An Agent-based Model Approach to Assessing Risk Events for Hedge Funds

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1. Introduction

1.1 Study Purpose and Scope

Many scientists have devoted study to the credit crisis which started in 2007 and have in turn asked, “Could this have been predicted?” Analytically, this would be difficult--dynamics of realistic interactions between large populations of economic agents are far too complicated to compute analytically. However, where traditional economic analysis falls short, it is possible that agent-based modeling (ABM) can provide some insight due to the ability to model interactions between agents and therefore how an economic system changes over time due to these agent-to-agent interactions—essentially building an economy from the ground-up. Specifically, the purpose of this study is to evaluate whether or not ABM can be used to successfully model a financial system and study the dynamic properties of interactions and their connection to potential financial crisis.

ABM shall be used as the main method for studying and predicting the emergence of risk events associated with a failed hedge fund. The rationale for scoping the study using a failed hedge fund is three-fold. First, modeling the global economy is infeasible due to the size of the global economy (would require potentially millions of specialized agents) and would require in-depth knowledge of mathematics, sociology, and psychology—modeling a few hedge funds and a few associated entities (other hedge funds, banks, and investors) is achievable given the timeline of the study. Second, as hedge funds have more relaxed regulatory requirements than mutual funds, they can engage in more risky trading behavior, exposing themselves to potentially more chances of making investments which lose value—in turn causing a “financial crisis” for the hedge fund. Third, there are many examples in the history of the financial market of failed hedge funds to calibrate an agent-based model against. One such failed hedge fund is Long Term Capital Management (LTCM).

LTCM was a hedge fund management firm based in Greenwich, Connecticut. LTCM traders used fixed income arbitrage as its main strategy before moving to more risky arbitrage by going long[1] on shorter maturity bonds[2] and going short[3] on longer maturity bonds[4]. The firm's main hedge fund, Long-Term Capital Portfolio L.P., collapsed in 1998. In response, the Federal Reserve supervised an agreement made in September 1998 among 14 financial institutions for a $3.65 billion recapitalization (bailout).

John Meriwether, founder of LTCM, was "renowned as a relative-value trader" (Shirreff 1).

> Relative-value arbitrage is an investment strategy that seeks to take advantage of price differentials between related financial instruments, such as stocks and bonds, by simultaneously buying and selling the different securities—thereby allowing investors to potentially profit from the "relative value" of the two securities.
>
> Arbitrage involves buying securities on one market for immediate resale on another market in order to profit from a price discrepancy. But in the hedge fund world, arbitrage more commonly refers to the simultaneous purchase and sale of two similar securities whose prices, in the opinion of the trader, are not in sync with what the trader believes to be their "true value." Acting on the assumption that prices will revert to true value over time, the trader will sell short the overpriced security and buy the underpriced security. Once prices revert to true value, the trade can be liquidated at a profit (barclayhedge.com).
>
> Trades typical of early LTCM were, for example, to buy Italian government bonds and sell German Bond futures; to buy theoretically underpriced off-the-run US treasury bonds (because they are less liquid) and go short on-the-run (more liquid) treasuries. It played the same

[1] Buying stock with the expectation that the stock will rise or buying an options contract
[2] A short bond has a maturity of less than five years
[3] Selling a borrowed security, commodity, or currency or the sale of an options contract
[4] A long bond has a maturity of 12 or more years

> arbitrage in the interest-rate swap market, betting that the spread between swap rates and the most liquid treasury bonds would narrow. LTCM was one of the biggest players on the world's futures exchanges, not only in debt but also equity products (Shirreff 1-2).
>
> LTCM traded the credit spread between mortgage-backed securities (such as Danish mortgages) or double-A corporate bonds and the government bond markets. It also ventured into equity trades, selling equity index options. It also took positions in takeover stocks. SEC filings for June 30, 1998 showed that LTCM had stakes in 77 companies, worth $541 million. LTCM also traded in emerging markets such as Russia (Shirreff 2).

After the 1997 Asian crisis, the 1998 Russian crisis witnessed Russia defaulting on their bonds, causing a flight-to-liquidity. Investors then rushed into purchasing more stable US treasury bonds. Since LTCM's position reflected short (sell) positions in more liquid bonds and long (buy) positions in less liquid bonds, there was a huge gap in prices (US bonds price jumped, while Russian bond prices plummeted). In order to keep up the short positions before the prices converge, LTCM needed to have enough equity (margin call[5]) required by the clearing-house, which LTCM clearly did not have. With that LTCM took major losses[6], and unwound[7] other positions for reducing loss.

Although it is uncertain whether the ABM model will produce results similar (in other words, the model may show that an LTCM-like hedge fund's overall portfolio value has decreased similarly to 1998 crash levels) to that of the LTCM crash in 1998, the ABM model could have important potential to study general financial failure for hedge funds. Financial failure is defined as

[5] A broker's demand on an investor using margin to deposit additional money or securities so that the margin account is brought up to the minimum maintenance margin. Margin calls occur when your account value depresses to a value calculated by the broker's particular formula (Investopedia.com).
[6] September 2, 1998: John Meriwether sent a letter to his investors saying that the fund had lost $2.5 billion or 52% of its value that year (Shirreff 3)
[7] For example, LTCM had to liquidate a $2.3 billion position in Royal Dutch Petroleum and Shell Transport, two closely related stocks (Bloomberg)

extreme portfolio equity loss when equity lost exceeds equity required to cover losses. Value At Risk (VaR) traditionally computes a probability of when a certain equity level is not exceeded within a set number of business days. If the ABM model clearly demonstrates a higher likelihood of extreme events to include heavy portfolio loss for a LTCM-like hedge fund when compared to traditional approaches such as VaR, the proposed ABM model can become a feasible baseline in the future for other hedge funds with their own distinct trading strategies and inherent risks.

1.2 Capability Gap

Neoclassical Economics describes methods in economics which "became prominent in the late 19th century" and are "now the most widely taught form of economics" (Brennan 1; investopedia.com). It focuses on explaining the "determination of prices, outputs, and income distributions through supply and demand, often mediated through a hypothesized maximization of utility" (real numbers representing personal values) "by income-constrained individuals and of profits by cost-constrained firms and factors of production, in accordance with rational choice theory" (wikipedia.com).

Neoclassical Economics relies on three basic assumptions:

1. People have rational preferences among choices, and those preferences can be expressed as a value (utility).
2. "Individuals maximize utility and firms maximize profits" (wikipedia.com).
3. Individuals make choices based on perfect information independent of other individuals.

While these assumptions simplify an economic system and allow it to be studied analytically, they inject limitations. For example, if a person decides to make a purchase of some good, he

or she has taken into consideration all other possible things on which the money could be spent and has picked the best good at the best price. The purchase also hypothetically maximizes his or her utility. The person has also accounted for whether or not to save the money, which assumes perfect knowledge of current and estimated market movements, government intervention, etc. In reality, maximizing utility and acting on perfect information results in many calculations, involving information that may be hard to get if at all (confidential information). These assumptions do not properly reflect a model of human behavior.

> Neoclassical economics also assumes that if people want to trade, the economic system is out of equilibrium and therefore a more optimal allocation of goods exists. Once prices are established, people would be able to trade and move toward a more satisfied state. Once all people were satisfied, no trading then occurs and an equilibrium is reached. Prices are set by an auctioneer using a chosen good as money. As is standard in an auction, if there was more demand than supply, prices would increase, and if there was more supply than demand, prices would decrease. This is accomplished across all possible goods, and once prices are established, then people trade. Again, people act rationally in their own self-interest (Hagen 9).

Also, the use of an auctioneer makes the economic system mathematically simpler but also centralizes pricing. In reality, pricing is decentralized--some people buy goods at different prices than the best one due to “asymmetric information, strategic interaction, expectation formation on the basis of limited information, mutual learning, social norms, transaction costs, externalities, market power, predation, collusion, and the possibility of coordination failure” (Tesfatsion 6). “Market protocols, rationing rules, antitrust legislation, and other institutions” become important as economic entities--ensuring that economic order is maintained (Tesfatsion 6).

> Agent-based Modeling (ABM) addresses the potential gaps in using traditional and rational equilibrium models for computing risk events. ABM is the computational study of economic processes modeled as dynamic systems of interacting agents. An "agent" consists of data and behavioral mechanisms which represent an entity in a computationally constructed world. Agents could be "individuals (e.g. consumers, workers), social groupings (e.g. families, firms, government agencies), institutions (e.g. markets, regulatory systems), biological entities (e.g. crops, livestock, forests), and physical entities (e.g. infrastructure, weather, and geographical regions). Agents can then span from decision-making entities to entities with no cognitive capabilities (Tesfatsion 6).

Utilizing ABM can allow for empirical understanding (e.g. "why have particular observed regularities evolved and persisted despite the absence of top-down planning and control?"), normative understanding (e.g. "can good economic designs be discovered from modeling economic systems growing from the ground-up?"), and qualitative insight and theory generation (e.g. "can insight be gained about an economic system through how it changes over time using a fuller range of potential behaviors") (Tesfatsion 8-9).

This study will use the normative understanding aspect of ABM to model LTCM-like hedge funds and a few associated entities to study the dynamic properties of agent-to-agent interactions and their connection to potential financial crisis.

1.3 Stakeholders

Stakeholders for this study can be defined into two groups: first-order stakeholders and second-order stakeholders.

First-order stakeholders are defined as those by which the outcomes of this study are immediately impacted. Due to this definition, the first-order stakeholders are Dr. K. C. Chang, the study's sponsor, and the Systems Engineering and Operations Research Department faculty.

Second-order stakeholders are defined as those which could potentially use the results of this study. Due to this definition, second-order stakeholders primarily include finance and academic societies that are interested in assessing the utility of an ABM approach to quantifying financial risk. In addition, other second-order stakeholders may include interested academic and practicing economists, sociologists, mathematicians, etc. As the size of the second-order body of stakeholders is undefined and possibly large, these stakeholders cannot participate in the study directly. The results of the study, however, will be prepared such that a second-order stakeholder can understand and use the results as they need.

2. Technical Approach

As mentioned in section 1.2, the scope of this study is to simulate the interactions of hedge funds along with other relevant entities in order to ascertain if hedge fund interactions can lead to hedge fund failure. The failed hedge fund chosen as a blueprint for modeling is Long Term Capital Management (LTCM).

2.1 Problem-solving Methodology

The ABM model is specified in Repast Simphony. Repast "(REcursive Porous Agent Simulation Toolkit) toolkit was originally developed as a Java implementation...Repast is a free, open source agent-based modeling and simulation toolkit and has been widely used in various simulation applications" (Macal and North 95 - 96).

> Repast is designed to provide visual point-and-click tools for agent model design, agent behavior specification, model execution, and results examination. The developer can build and edit the ABM model within a Java Eclipse[8] environment, and can conveniently run the model in Eclipse for testing purposes. Once fully operational, the model can show visually how the ABM is doing over a specified period of time. Furthermore, results can be exported to easy to use formats for further data mining and statistical analysis (Macal and North 96).

The following set of steps based loosely on the Cross Industry Standard Process for Data Mining (CRISP-DM) generalizes the methodology used for model implementation.

1) Understand Market Context

The market context will center around three hedge funds, miscellaneous investors, banks, and regulators. Those three hedge funds reflect three different sizes based on equity amount. Initial

[8] Eclipse is a multi-language Integrated development environment (IDE) which can be used to develop applications in Java.

sizes start at one, five, and 10 billion U.S. dollars respectively. Behavior that the hedge funds exhibit are various trading strategies—convergence trades, interest rate swaps, and volatility trades.

A convergence trade is a trade that is designed to benefit from a price disparity between two assets. In the credit derivatives market, “convergence trades are often put on because the trader believes that the spreads of two similar or related credits will converge” (creditflux.com).

An interest rate swap is a contractual arrangement between two parties, or “counterparties”. The two counterparties agree to exchange payments based on a defined principal amount, for a fixed period of time. In an interest rate swap, the principal amount is not exchanged between the counterparties. The counterparties exchange interest rate payments based on a “notional principal.” Essentially, an interest rate swap exchanges one interest rate basis to a different rate basis, such as exchanging a floating rate to a fixed interest rate. The first counterparty makes floating rate payments to the second, and the second counterparty makes fixed-rate payments to the first.

Volatility trading can be made by trading options believed to be either undervalued or overvalued in the market. The traders buy these options in hope to buy or sell before the market corrects its prices, profiting from the market price adjustments. In general, traders execute trades by observing the implied (expected) volatility. If implied volatility for an option is high, which implies that the option is more expensive, and the trader believes the volatility will revert back to the mean, then the trader sells the option. If implied volatility is low, and the trader believes that the option value will rise, then the trader buys the option. Moreover, each trader has a subjective bias for what constitutes a significant trading opportunity, and therefore, the difference between the implied volatility and the forecast volatility must cross a certain

threshold (Rama). Traditional methods for forecasting volatilities are to use historical standard deviation of the log returns (Reider).

These are three main trades that LTCM used, and therefore are the three trades the hedge funds use in the model. Other associated agents such as lending banks and investors come into play and interact with the hedge fund agents.

2) Collect Data

The George Mason Bloomberg terminal is the main source of data in the ABM simulation to reflect real conditions as best as possible for a two year span based on data recent historical data. Data from 1997 to 1998 would be preferable since that is period in which LTCM failed, but the Bloomberg terminal does not archive historical options contract data, limiting the selection to current options data (approximately from 2013 to 2014). In addition, because the simulation requires approximately two months (58 days) of underlying security values, actual value data is from the beginning of 2011. In order to reconcile the mismatch in dates among the option contract expiration dates and security value data dates, option contract expiration dates were shifted back two years. Although this renders the data logically usable in the simulation, trade decisions made on future contract data based on historical security values introduces a source of uncertainty. The remaining data for the simulation starts in the beginning of 2011.

The breakdown of discrete data sources used per agent interaction type is given by the following table:

	Interest Rate Swap	**Loan Request**	**Convergence Trade**	**Volatility Trade**	**Contrarian Trade**	**Value Trade**
SPX 500 Daily Values (2011-2012)				✔	✔	✔

SPX 500 Call Options (2013-2014)				✔		
SPX 500 Put Options (2013-2014)				✔		
CAC Daily Values (2011-2012)				✔		
CAC Call Options (2013-2014)				✔		
CAC Put Options (2013-2014)				✔		
DAX Daily Values (2011-2012)				✔		
DAX Call Options (2013-2014)				✔		
DAX Put Options (2013-2014)				✔		
UK FTSE Daily Values (2011-2012)				✔		
UK FTSE Call Options (2013-2014)				✔		
UK FTSE Put Options (2013-2014)				✔		
US 30-Year Treasury Rate	✔	✔				
Historic Average 30-Year Treasury Rate	✔					
LIBOR Forward Rates	✔					
Current LIBOR Rates	✔					

Historic Average LIBOR Rates	✔					
Treasury Bond Price and Yield Spread			✔			

Table 1 - Model Financial Data Requirements

3) Specify Agent Types

Types are limited to hedge funds that contain similar LTCM arbitrage trading strategies, wealthy investors, lending banks, and the US Federal Reserve (acting as a regulator). The study populated the ABM system with 59 agents in total.

