of risks based on short-term history

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[3] One of the world's leading financial management and advisory companies, providing financial advice and investment banking services.

and because events such as the Russian default has not happened in a long time, the model calculated the risk of these kinds of events to occur to be of zero probability. What also made them fail even more was that they used leveraging with dangerously high ratios (at most up to 55:1 which means that they borrowed 55 times their investment to increase the return of investment). Normally leverage is only used with low-risk investment since leveraging itself increases the risk and thereby the total risk of investment stays reasonably low, but since LTCM miscalculated the initial risk the risk of leveraging was multiplied and this lead to an even greater fall than LTCM ever could have imagined. (5)

Our conclusion after studying the LTCM case is that no mathematical model can take everything into account. When evaluating the risks involved one has to keep in mind that there always exist risks that are hidden and even if history has a tendency of repeating itself improbable events occur. Extreme cases such as financial crisis and defaults are hard (impossible) to model and mxt be taken into account by experience. However, we believe assessing risks by market experience and knowledge combined with academics provides the user with strong prerequisites to succeed and lower the risks involved.

Reading guide

For those who are more interested in the subject and wants to learn more we initially would like to recommend the book "When Genius Failed - The Rise and Fall of Long-Term Capital Management" by Roger Lowenstein (available as e-book at the Chalmers library). This book gives a comprehensive view of what happened and explains more in detail about the strategies used. For further reading we recommend the books and articles seen in references below. Finally, for those who want to get acquainted with the history of mathematical finance models and Long-Term Capital Management's journey we recommend the documentary film "The Midas Formula - Trillion Dollar Bet" by BBC Horizon.

References

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5.   Jorion P. Risk management lessons from Long-Term Capital Management. European Financial Management. 2000;6(3):277-300.