4) Specify Associated Rules

Each agent type has a set of well-defined rules that describes its behavior. For instance, LTCM-like hedge funds have a rule defined for handling long positions and one for short positions. Stochastic distributions are also considered to dictate the type of action taken and to what degree the action will be taken. This will ensure a greater level of randomness in the ABM results.

5) Associate Agents with Relevant Visual Contexts

In Repast, agents are required to be associated with contexts in which a context can be used to appropriately configure ABM visualizations. The ABM visualization in this project study maintains a network context for depicting between two agents an edge, which represents an interaction. The internal Repast simulation engine manages the scheduling of a pair of any two agents that are both available for an action.

The following is the agent to agent interaction matrix that contains a summary of the interaction logic used in the ABM simulation:

	Hedge Fund	Banks	Investors	Regulators
Hedge Fund	1) Volatility trade 2) Treasury convergence (assuming hedge fund counterparty already agrees)	1) Request loan 2) Interest rate swap trade	1) Volatility trade	N/A
Banks	1) Provide loan 2) Interest rate swap trade	1) Request and provide overnight loan at discount rate	N/A	1) Receive reserve requirement from regulator
Investors	1) Volatility trade	N/A	1) Volatility trade	N/A
Regulators	N/A	1) Set reserve requirement set interest rate	N/A	N/A

Table 2 - Agent Interaction Summation Matrix

6) Analyze Model Results

Repast easily presents data results in graphical or spreadsheet form. Output currently comprises of hedge fund equity changes and accumulated counts of trade types per hedge fund.

7) Form Insights and Finalize Conclusion

Each model run begins in January 2011 and is set for a length of approximately 58 trading days (limited by the amount of treasury convergence related data). All agents adhere to their own set of specified behavioral rules, and the collective interactions of all agents could form an overall emerging pattern at the end of each run. Taking the aggregated results over all runs as a Monte Carlo simulation, the likelihood of equity losses via VaR for the LTCM-like hedge fund agents are compared to the results from a conventional VaR model where the normal distribution is assumed.

2.2 Assumptions and Constraints

Assumptions for this study include:

1. Human behavior and cognition can be approximated and simulated using a set of rules specified in Repast.
2. When required data exists but cannot be found, notional data can be used as appropriate, and the use of such notional data will be documented.
3. The final set of agents specified constitutes an appropriate set of entities required for a realistic ABM financial model.
4. Results from the ABM model can be extended to other financial institutions.
5. Each agent can take multiple actions per day among other agents.
6. The hedge funds will always be the buyer (i.e. pay the fixed rate payments) and the banks will always be the seller (i.e. pay the floating rate payments) in an interest swap trade.
7. Modeling hedge fund trading can be realistically modeled by having the type of trade chosen by a hedge fund dependent on comparing a uniform random variable to a discrete probability distribution.

8. Modeling bank loan interactions can be realistically modeled as banks lending only to hedge funds and other banks. When banks lend to other banks, the loan period is only for one day, and the interest rate on the loan is the discount rate for that day.

9. The starting deposit base of each bank can be realistically modeled as a set notional value. The changing of this deposit base can be realistically modeled as adding or subtracting a random amount per day.

10. Interest rate swaps can be realistically modeled as having either a maturity of three years or two years. The three year maturity interest rate swaps have semi-annual payments, while the two year maturity interest rate swaps have quarterly payments.

11. Banks accept hedge fund request for loans and interest rate swaps based on comparing a uniform random variable between 0 and 1 to a threshold value. If the random variable meets the threshold value, the bank will accept the loan or the interest rate swap as long as the bank's net asset value is greater than its reserve requirement as dictated by the regulator agent.

12. Bank overnight loan requests can be realistically modeled as comparing a uniform random variable between 0 and 1 to a threshold value.

13. All hedge fund portfolios can be realistically modeled into three different kinds of categories: large with $10 billion equity, mid-size with $5 billion equity, and small with $1 billion equity.

14. The reserve requirement can be modeled as a single percentage of deposit base set at 3% (federalreserve.gov).

15. Hedge fund to bank interactions can be realistically modeled without modeling margin calls.

16. As margin calls are modeled and with the current market data, convergence trades will generate a profit for the hedge funds most of the time.

17. Interest rates for loans can be realistically modeled as the current US 30-year treasury rate.

18. Convergence trades in this model already assume the counterparty has already accepted the other side of the long and short positions.

19. Volatility trading execution based on standard deviation of past log returns constitutes a reasonable forecast.

20. The contrarian and value trades can be realistically modeled using fixed values for December 2013 call and put options.

21. The contrarian and value trades can be realistically modeled to long and short on option index, not underlying index stocks. A probability distribution between 0 and 1 is also used in implementing this trade.

22. At the end of one trial simulation, an equity result below 50% of the original starting equity for that hedge fund is considered a failure.

23. Once a hedge fund reaches $0 in equity, the hedge fund stops trading.

Constraints for this study include:

1. The period of performance for this study is 29 August 2013 to 13 December 2013.

2. Study scope--as mentioned in Section 1.2, modeling the global economy in infeasible given constraint 1. Therefore the study will focus on modeling hedge funds and its interactions with related entities.

3. Access to original hedge fund financial data might be limited in scope. Also, all the detailed data will not be fully incorporated into the model based on ABM.

4. The work will be accomplished utilizing three study members, all of which are graduate students at George Mason University.

2.3 Inputs

The following is a listing of the inputs required for the model. To see the actual values used, please refer to Appendix B.

1. Hedge fund initial equity
2. Model start date
3. Decide action threshold
4. Perform strategy thresholds for hedge funds
5. Interest rate swap type choice threshold for hedge funds
6. Interest rate swap decision threshold for interest rate swaps
7. Bank loan decision threshold for hedge fund loan requests
8. Bank loan decision threshold for bank overnight loan requests
9. Bank decision threshold to ask for overnight loan from other bank
10. LIBOR[9] and LIBOR Forward[10] rates
11. Discount rates[11] and reserve requirements[12]
12. US 30-year treasury rates
13. Historic US 30-year treasury rates
14. Historic LIBOR Average
15. Bond and yield rates
16. France CAC[13] rates

[9] The London Interbank Offered Rate is the average interest rate estimated by leading banks in London that they would be charged if borrowing from other banks. It is usually abbreviated to Libor or LIBOR, or more officially to BBA Libor (for British Bankers' Association Libor) or the trademark bbalibor. It is the primary benchmark, along with the Euribor, for short term interest rates around the world. Libor rates are calculated for ten currencies and fifteen borrowing periods ranging from overnight to one year and are published daily at 11:30 am (London time) by Thomson Reuters. Many financial institutions, mortgage lenders and credit card agencies set their own rates relative to it. At least $350 trillion in derivatives and other financial products are tied to the Libor (Wikipedia)

[10] The forward rate is the future yield on a bond. It is calculated using the yield curve. For example, the yield on a three-month Treasury bill six months from now is a forward rate (Wikipedia)

[11] Interest rate that an eligible depository institution is charged by its Federal Reserve Bank to borrow funds (usually for a short-term period). There are three discount rates (primary credit rate, secondary credit rate, seasonal credit rate, and the adjustment credit rate)

[12] Amount that a bank must maintain either in its own vault or at a Federal Reserve Bank in order to cover deposit liabilities

17. France CAC call[14] rates

18. France CAC put[15] rates

19. Germany DAX[16] rates

20. Germany DAX call rates

21. Germany DAX put rates

22. SPX[17] 500 rates

23. SPX 500 call rates

24. SPX 500 put rates

25. United Kingdom (UK) FTSE[18] rates

26. UK FTSE call rates

27. UK FTSE put rates

28. Bond and yield rates

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[13] The CAC 40 is a benchmark French stock market index. The index represents a capitalization-weighted measure of the 40 most significant values among the 100 highest market caps on the Paris Bourse (now Euronext Paris). It is one of the main national indices of the pan-European stock exchange group Euronext alongside Brussels' BEL20, Lisbon's PSI-20 and Amsterdam's AEX (Wikipedia)

[14] An option contract giving the owner the right (but not the obligation) to buy a specified amount of an underlying security at a specified price within a specified time (Investopedia)

[15] An option contract giving the owner the right, but not the obligation, to sell a specified amount of an underlying asset at a set price within a specified time. The buyer of a put option estimates that the underlying asset will drop below the exercise price before the expiration date

[16] The DAX (Deutscher Aktien IndeX, formerly Deutscher Aktien-Index (German stock index)) is a blue chip stock market index consisting of the 30 major German companies trading on the Frankfurt Stock Exchange. Prices are taken from the electronic Xetra trading system. According to Deutsche Börse, the operator of Xetra, DAX measures the performance of the Prime Standard's 30 largest German companies in terms of order book volume and market capitalization (Wikipedia)

[17] The S&P 500, or the Standard & Poor's 500, is a stock market index based on the market capitalizations of 500 large companies having common stock listed on the NYSE or NASDAQ. The S&P 500 index components and their weightings are determined by S&P Dow Jones Indices. It differs from other U.S. stock market indices such as the Dow Jones Industrial Average and the Nasdaq Composite due to its diverse constituency and weighting methodology. It is one of the most commonly followed equity indices and many consider it the best representation of the U.S. stock market as well as a bellwether for the U.S. economy (Wikipedia)

[18] The FTSE 100 Index, also called FTSE 100, FTSE, or, informally, the "footsie" is a share index of the 100 companies listed on the London Stock Exchange with the highest market capitalization. It is one of the most widely used stock indices and is seen as a gauge of business prosperity for business regulated by UK company law. The index is maintained by the FTSE Group, a subsidiary of the London Stock Exchange Group (Wikipedia)

2.4 Algorithms and Specification

Agent Type: Hedge Fund

Number Represented in System: 3

Agent Description:

The hedge fund agents will be based on Long Term Capital Management (LTCM), its overall investment strategy, and its internal trading operations. Hedge funds are primarily interested in taking advantage of arbitrage opportunities in the market to profit, but to accomplish this, hedge funds sometimes require high leverage, or borrowed capital usually from banks, to perform high-volume trading to even make substantial profit. The arbitrage can take many forms, and hedge funds have developed different trades as a result. LTCM primarily used three different types of trades:

1. Convergence Trade
2. Interest Swap Trade
3. Volatility Trade

The trades reflect the magnitude of some of the reported losses at LTCM in September 1998: $1.6 billion in swaps; $1.3 billion in equity volatility; $430 million in Russia and other emerging markets, etc. (Ganesh).

When each hedge fund agent is first instantiated in the model, all agents shall have empty portfolios and an initial amount of initial capital.

Initial Parameters:

Initial Equity: This describes the initial capital value the hedge fund will start with in January 2011.

Agent Operations/Rules:

1. Decide Action: This is a high level operation for the hedge fund in which a discrete probability distribution determines what lower level operation to do. A lower level operation includes the following: perform strategy or do nothing. The remaining operations purchase, sell, etc. are sub-operations associated with perform strategy (e.g. execute a convergence trade by purchasing on shorter maturity bonds and selling on longer maturity bonds, etc.). Below are the rules for the discrete probability distribution used.

a. If R <= RQ, where R is a uniform random variable, RQ is the threshold for performing a strategy

a.1) Perform strategy

b. If R > RQ, where R is a uniform random variable, RQ is the threshold for performing a strategy

b.1) Do nothing

2. Perform Strategy: When an agent performs a strategy, a discrete probability distribution is applied to decide which trade to perform during one trading day, resulting in added randomness. The probabilities for all three available strategies will initially be equal, but sensitivity analysis later in the results phase can accommodate changes to the probabilities. Any changes shall be noted.

a. If R1 <= RQ1, where R1 is a uniform random variable and RQ1 is the threshold for performing a convergence trade (Treasury bond swap)

a.1) Perform convergence trade (Treasury bond swap)

b. If R2 <= RQ2, where R2 is a uniform random variable, and RQ2 is the threshold for performing an interest rate swap

b.1) Perform interest rate swap

c. If R3 <= RQ3, where R3 is a uniform random variable, and RQ3 is the threshold for performing a volatility trade

c.1) Perform volatility trade

3. Convergence Trade (Treasury Bond Swap):

Background: Convergence trades were used as one of the main trading strategies by LTCM. The concept of this strategy is relatively easy; however, unforeseeable risks can still arise and results in losses. As mentioned previously, a convergence trade is defined as a trade where future prices converge to cash prices when the contract is near expiration (Investopedia). In this case, government bonds serve as convergence trading tools.

The trade consists of two positions – long and short. The investor will execute these two positions simultaneously in order to capture a profit. Often, the investor will short the on-the-run[19] bond (which is newly issued with longer maturity), and long off-the-run[20] bond. Once issued, the on-the-run bond tends to have a higher value than the other bond and will converge to a lower price after a few days. If the investor times it right, he will likely to capture profit resulted from the price difference.

[19] The on-the-run bond or note is the most frequently traded Treasury security of its maturity. Because on-the-run issues are the most liquid, they typically trade at a slight premium and therefore yield a little less than their off-the-run counterparts. Some traders successfully exploit this price differential through an arbitrage strategy that involves selling (or going short) on-the-run Treasuries and buying off-the-run Treasuries.

[20] Once a new Treasury security of any maturity is issued, the previously issued security with the same maturity becomes the off-the-run bond or note. Because off-the-run securities are less frequently traded, they typically are less expensive and carry a slightly greater yield (Investopedia).

[20]

But where do investors get the securities to make a short sell? The answer is borrowing from another financial entity. Of course, this comes with associated costs such as commission and a collateral holding fee.

LTCM executed trades that are very similar to what is described above only with Russian bonds. The proximate cause for LTCM's debacle was Russia's default on its government obligations (GKOs). LTCM believed it had somewhat hedged its GKO position by selling rubles. In theory, if Russia defaulted on its bonds, then the value of its currency would collapse and a profit could be made in the foreign exchange market that would offset the loss on the bonds.

Unfortunately, the banks guaranteeing the ruble hedge shut down when the Russian ruble collapsed, and the Russian government prevented further trading in its currency (The Financial Post, 9/26/98). While this caused significant losses for LTCM, these losses were not even close to being large enough to bring the hedge fund down. Rather, the ultimate cause of its demise was the ensuing flight to liquidity (Sungard, Bancware Erisk).

The ultimate cause of the LTCM debacle was the "flight to liquidity" across the global fixed income markets. As Russia's troubles became deeper and deeper, fixed-income portfolio managers began to shift their assets to more liquid assets. In particular, many investors shifted their investments into the U.S. Treasury market. In fact, so great was the panic that investors moved money not just into Treasuries, but into the most liquid part of the U.S. Treasury market -- the most recently issued, or "on-the-run" Treasuries. While the U.S. Treasury market is relatively liquid in normal market conditions, this global flight to liquidity caused the spread between the yields of on-the-run Treasuries

and off-the-run Treasuries to widen dramatically. Even though the off-the-run bonds were theoretically cheap relative to the on-the-run bonds, they got much cheaper still (on a relative basis).

What LTCM had failed to account for is that a substantial portion of its balance sheet was exposed to a general change in the "price" of liquidity. If liquidity became more valuable (as it did following the crisis) its short positions would increase in price relative to its long positions. This was essentially a massive, un-hedged exposure to a single risk factor.

As an aside, this situation was made worse by the fact that the size of the new issuance of U.S. Treasury bonds has declined over the past several years. This has effectively reduced the liquidity of the Treasury market, making it more likely that a flight to liquidity could dislocate this market (Sungard, Bancware Erisk).

Bottom line, the spread in trading Treasury bonds was much more overpriced than what LTCM had accounted for. This led to a large requirement on a margin call and thus became one of the main reasons why LTCM became bankrupt.

As for on the run/ off the run spread—the spread is calculated by subtracting the on-the-run Treasury yield by the off-the-run treasury yield. Treasury bonds with same maturity dates should have similar yield rate; however, historically an on-the-run (newer) bond tends to have a lower yield with a higher premium than an off-the-run yield. The off-the-run yield is used to construct a yield curve. The spread will be equal to the on-the-run yield (newly issued date) - the off-the-run yield.

The convergence trade (Treasury bond swap) in the ABM model is modeled after LTCM.

a. Short newly issued bond with higher price

a.1) Long the older bond

a.2) Short sell the new bond, upon issuance

a.3) Purchase the old bond in order to lock in a bet on the spread

a.4) Hold the spread position until the next auction date, then unwind the smaller spread of potentially 3bps

a.5) Spread new and old bond will converge toward zero as time passes. Short new bonds and purchasing old bonds have potentials to guarantee profit (Arvind Krishnamurthy)

a.6) Define: new bonds "on the run" - 30 year American Treasury bond and old bonds as "off the run" - 30 years bond but issued auction 6 months earlier

b. Execute the trade

b.1) If spread ≥ 12: execute short sell and buy old bond

b.2) If spread ≤ 3: stop trade and unwind positions (long new, sell old)

c. Execute the trade: Trade mechanics

c.1) The trader deposits cash equal to bonds (P(t)) with which the reverse[21] is conducted. Settlement on this transaction is the same day.

c.2) If the short is reversed tomorrow, the trader buys back the bonds for settlement the following day and delivers the bonds against the overnight reverse, and receives back the cash that was deposited plus interest.

(Arvind Krishnamurthy).

d. Profit Calculation:

[21] When the trader deposits cash, the other party deposits the bonds. The position is then reversed when the borrowing period expires.

d.1) Profit from purchasing Θ(tn) units of the old bond on tn. Unwinding position at tn+1:

d.1.1) $\Theta(tn)(P(tn+1) - P(tn))$ (1)

d.2) Profit from Shorting Θ' (tn) units of new bond on tn:

d.2.1) $-\Theta'(tn)(P'(tn+1) - P'(tn))$ (2)

d.2.2) From (1) and (2), profit π(tn):

d.2.2.1) $\Theta'(tn)DP'(tn) = \Theta(tn)DP(tn)$ (3)

d.2.2.2) → Θ(tn) = free variable

d.2.2.3) Total Profit = (3)

d.3) If (3) > 0, record a profit

d.4) If (3) < 0, record a loss (record in another column)

d.5) If total loss (add up all losses) ≥ percentage of profit, unwind positions → this is a day to day Trade (Business day)

4. Interest Rate Swap

Background: LTCM entered into interest rate swaps where it paid to its counterparty if "yield spreads between LIBOR-based instruments and government bonds widened, but would receive payments from its counterparty if yield spread on bonds narrowed" (Edwards 10). LTCM would take the fixed rate position (i.e. LTCM would be the buyer, the other counterparty the seller). LTCM had swap positions in the U.S., Belgium, Denmark, France, Germany, Great Britain, Hong Kong, Italy, the Netherlands, New Zealand, Spain, Sweden, and Switzerland.

a. Compute Swap Rate

a.1) If R <= RQ, where R is a uniform random variable and RQ is the threshold for deciding whether to use a 3-year semi-annual interest rate swap payment cycle

a.1.1) Use a 3-year semi-annual interest rate swap payment cycle

a.2) If R > RQ, where R is a uniform random variable and RQ is the threshold for deciding whether to use a 3-year semi-annual interest rate swap payment cycle

a.2.1) Use a 2-year quarterly interest rate swap payment cycle

a.3) Calculate Present Value (PV) of floating rate payments

a.3.1) Compute time periods for payments

a.3.2) Compute period number for time periods

a.3.3) Compute days in period (i.e. 180 days for semi-annual frequency, 90 days for quarterly frequency)

a.3.4) Match annual forward rate to time period

a.3.5) Compute period forward rate (e.g. if annual forward rate for period p is 4.0%, semi-annual forward period rate for period p is 4.0%/2 = 2.0%)

a.3.6) Compute actual floating rate payment at end of time period (e.g. =principal*results from step a.3.5 for time period p)

a.3.7) Compute floating rate discount factor for time period (e.g. 1/[(1+forward rate for time period 1)(1+forward rate for time period 2)…(1+forward rate for time period p)])

a.3.8) Compute PV of floating rate payment at end of period (=result from step a.3.6*result from step a.3.7 for time period p)

a.3.9) Sum PV floating rate payment for all time periods (=PV floating rate payment for time period 1 + PV floating rate payment for time period 2 + … + PV floating rate payment for time period p)

a.3.10) Update forward rate for time period with actual rate for time period to compute actual payment for period

a.4) Calculate PV of fixed-rate payments

a.4.1) Compute time periods for payments

a.4.2) Compute period number for time periods

a.4.3) Compute period length (i.e. 180 days for semi-annual frequency, 90 days for quarterly frequency)

a.4.4) Match annual forward rate to time period

a.4.5) Compute period forward rate (e.g. if annual forward rate for period p is 4.0%, semi-annual forward period rate for period p is 4.0%/2 = 2.0%)

a.4.6) Match principal to time period (principal should be the same for every time period)

a.4.7) Compute floating rate discount factor for time period (e.g. 1/[(1+forward rate for time period 1)(1+forward rate for time period 2)…(1+forward rate for time period p)])

a.4.8) Compute PV of principal at end of period (=principal for period*(period length/360)*result from step a.4.7 for period)

a.4.9) Sum PV principal for all time periods (=PV principal for time period 1 + PV principal for time period 2 + … + PV principal for time period p)

a.4.10) Update forward rate for time period with actual rate for time period to compute actual payment for period

a.5) Calculate swap rate

a.5.1) Swap rate = result from step a.3.9 / result from step a.4.9

b. Compare published reference rates for swap maturity to historical averages

b.1) If LIBOR rate for time periods > historical LIBOR for time period

b.1.1) Buy swap (i.e. pay fixed rate--bet that the spread will narrow)

b.2) If government bond yield < historical yield for time period

b.2.1) Buy swap (i.e. pay fixed rate--bet that the spread will narrow)

b.3) If LIBOR rate for time periods <= historical LIBOR for time period

b.3.1) Do nothing

b.4) If government bond yield <= historical yield for time period

b.4.1) Do nothing

5. Volatility Trade

Background: Volatility trading is one of three main trading strategies LTCM employed during the late 1990s leading up to the 1998 portfolio disaster. LTCM made numerous volatility trades on markets' indices such as S&P 500, France's CAC, Germany's DAX, and United Kingdom's FTSE (Marthinsen). During market turbulence in 1997 and 1998, LTCM executed volatility trades on a variety of these financial index instruments to take advantage of the arbitrage opportunity presented by inaccurate volatility of the index.

Volatility trading can be made by trading options believed to be either undervalued or overvalued in the market. The traders buy these options in hope to buy or sell before the market corrects its prices, profiting from the market price adjustments. In general, a trader executes trades by observing the implied (expected) volatility. If implied volatility for an option is high, which implies that the option is more expensive, and the trader believes the volatility will revert back to a forecast volatility, then the trader sells the option. If implied volatility is low, and the trader believes that the option value will rise, then the trader buys the option. Moreover, each trader has a subjective bias for what constitutes a significant trading opportunity, and therefore, the difference between the implied volatility and the forecast volatility must cross a certain threshold (Rama). Traditional methods for forecasting volatilities are to use historical standard deviation of the log returns (Reider).

The heart of the trade is mathematically based on the Black-Scholes formula. The Black-Scholes formulas are as follows:

$$C(S,t) = N(d_1)S - N(d_2)Ke^{-r(T-t)}$$

$$d_1 = \frac{1}{\sigma\sqrt{T-t}}\left[\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)\right]$$

$$d_2 = \frac{1}{\sigma\sqrt{T-t}}\left[\ln\left(\frac{S}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)(T-t)\right]$$

$$= d_1 - \sigma\sqrt{T-t}$$

$$P(S,t) = Ke^{-r(T-t)} - S + C(S,t)$$

$$= N(-d_2)Ke^{-r(T-t)} - N(-d_1)S$$

As shown in the above equations, the call and put options are priced based on several variables: the underlying stock price (S), exercise price (K), time to expiration (T), risk free interest rate (r), and volatility (σ).

In addition, it is possible to back out the implied volatility based on what the market thinks is the value of the option contract. Implied volatility has 1-to-1 correspondence relationship with the option price. Traders use implied volatility instead of options' prices. To back out the implied volatility from the Black-Scholes formula, the computation enters the five variables other than volatility into the formula and solves for volatility.

a. Compute a forecast volatility based on historical return information. It shall be the standard deviation of log returns.

b. Compute the implied volatility by inverting the Black-Scholes formula to solve for sigma based on the historical market price of option.

c. Compute threshold for all agents involved in volatility trading based on a notional probability distribution such as a normal random variable with parameters N(100, 20) in terms of percentage basis points. Each agent is then assigned a normal random variate, which becomes its threshold at the current time step.

d. Compute the difference between forecast volatility and implied volatility.

d.1) If $|\sigma_f - \sigma_i| \geq \varepsilon(t)_k$

d.1.1) Proceed to make comparison between forecast volatility and implied volatility.

d.1.2) If $\sigma_f > \sigma_i$

d.1.2.1) Purchase the options contract on expectation that the option value will rise.

d.1.2.2) Hedge by selling underlying stock to keep portfolio delta-neutral. Calculation is performed by taking delta (change in price of option with respect change in price of stock at one time step) and multiplying that with amount of stock represented by option purchase.

d.1.2.3) (Optional) Choose a dynamic hedging or static hedging approach.

d.1.3) If $\sigma_f < \sigma_i$

d.1.3.1) Sell the options contract on expectation that the option value will fall.

d.1.3.2) Hedge by purchasing underlying stock to keep portfolio delta-neutral. Calculation is performed by taking delta (change in price of option with respect change in price of stock at one time step) and multiplying that with amount of stock represented by option purchase.

d.1.3.3) (Optional) Choose a dynamic hedging or static hedging approach.

d.1.4) If $\sigma_f = \sigma_i$

d.1.4.1) Do nothing

d.2) If $|\sigma_f - \sigma_i| < \varepsilon(t)_k$

d.2.1) Agent does not act on implied volatility information.

e. Compute current profit based on previous comparison

e.1) If long on option with no commission fees, then profit is $(v_f - v_i)*n - \Delta(100*n)(s_p - s_e)$ where n is the number options contracts purchased.

e.2) If short on option with no commission fees, then profit is $(v_i - v_f)*n - \Delta(100*n)(s_e - s_p)$ where n is the number options contracts sold.

6. Request Leverage

a. If a hedge fund does not have enough equity on hand (E) to make a trade (TE) (If E <= TE)

a.1) Request loan of size E from bank, with interest rate i and payments on E every 30 days

Agent Type: Investors

Number Represented in System: 50

Agent Description:

Other investors in the ABM system shall comprise the majority of initiated agents. These investors may loosely model extremely wealthy investors, and in the market, could have influential effects such as perturbing spreads among bonds or affecting the value of stock.

There is an assumption that these investors are either value or contrarian investors despite having access to the same type of trading operations a hedge fund agent has. As a value oriented investor, individuals or institutions rely on future potential company earnings, and discount them to present for evaluation. As a contrarian investor, the trader tends to trade against the wisdom of the market in hopes that the market is wrong.

In addition, investors are allowed to perform volatility trades with other investors and hedge funds.

Initial Parameters:

Initial Equity

Agent Operations/Rules:

1) Decide Action: This is a high level operation for the investor in which a discrete probability distribution shall determine what lower level operation to do. A lower level operation includes the following: perform strategy and do nothing. The remaining operations purchase and sell are sub-operations associated with perform strategy (e.g. purchase treasury bonds, etc). Below is a notional fixed discrete probability distribution.

a. If R <= RQ, where R is a uniform random variable, RQ is the threshold for performing a strategy

a.1) Perform strategy

b. If R > RQ, where R is a uniform random variable, RQ is the threshold for performing a strategy

b.1) Do nothing

2. Perform Strategy:

a. If value-oriented, then compute forecast of financial instrument's future value discounted to present. If this is higher/lower than the trader's expectation, then perform appropriate trade (long or short).

a.1) Perform value trade

b. If contrarian, then compute deviation percentage from historical mean. If this deviation is greater than the result of a uniform random variate -- U(0,1) -- then accept the contrarian play (long or short).

b.1) Perform contrarian trade

c. Investor performs volatility trade (full description given in the hedge fund above).

Agent Type: Banks

Number Represented in System: 5

Agent Description:

Hedge funds can borrow money (margin loan) from a bank. When a hedge fund borrows money from a bank, the bank requires the hedge fund to provide securities for collateral. In fact, "banks are the main source of credit for hedge funds" (Gatev 6). Borrowing cash from a bank allows a hedge fund to make larger bets on their investments--the hedge fund will then have higher profits for positive returns and "incrementally higher losses" when investments fail to have higher returns (Stowell).

The duration of the margin loan is typically "short-term" (Gatev 7). Banks "have an advantage in hedging systematic liquidity risk because their transaction deposits, protected by FDIC insurance and an implicit government safety net, receive liquidity during short-term flights to quality" (Gatev 8).

Some banks that interacted with LTCM were: Citigroup, Chase Manhattan, Merrill Lynch, Goldman Sachs, J.P. Morgan, UBS, Credit Suisse, Deutsche Bank, Sumitomo (Holson and O'Brien).

Banks will also be the counterparty with LTCM on the interest rate swap. Banks will be the seller (i.e. pay floating rate payments) of an interest rate swap.

Initial Parameters:

Bank initial deposit base

Bank initial hedge loan amount

Federal Reserve requirement for bank

Interest rates

Bank net asset value

Initial interest rate swap payment

Agent Operations/Rules:

1. Update bank deposit base: $D_j = D_{j-1} + \Delta D$, where D is the deposit base value, j is the current tick count, and j-1 is the previous tick count

2. Update Federal Reserve requirement (input from fed agent)

3. Compute bank net asset value: $V_j = D_j + \Sigma(i*P_j) + \Sigma(bi*BP_j) + SI_j - SO_j$ where V is the net asset value, D is the deposit base value, i is the agreed upon interest rate for the hedge fund loan, P is the principal left on the hedge fund loan, bi is the interest rate for an overnight bank loan, BP is the principal of the overnight bank loan, SI is the interest rate swap payment made to the bank by the hedge fund, SO is the interest rate swap payment made by the bank to the hedge fund, j is the current tick count

4. Consider hedge fund loan request, if a hedge fund has made a request

a. If $V_j - P < F_j$ and R > RQ where V is the net asset value, P is the hedge fund loan request (principal), F is the reserve requirement amount (deposit base * reserve requirement), R is a uniform random variable, RQ is the threshold for accepting a loan, and j is the current tick count

a.1) Do not lend to hedge fund

b. If $V_j - P > F_j$ and R <= RQ where V is the net asset value, P is the hedge fund loan request (principal), F is the reserve requirement amount (deposit base * reserve requirement), R is a uniform random variable, RQ is the threshold for accepting a loan, and j is the current tick count

b.1) Lend to hedge fund

b.2) Update net asset value $V_j = V_{j-1} - P$, where V is the net asset value, P is the hedge fund loan request (principal)

5. Ask for overnight loan from another bank

a. If R > RQ, where R is a uniform random variable, RQ is the threshold for asking for a loan

a.1) Ask for an overnight loan from bank

6. Consider bank loan request, if a bank has made a request

a. If $V_j - BP < F_j$ or R > RQ where V is the net asset value, BP is the bank loan request (principal), F is the reserve requirement amount (deposit base * reserve requirement), R is a uniform random variable, RQ is the threshold for accepting a loan, and j is the current tick count

a.1) Do not lend to bank

b. If $V_j - BP > F_j$ and R <= RQ where V is the net asset value, P is the hedge fund loan request (principal), F is the reserve requirement amount (deposit base * reserve requirement), R is a uniform random variable, and RQ is the threshold for accepting a loan, and j is the current tick count

b.1) Lend to bank

b.2) Update net asset value $V_j = V_{j-1}$ - BP, where V is the net asset value, BP is the bank loan request, and j is the current tick count

7. Consider interest rate swap with hedge fund, if a hedge fund has made a request

a. If V_j - SO < F_j or R > RQ, where R is a uniform random variable, and RQ is the threshold for accepting an interest rate swap request, V is the net asset value, SO is the current interest rate swap payment the bank would make, F is the reserve requirement amount (deposit base * reserve requirement), and j is the current tick count

a.1) Do not take interest rate swap

b. If V_j - SO > F_j and R <= RQ, where R is a uniform random variable, and RQ is the threshold for accepting an interest rate swap request, V is the net asset value, SO is the current interest rate swap payment the bank would make, F is the reserve requirement amount (deposit base * reserve requirement), and j is the current tick count

b.1) Enter into interest rate swap with hedge fund

b.2) Update net asset value $V_j = V_{j-1}$ - SO, where V is the net asset value, SO is the current interest rate swap payment, and j is the current tick count

Agent Type: Regulator

Number Represented in System: 1

Agent Description:

The regulator agent shall be largely modeled after the U.S. Federal Reserve. The Federal Reserve utilizes “tools” of monetary policy to affect inflation, economic output, and employment. These tools are:

1) Discount Rate

2) Reserve Requirements

Initial Parameters:

January 2011 Reserve Requirements

January 2011 Discount Rate

Agent Operations/Rules:

1. Get reserve requirement: At every tick count, the banks call the reserve requirement, which is held by the regulator. The regulator opens a csv file holding the reserve requirement, loops through the dates, finds the date in the file corresponding to the current tick count, and returns the current reserve requirement to the bank.

2. Get discount rate: When a bank asks for a loan from another bank and if the bank accepts the loan request, the banks need the discount rate in order to set the price for the asking bank to borrow money overnight. The regulator opens a csv file holding the discount rates, loops through the dates, finds the date in the file corresponding to the current tick count, and returns the current discount rate to the banks.

2.5 Verification

Verification is defined as “the process of evaluating work-products (not the actual final product) of a development phase to determine whether they meet the specified requirements for that phase” (Software Testing Fundamentals). In other words, verification is the process of testing whether or not the product was built correctly.

Verification for the ABM model was accomplished in two phases, as code was constructed by all project team members. The first phase was testing by individual team members of their project

code. This was accomplished by giving code starting data, running the code, and checking the output to see if the results of the code matched the expected results--essentially giving the code the starting values for a problem for which the testers already knew the answer. If the code's answer did not match the expected answer, the code was checked and modified until the output matched the expected results. The second phase of testing was accomplished as individual team member's code was integrated together. This was accomplished in the same manner as the first phase, but the testing was accomplished by one tester. The tester ran the code, checked the output, and informed the other team members when code output did not match results. During the integrated code testing process, the tester set breakpoints in the code, so that way when code output was not as expected, the tester had an indication as to where the errors were being injected. Corrections were made by all team members until the code output matched expected results.

3. Results

In the model, LTCM was taken as a template, and some of its primary arbitrage strategies were used as to scope the kinds of actions the three hedge funds in the simulation take. The analysis that proceeds takes this into consideration. The three model hedge funds are examined with different initial equity values. The large hedge fund has an initial equity of $10 billion, the medium hedge fund with $5 billion, and the small hedge fund with $1 billion. Furthermore, each hedge fund has a different probability that it will take a trade action - 0.30 for the small fund, 0.60 for the medium fund, and 0.90 for the large fund. When a hedge fund takes an options contract or stock position, the same set of trade volumes are available to all three hedge funds.

To test how these hedge funds perform, there is a baseline batch of 20 model runs for 58 trading days. Then, there is a second batch run of 40 trials to understand how much variance reduction will impact the accuracy of the results. Note that batch runs were done manually in the context of result testing owing to some challenges in automating batch runs. After the first two model batch runs, there are two test cases where the model parameters are changed to understand how changing the initial conditions will impact model results. Both test cases are set up so that no convergence trade would take place and the other two trading strategies would be greedily considered all the time (in other words, each hedge fund will always execute an action, and for each action, a volatility trade or an interest rate swap is always considered). In removing the convergence trades, this allows for increasing the model timeframe from 58 trading days to 221 trading days. In the second test case, one additional change was made: the number of investors is increased to 100.

For the purposes of understanding the results, fund 1 refers to the small fund, fund 2 refers to the medium fund, and fund 3 refers to the large fund.

Baseline – 20 trials

Rationale: It was determined that 20 batch trials was manually feasible to process. Since each trial replication length is set to 58 trading days, this amounts to approximately 1,000 data points of equity change per hedge fund type, which is enough to conduct a VaR comparison with the financial industry's conventional way of doing VaR. The average equities for every trial for each of the three hedge funds are shown in Table 3:

Trials' averages		
Fund 1	Fund 2	Fund 3
1,208,848,650.39	5,091,370,496.99	4,115,317,068.88
1,030,627,057.53	4,299,688,754.23	7,165,808,926.38
1,019,579,301.48	5,063,288,708.80	6,574,178,291.08
1,040,230,817.51	566,396,880.38	6,990,219,278.88
1,025,770,750.55	5,050,561,242.29	10,083,627,954.84
1,073,885,890.53	1,213,937,498.66	10,081,688,280.85
1,016,212,740.99	1,859,800,898.89	10,036,943,110.70
1,016,299,680.04	3,125,424,285.16	7,306,986,294.38
300,362,464.45	5,092,824,595.82	10,140,539,343.49
490,190,514.91	5,078,330,267.62	10,149,256,950.63
1,044,673,164.90	5,043,284,302.54	10,076,223,850.95
1,004,051,854.23	5,148,736,398.29	10,114,955,371.65
282,913,725.68	5,046,147,528.16	5,704,648,577.92
108,823,658.29	1,928,110,247.13	10,062,405,707.98
1,037,585,434.69	5,039,893,908.75	10,069,181,933.48
53,166,734.41	5,071,351,293.92	4,041,381,071.24
181,988,579.71	5,038,599,664.90	10,127,013,846.21
288,135,593.22	2,296,029,893.24	10,061,382,918.05
116,580,353.74	5,075,041,200.05	10,104,480,569.82
1,041,084,356.07	795,689,676.40	5,397,563,640.21

Table 3 - Average Equity at the End of 58 Trading Days (Baseline)

Below are graphs for each of the individual hedge funds depicting per trial ending equity average:

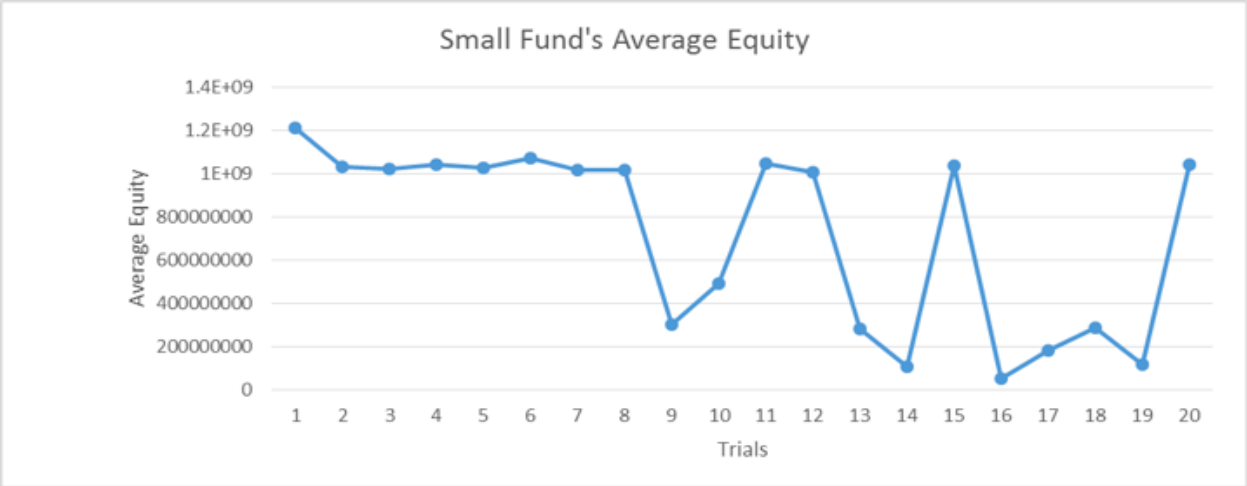

Figure 1: Small Fund's Average Equity at the End of 58 Trading Days for Each Trial (Baseline)

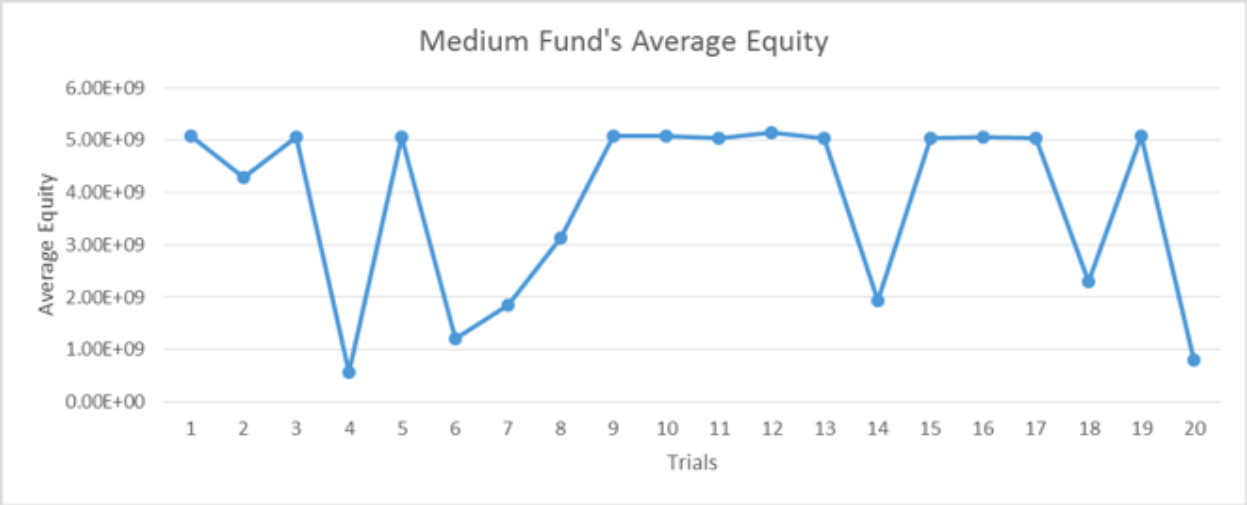

Figure 2: Medium Fund's Average Equity at the End of 58 Trading Days for Each Trial (Baseline)

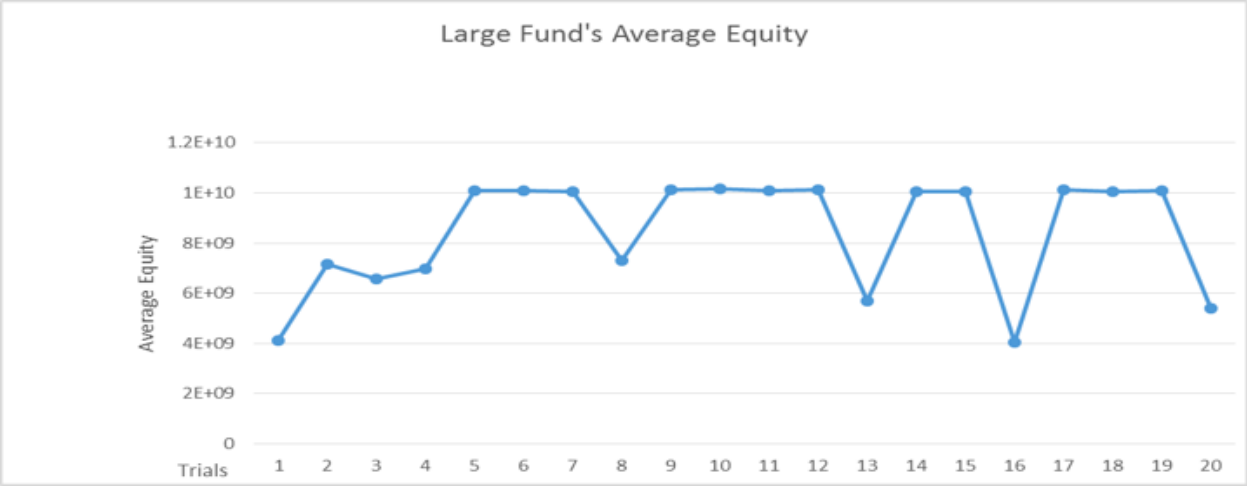

Figure 3: Large Fund's Average Equity at the End of 58 Trading Days for Each Trial (Baseline)

After coming up with the average of each trial, the average calculation over all 58 trading days was calculated (Table 4).

Average of all 20 trials		
Fund 1	Fund 2	Fund 3
719,050,566.17	3,846,225,387.11	8,420,190,149.38

Table 4 - Average Equity Over 20 Trials for Each Fund for 58 Trading Days (Baseline)

With both of these tables, the batching procedure to come up with the variance for each hedge fund is applied.

Variance S	178,436,523,880,703,000.00	2,932,962,482,481,440,000.00	5,055,089,069,159,350,000.00
STDEV	94,455,419.08	382,946,633.52	502,746,907.95

Table 5 - Variance of Baseline Trial Set

Because there are 20 trials, the degree of freedom is then 20 - 1 = 19. Alpha = 0.05, thus the T-test statistic that is used is 2.093. Applying the t-test to calculate the confidence interval, the confidence intervals are shown in the table below:

Confidence Interval		
Fund 1	**Fund 2**	**Fund 3**
(521,355,374.03, 916,745,758.31)	(3,044,718,083.15, 4,647,732,691.07)	(7,367,940,871.03, 9,472,439,427.73)

Table 6 - Confidence Intervals for Baseline Trial Set

The confidence interval above shows the equity range that each hedge fund would likely have at the end of their run time of 58 trading days. If each of these hedge funds has its equity above the upper bound after 58 trading days, then it is an over-performed hedge fund. If the fund's equity is below the lower bound, then it is an under-performed hedge fund. Given the same access to data and similar trading strategies, each hedge fund with different initial equity values after 40 trial runs is likely to have different over-performance and under-performance ratios.

Second Batch – 40 Trials (with Baseline Initial Conditions)

Rationale: It was desired that the analysis show more accurate aggregated average equity results via variance reduction. All steps are similarly performed as the first batch with the exception that each hedge fund was run for 40 trials.

Trial Averages		
Fund 1	Fund 2	Fund 3
1,048,873,386.76	1,914,969,707.55	10,095,808,799.55
1,040,000,000.00	3,940,000,000.00	10,100,000,000.00
369,954,085.97	5,049,563,494.83	10,058,601,799.83
1,035,853,431.67	5,085,052,962.59	5,688,740,496.90
1,026,543,100.59	2,949,156,314.66	10,102,127,123.51
1,012,790,908.09	2,949,156,314.66	7,320,761,750.10
1,012,790,908.09	5,127,522,959.37	7,320,761,750.10
1,037,842,353.92	5,052,024,243.74	10,164,460,150.15
1,033,231,342.27	3,356,468,276.60	6,321,085,061.80
1,068,496,854.96	3,393,882,560.43	10,111,502,284.02
1,024,938,437.30	5,068,991,630.41	10,097,808,935.47
314,933,839.06	5,032,769,774.07	10,118,368,234.87
985,740,047.84	4,202,984,278.21	7,398,896,833.75
1,058,143,380.81	5,120,197,438.26	10,084,614,946.48
1,005,093,175.22	5,071,938,463.04	10,108,643,803.09
1,060,000,000.00	5,130,000,000.00	10,095,253,641.92
1,033,189,485.54	5,053,034,283.61	10,200,000,000.00
1,142,119,669.40	1,366,166,587.00	10,089,207,796.70
1,020,000,000.00	5,070,000,000.00	6,262,141,133.73
1,026,740,083.69	5,059,654,631.88	7,890,000,000.00
129,000,000.00	3,950,000,000.00	10,101,065,838.50
1,029,676,154.75	3,069,376,202.49	10,000,000,000.00
1,060,000,000.00	5,040,000,000.00	10,083,862,555.58
1,030,000,000.00	3,870,000,000.00	8,340,000,000.00
1,010,000,000.00	2,560,000,000.00	10,200,000,000.00
1,050,000,000.00	2,200,000,000.00	10,100,000,000.00
1,060,000,000.00	5,100,000,000.00	7,750,000,000.00
1,050,000,000.00	2,200,000,000.00	10,200,000,000.00
989,000,000.00	5,030,000,000.00	7,750,000,000.00
1,030,000,000.00	5,110,000,000.00	8,060,000,000.00
1,040,000,000.00	5,100,000,000.00	7,790,000,000.00
1,050,000,000.00	5,070,000,000.00	10,100,000,000.00
989,000,000.00	5,050,000,000.00	10,100,000,000.00
1,030,000,000.00	2,410,000,000.00	10,100,000,000.00
1,040,000,000.00	5,102,919,643.71	10,100,000,000.00
628,000,000.00	5,070,000,000.00	8,513,878,857.13
1,060,000,000.00	5,047,333,428.74	10,100,000,000.00
210,455,924.39	5,046,738,650.84	7,492,383,452.88
1,050,000,000.00	1,580,000,000.00	10,055,225,956.33
140,913,511.91	5,053,034,283.61	8,520,000,000.00

Table 7 - Average Equity at the End of 58 Trading Days Per Trial (40 Trial Set)

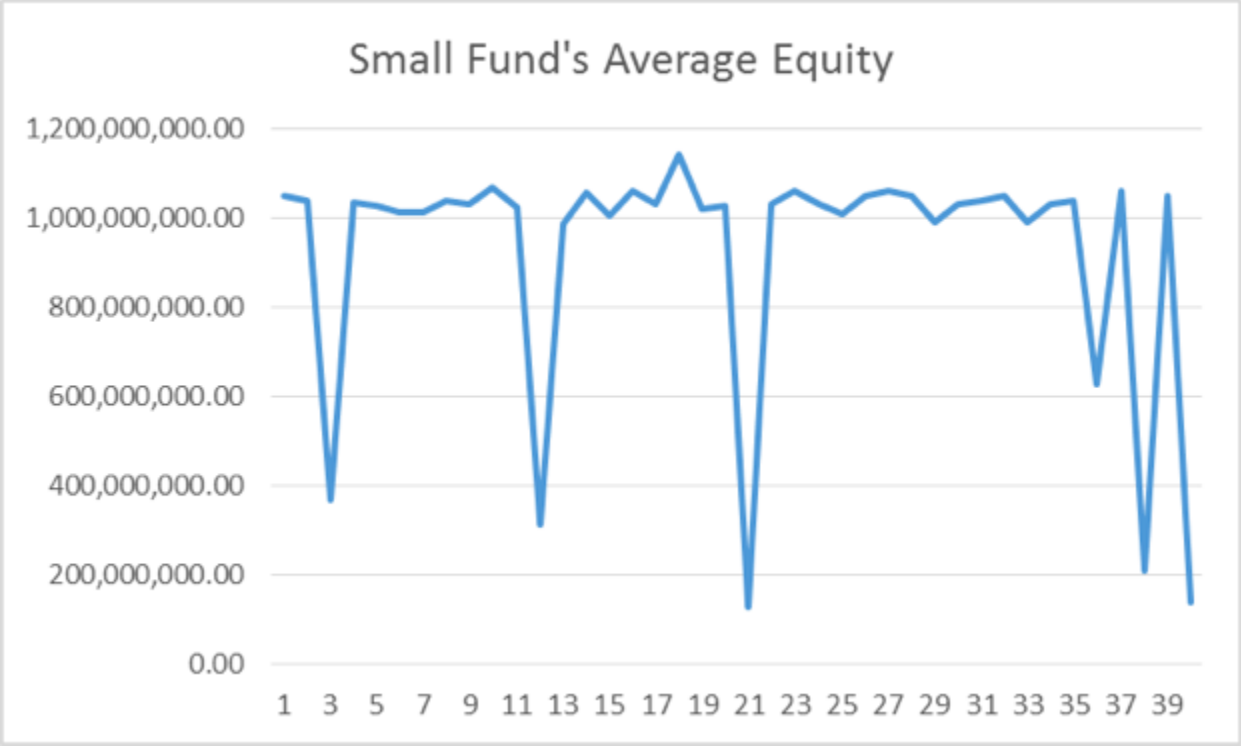

Figure 4: Small Fund's Average Equity at the End of 58 Trading Days for Each Trial (40 Trial Set)

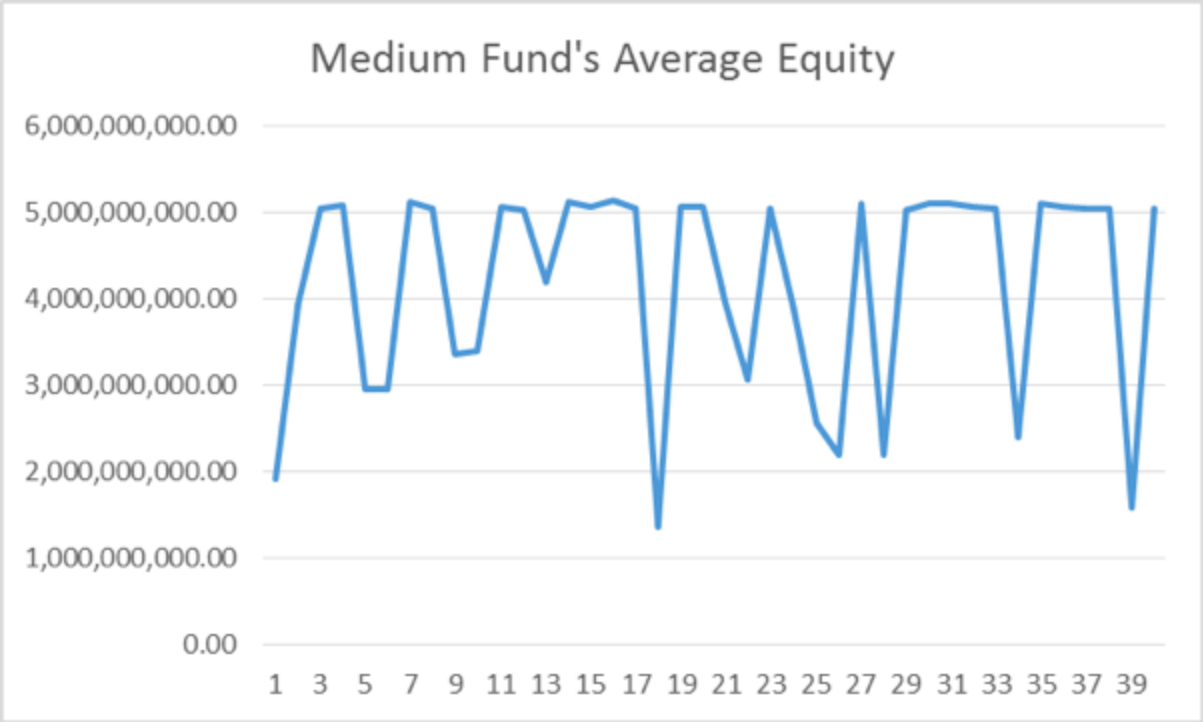

Figure 5: Medium Fund's Average Equity at the End of 58 Trading Days for Each Trial (40 Trial Set)

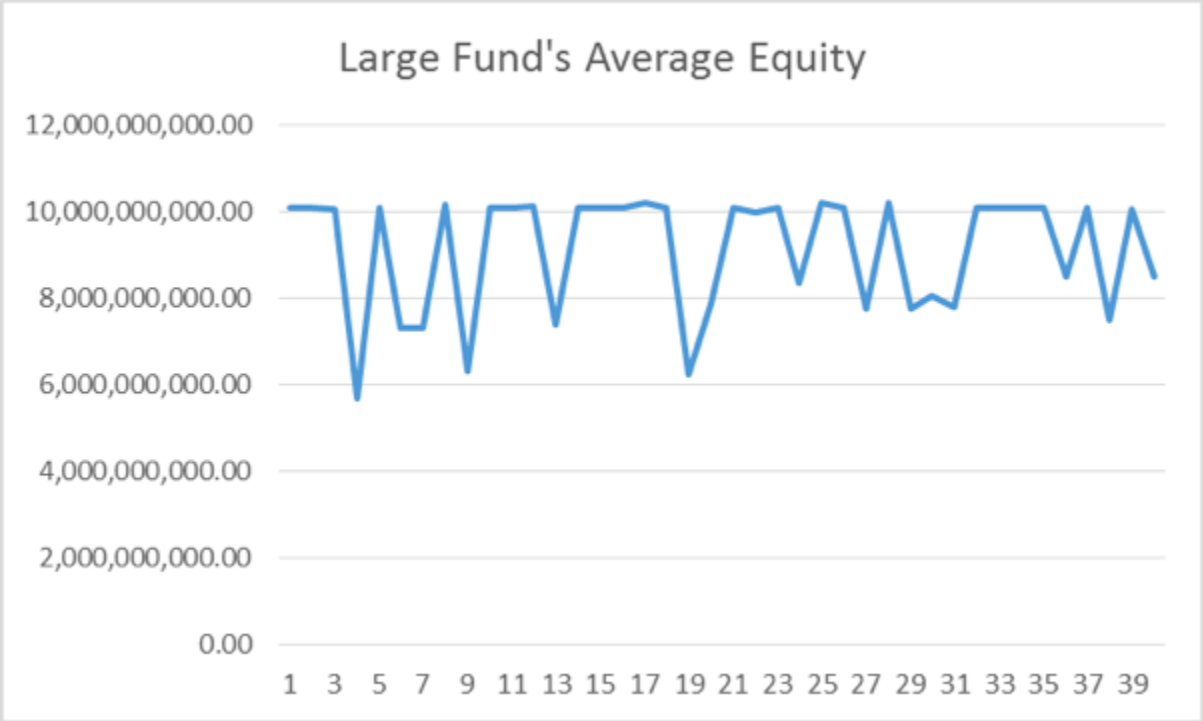

Figure 6: Large Fund's Average Equity at the End of 58 Trading Days for Each Trial (40 Trial Set)

Averages of 40 trials:

Average of all 40 trials		
Fund 1	Fund 2	Fund 3
925,833,002.06	4,191,323,403.26	9,127,130,030.06

Table 8 - Average Equity Over 40 Trials for Each Fund for 58 Trading Days (40 Trial Set)

Variances:

Variance S	98,296,104,368,150,400.00	1,945,498,052,023,010,000.00	4,026,760,204,670,260,000.00
Standard Deviation	49,572,195.93	220,539,001.77	317,283,792.71

Table 9 - Variance of 40 Trial Set

Confidence interval:

Confidence Interval		
Fund 1	Fund 2	Fund 3
(825,563,321.4, 1,026,102,683.0)	(3,745,239,164.0, 4,637,407,642.0)	(8,485,360,103.0, 9,768,899,958.0)

Table 10 - Confidence Intervals for 40 Trial Set

The confidence interval in Table 10 shows the equity range that each hedge fund would likely have at the end of their run time of 58 days. When increasing the number of trials to 40, as expected, the confidence interval (CI) is narrowed down from the previous CI. This variance reduction is expected.

With 20 trials, the interval lengths are:

Interval Length
395,390,384.28
1,603,014,607.91
2,104,498,556.70

Table 11 - Confidence Interval Length for Baseline

With 40 trials, the interval lengths are:

Interval Length
200,539,361.41
892,168,477.75
1,283,539,855.03

Table 12 - Confidence Interval Length for 40 Trial Set

The interval length is narrowed by approximately 195 million, 711 million, and 821 million respectively for the small fund, medium fund, and large fund.

If each of these hedge funds has its equity above the upper bound after 58 days, then it is an over-performed hedge fund. If the fund's equity is below the lower bound, then it is an under-performed hedge fund. As with the baseline, given the same access to data and similar trading strategies, each hedge fund with different initial equity values after 40 trial runs is likely have different over-performance and under-performance ratios.

Test Case 1 (20 Trials)

Rationale: It was desired to show more data points per trial by removing the convergence trades, extending each trial replication length to 221 trading days. With 20 trials, each hedge fund now produces approximately 4,000 data points. Another condition that was changed is that each hedge fund now fully considers executing both an interest swap trade and volatility trade (when and if the hedge fund is able to take an action). This renders all hedge funds greedier as a result.

Trial Averages		
Fund 1	Fund 2	Fund 3
7,750,356.58	6,446,139,615.33	12,031,754,754.80
1,838,788,163.55	6,479,840,797.61	11,747,633,865.01
63,886,562.82	140,336,240.39	11,933,055,851.21
2,270,000,000.00	494,000,000.00	12,100,000,000.00
1,362,869,213.84	5,942,765,619.33	1,617,005,137.32
1,835,781,827.41	7,184,835,302.55	11,909,277,825.76
1,994,254,172.96	6,298,029,339.91	1,251,044,568.78
1,693,517,512.02	6,492,449,195.89	205,172,085.27
27,523,774.53	6,083,613,052.90	11,510,456,417.06
1,973,807,147.94	6,121,429,325.38	441,849,454.50
138,000,000.00	342,000,000.00	524,000,000.00
1,180,000,000.00	914,000,000.00	10,300,000,000.00
53,600,000.00	5,960,000,000.00	1,430,000,000.00
1,620,000,000.00	5,850,000,000.00	11,200,000,000.00
1,550,000,000.00	6,080,000,000.00	11,200,000,000.00
1,477,850,344.07	5,686,622,005.63	2,651,962,324.43
1,790,000,000.00	475,000,000.00	4,330,000,000.00
1,870,000,000.00	1,060,000,000.00	11,300,000,000.00
167,000,000.00	5,590,000,000.00	10,900,000,000.00
2,211,865,124.77	6,406,189,988.53	1,749,996,532.81

Table 13 - Average Equity at the End of 221 Trading Days Per Trial (Test Case 1)

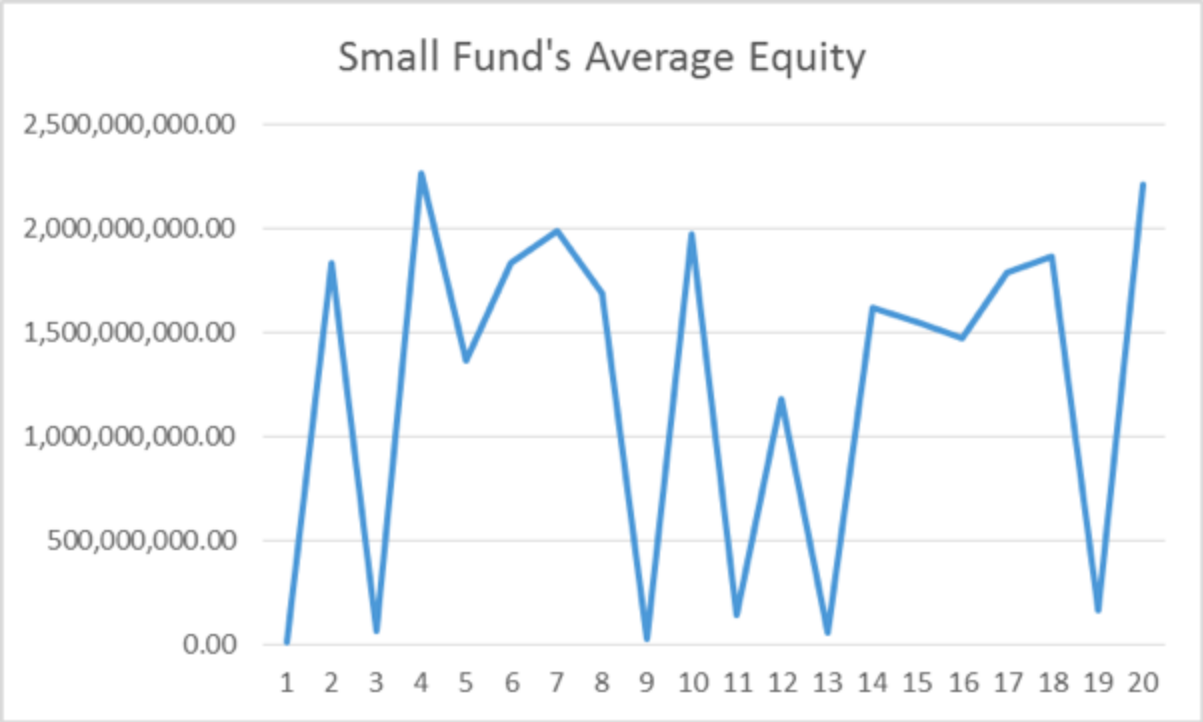

Figure 7: Small Fund's Average Equity at the End of 221 Trading Days for Each Trial (Test Case 1 20 Trial Set)

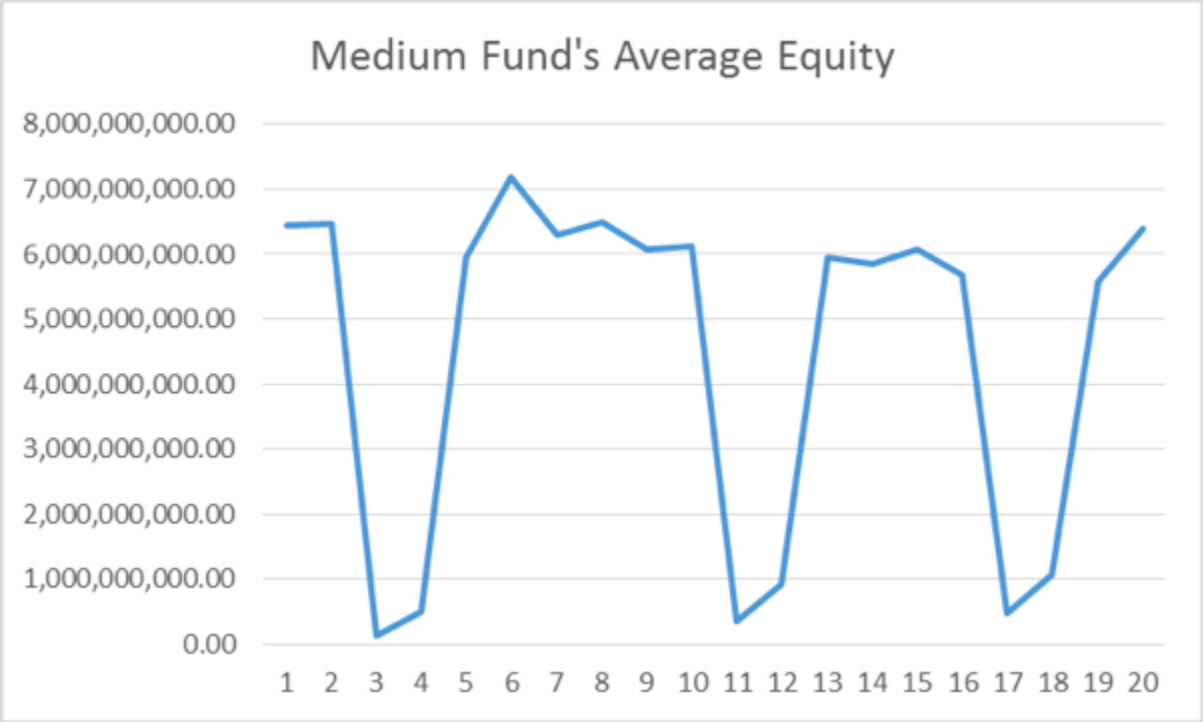

Figure 8: Medium Fund's Average Equity at the End of 221 Trading Days for Each Trial (Test Case 1 20 Trial Set)

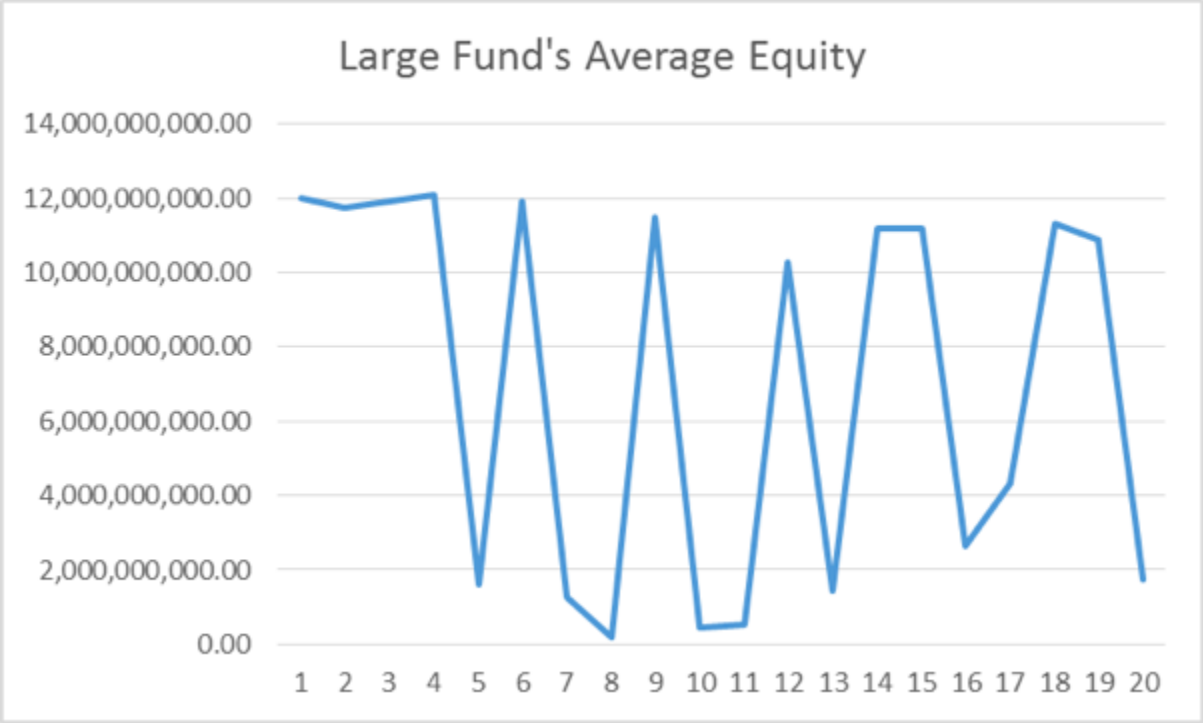

Figure 9: Large Fund's Average Equity at the End of 221 Trading Days for Each Trial (Test Case 1 20 Trial Set)

Averages over all 20 trials per hedge fund (small fund on far left):

Averages of 20 trials		
Fund 1	**Fund 2**	**Fund 3**
1,256,324,710.02	4,502,362,524.17	7,016,660,440.85

Table 14 - Average Equity Over 20 Trials for Each Fund for 221 Trading Days (Test Case 1)

Confidence interval:

Confidence Interval		
Fund 1	**Fund 2**	**Fund 3**
(1,153,729,640.44, 1,358,919,779.61)	(4,297,951,168.91, 4,706,773,879.43)	(6,451,185,928.43, 7,582,134,953.26)

Table 15 - Confidence Intervals for Test Case 1

This confidence interval of the test case gives the estimate of each fund's equity averages after running a full 221 trading days and with the absence of treasury convergence trades.

Test Case 2 – (20 Trials)

Rationale: It was desired to retain all parameter changes in test case 1, but also introduce another parameter change to potentially increase the nonlinear complexity to much higher levels in the ABM simulation. In this test case, the number of investors is set to a count of 100 from 50.

Trial Averages:

Trial Averages		
Fund 1	Fund 2	Fund 3
1,777,654,797.37	5,752,073,520.26	2,109,058,964.17
176,325,446.74	5,726,695,619.04	10,920,509,749.99
167,134,013.56	5,552,708,824.97	10,798,273,510.15
1,502,602,026.23	1,210,131,504.88	10,841,663,322.72
794,990,508.62	5,586,698,579.55	10,812,490,056.38
1,161,384,357.02	5,827,482,627.08	669,187,545.51
1,300,000,000.00	4,180,000,000.00	2,570,000,000.00
1,914,497,812.23	6,186,083,466.41	11,233,650,883.18
1,695,048,834.49	6,063,908,745.63	2,533,683,206.30
1,240,572,341.38	5,652,312,912.93	665,413,781.15
77,705,916.30	5,804,266,018.96	471,224,546.52
1,275,795,243.27	5,524,394,691.11	10,832,396,128.04
1,525,234,396.15	430,933,082.73	10,946,475,990.14
96,039,330.15	168,885,631.71	10,853,023,487.21
49,000,000.00	1,610,000,000.00	10,700,000,000.00
1,632,499,451.32	342,743,306.53	1,034,193,430.48
1,632,499,451.32	342,743,306.53	1,034,193,430.48
1,285,766,312.15	5,449,324,578.63	1,597,695,684.32
190,623,754.80	5,390,263,566.22	10,551,699,085.32
1,050,797,520.57	5,313,939,149.23	10,469,021,295.79

Table 16 - Average Equity at the End of 221 Trading Days Per Trial (Test Case 2)

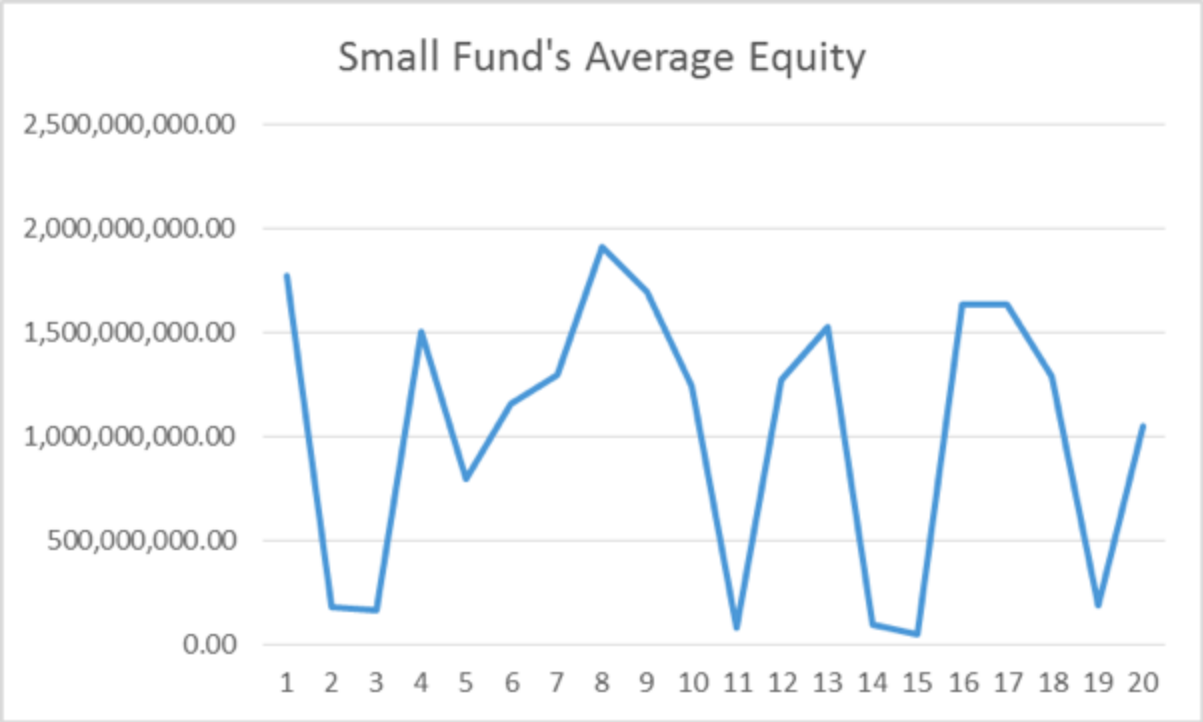

Figure 10: Small Fund's Average Equity at the End of 221 Trading Days for Each Trial (Test Case 2 20 Trial Set)

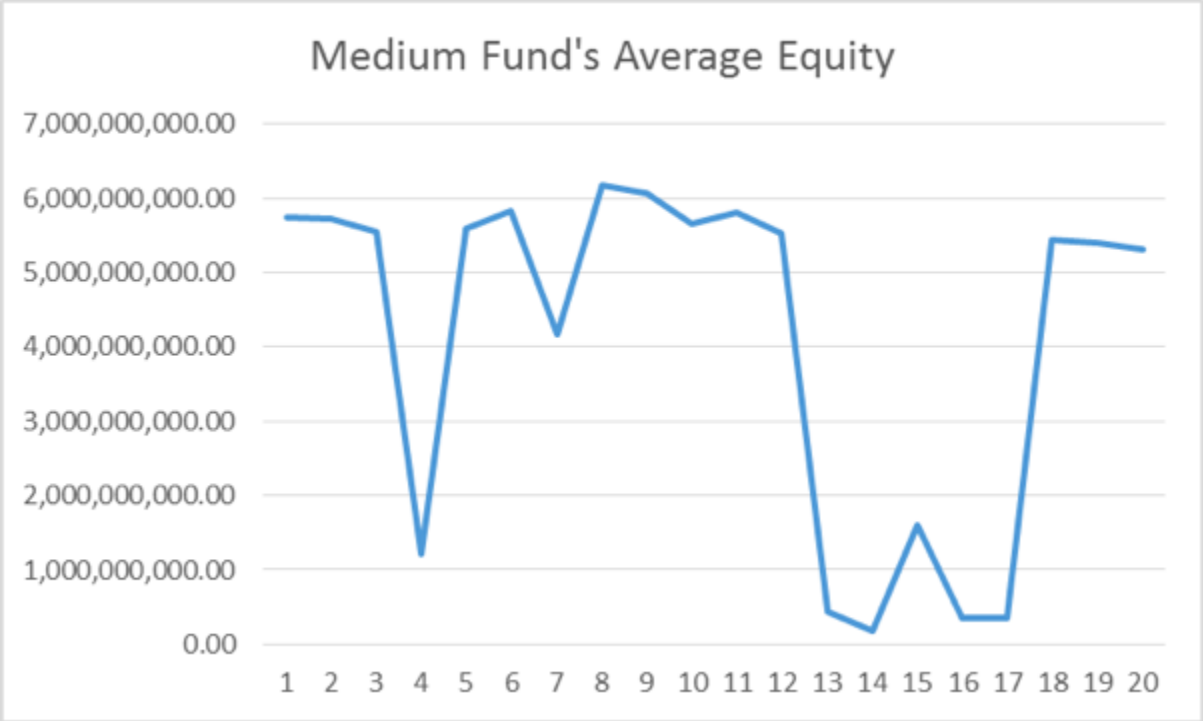

Figure 11: Medium Fund's Average Equity at the End of 221 Trading Days for Each Trial (Test Case 2 20 Trial Set)

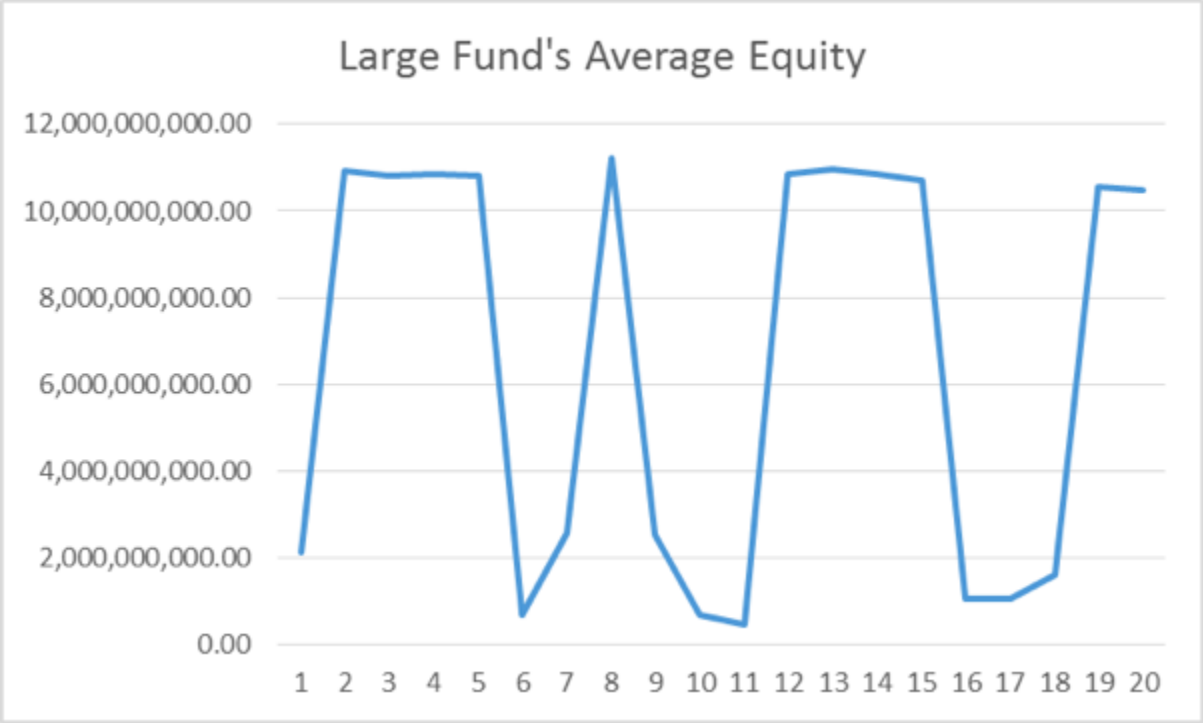

Figure 12: Large Fund's Average Equity at the End of 221 Trading Days for Each Trial (Test Case 2 20 Trial Set)

Confidence intervals:

Confidence Intervals		
Fund 1	**Fund 2**	**Fund 3**
(1,024,786,599.74, 1,029,830,551.62)	(3,976,061,000.11, 4,235,497,913.13)	(6,164,869,226.37, 6,999,516,183.41)

Table 17 - Confidence Intervals for Test Case 2

These confidence intervals from this test case gives the estimate of each fund's equity averages after running full 221 trading days and with an absence of treasury convergence trades. This test case also runs with 100 investors. The equity averages within these confidence intervals are lower than the averages of the sensitivity test with the default number of investors (50).

VaR Analysis

VaR, or Value at Risk, is used extensively to estimate what loss level is such that one can be X% confident it the loss level will not be exceeded in N business days. When using conventional VaR to estimate the risk level, one should note that it assumes daily returns are normally distributed. In this analysis, conventional VaR computations under a normal distribution assumption were compared to the Agent Based Modeling VaR.

The three hedge funds stay the same: the small fund, medium fund, and large fund each with its initial equity value ($1 Billion, $5 Billion, and $10 Billion). An assumption for a hedge fund is that daily volatility fluctuates from 0.5% to 5%, and in addition, these volatility levels are standard out in the financial industry. The baseline estimates of conventional VaR corresponding to different confidence levels is shown in the following paragraphs.

In the ABM model, data from two batch runs was selected - the baseline 20 trials and the 20 trials of test case 1, and the equity changes from the trials is used to compute conventional VaR estimates. Daily changes in equity were computed for each trial, and then all of the daily changes for 20 trials was aggregated and ranked. From there, the 99% daily loss was found and it was multiplied by square root of 10 to get the 10 day VaR.

The table below shows the 10 day, 99% VaR for each fund calculated based on conventional way, which is to follow normality, with volatility ranging from 0.5% to 5%. The percentage on the right column is the percentage of VaR over the entire portfolio.

	Small fund	Medium Fund	Large fund	
	1,000,000,000.000	5,000,000,000.000	10,000,000,000.000	
Volatility Level				
0.005	36,840,535	184,202,674	368,405,347	3.68%
0.010	73,681,069	368,405,347	736,810,695	7.37%
0.015	110,521,604	552,608,021	1,105,216,042	11.05%
0.020	147,362,139	736,810,695	1,473,621,390	14.74%
0.025	184,202,674	921,013,369	1,842,026,737	18.42%
0.030	221,043,208	1,105,216,042	2,210,432,084	22.10%
0.035	257,883,743	1,289,418,716	2,578,837,432	25.79%
0.040	294,724,278	1,473,621,390	2,947,242,779	29.47%
0.045	331,564,813	1,657,824,063	3,315,648,127	33.16%
0.050	368,405,347	1,842,026,737	3,684,053,474	36.84%

Table 18 - Conventional VaR Calculations

First batch (Baseline): 20 trials

The 99% daily loss based on the simulation was computed and from this the 10-day VaR was calculated. There are roughly 1,200 points, and they were ranked from largest loss to lowest loss. After that, the 1% point that represents the loss on a single day was found, and it was multiplied by the square root of 10 to get a 10-day VaR.

	Small Fund	Medium Fund	Large Fund
VaR	1,256,029,145	8,948,069,412	4,810,657,153

Table 19 - VaR for Hedge Funds (Baseline)

The results from the conventional VaR and the ABM estimated VaR were charted together to illustrate the difference between ABM simulation VaR and conventional VaR. The orange bar is ABM VaR.

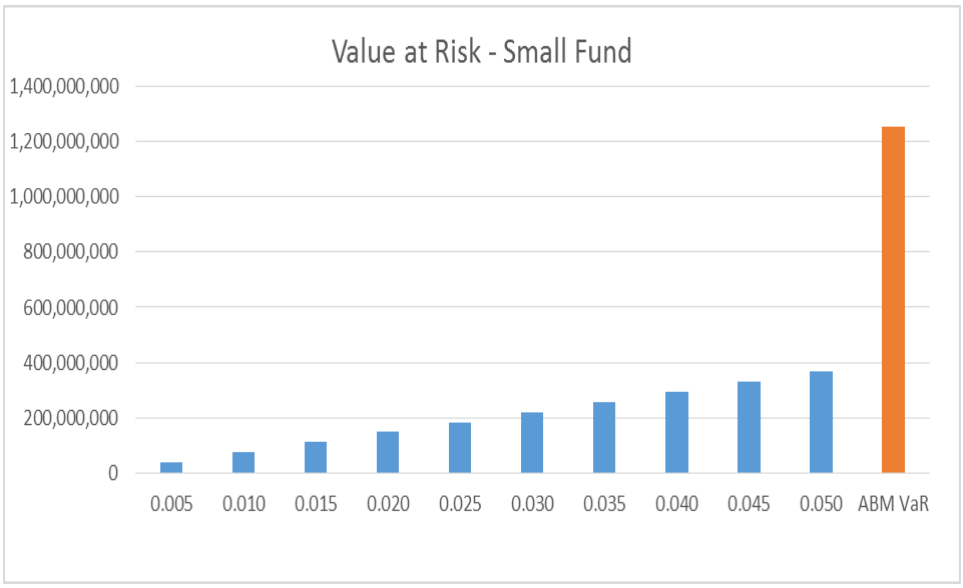

Figure 13 - VaR Comparison (Conventional and ABM) Small Hedge Fund (Baseline)

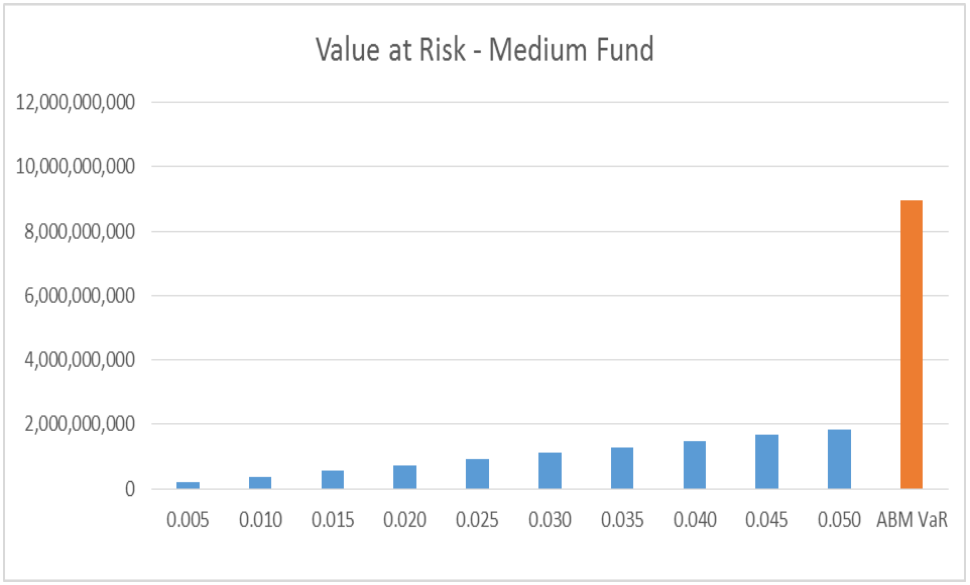

Figure 14 - VaR Comparison (Conventional and ABM) Medium Hedge Fund (Baseline)

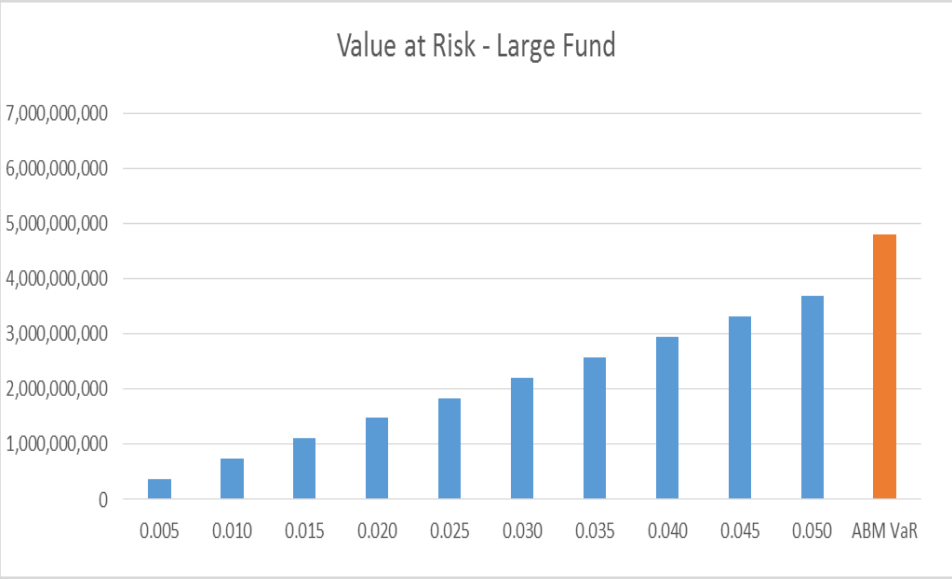

Figure 15 - VaR Comparison (Conventional and ABM) Large Hedge Fund (Baseline)

Test Case 1 – 20 trials

The 99% daily loss based on the simulation was computed, and the 10-day VaR was calculated. There are roughly 3,054 points, which are ranked from largest loss to lowest loss. After that, the 1% point which is the loss on a single day was found and multiplied by the square root of 10 to get a 10-day VaR.

	Small Fund	Medium Fund	Large Fund
ABM VaR	1,330,040,826	11,185,086,765	5,120,389,930

Table 20 - VaR for Hedge Funds (Test Case 1)

As before, the results from the conventional VaR and the ABM estimated VaR were charted together to illustrate the difference between ABM simulation VaR and conventional VaR. The orange bar is ABM VaR.

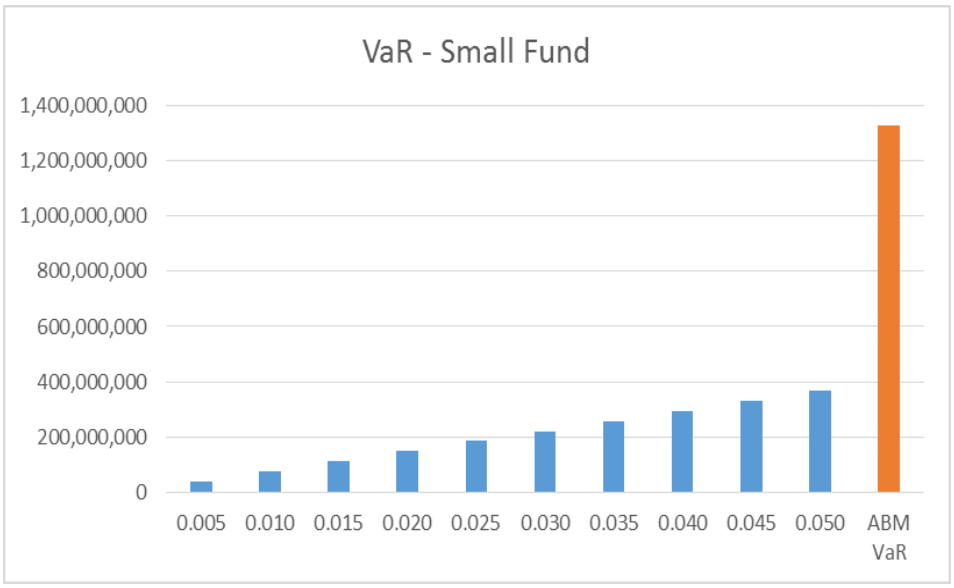

Figure 16 - VaR Comparison (Conventional and ABM) Small Hedge Fund (Test Case 1)

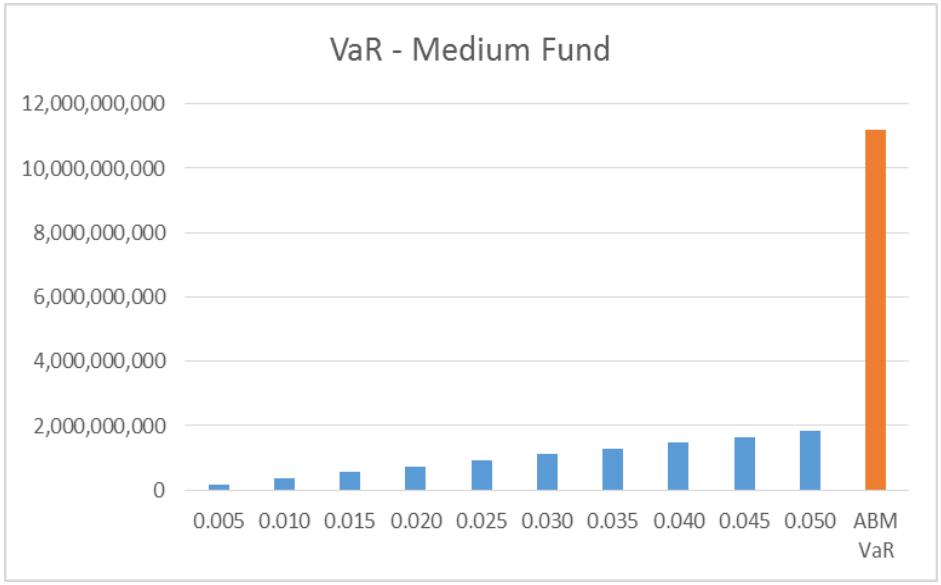

Figure 17 - VaR Comparison (Conventional and ABM) Medium Hedge Fund (Test Case 1)

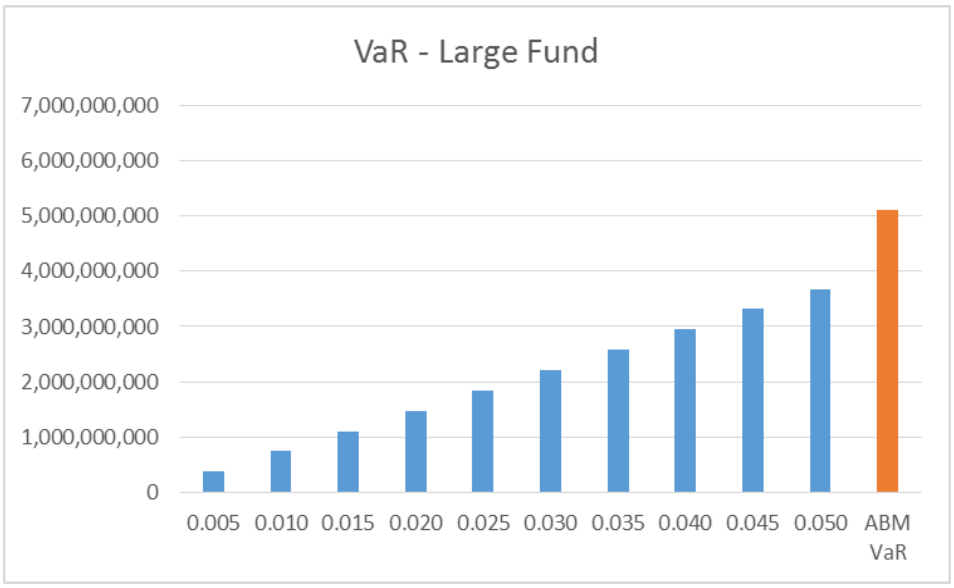

Figure 18 - VaR Comparison (Conventional and ABM) Large Hedge Fund (Test Case 1)

With the assumption of using the conventional VaR, which follows the normal distribution, the 10 day – 99% VaR was calculated. The volatility ranging from 0.5% to 5% per day was charted. Also included in the volatility chart is the 10-day ABM estimated VaR, which is calculated based on results from the ABM model. There are also tables that show 10-day VaRs for each fund and their associated percentage daily loss at 99% threshold based on ABM simulation.

For the baseline test, which includes all three trading strategies, it is shown that the day to day losses at the 99% confidence level for both small and medium size hedge funds are enormous. The 10-day VaRs for both the small and medium hedge funds are much greater than any of the conventional VaR calculations. The small and medium size hedge funds are in a very risky position; their losses are outliers in the fat-tailed distribution. The large hedge fund, on the other hand, stands at 2% daily change, so its VaR is in an acceptable range.

For the test case (no convergence trades), the computed 10-day VaRs based on ABM simulation for the small and medium hedge funds are also large and slightly higher than in the

baseline case. This supports the original intuition that more volatile conditions in the test case would be correlated with higher ABM VaR values.

When hedge funds are modeled after LTCM using the ABM approach, a result that occurs is that the small size and medium size funds will be in a very risky position, while the large fund VaR is only slightly higher than the conventional VaR. The conventional VaR method would not be able to take into account these outliers (large losses) for the small and medium funds, which seem to behave similarly to a fat-tailed walk. On the other hand, the ABM simulation could estimate the VaR and predict failure for both funds. In reality, the LTCM fund had the equity of around 4 billion dollars, which would roughly be equal to the size the medium fund. It is also noted that the medium size hedge fund failed when calculating VaR based on ABM simulation. Therefore, based on the results, our ABM simulation provides insight into the level of risk faced by LTCM.

Bernoulli Analysis

The Bernoulli discrete probability distribution is applied to analyze the failure classification of results. The success rate is defined as p and q = 1 - p as the failure rate. In this model, failure is defined by losing more than 50% of a hedge fund's initial equity. According to this simulation model, the assumption is that hedge funds require at most 50% of its equity be invested, in which the worst case scenario is that 50% of that investment is lost. As a result, the 50% remaining must be able to cover that worst-case loss.

Baseline – 20 trials

Fund 1 - Small Fund: There are 8 trial runs in which failure occurred. Therefore, the failure rate in 20 trials for Fund 1 is: 8/20 = 40%. Thus the success rate is 1-40% = 60%.

The expected value of success for Fund 1 is therefore: $E(X) = p = 0.6$ and the variance is $V(X) = p(1-p) = 0.6*0.4 = 0.24$. The confidence interval for p is (0.49, 0.7095).

Fund 2 - Medium Fund: There are 6 trial runs in which failure occurred. Therefore, the failure rate in 20 trials for Fund 2 is: 6/20 = 30%. Thus the success rate is 1 - 30% = 70%.

The expected value of success for Fund 2 is therefore: $E(X) = p = 0.7$ and the variance is $V(X) = p(1-p)= 0.7*0.3 = 0.21$. The confidence interval for p is (0.5975, 0.8025).

Fund 3 - Large Fund: There are 2 trial runs in which failure occurred. Therefore, the failure rate in 20 trials for Fund 3 is: 2/20 = 10%. Thus the success rate is 1 - 10% = 90%.

The expected value of success for Fund 3 is therefore: $E(X) = p = 0.9$ and the variance is $V(X) = p(1-p)= 0.9*0.1 = 0.09$. The confidence interval for p is (0.8329, 0.967).

Results rationale: Over 20 trial runs, the large fund seems to emerge as the safest fund to invest with a success rate of 90%. Since all hedge funds trade at similar trading volumes if a given trade is successful and consider each arbitrage trade with the same probabilities, it is reasonable that there is a higher likelihood that the large hedge fund would be able to retain average ending equity over 50% of its original.

Second Batch – 40 Trials

Fund 1 - Small Fund: There are 5 trial runs in which failure occurred. Therefore, the failure rate in 40 trials for Fund 1 is: 5/40 = 13%. Thus the success rate is then 1 - 13% = 87%.

The expected value of success for Fund 1 is therefore: E(X) = p = 0.87 and the variance is V(X) = p(1-p) = 0.87*0.13 = 0.1131. The confidence interval for p is (0.817, 0.92317).

Fund 2 - Medium Fund: There are 6 trial runs in which failure occurred. Therefore, the failure rate in 40 trials for Fund 2 is: 6/40 = 15%. Thus the success rate is 1 - 15% = 85%.

The expected value of success for Fund 2 is therefore: E(X) = p = 0.85 and the variance is V(X) = p(1-p) = 0.85*0.15= 0.1275. The confidence interval for p is (0.7935, 0.90645).

Fund 3 - Large Fund: There is 1 trial run in which failure occurred. Therefore, the failure rate in 40 trials for Fund 3 is: 1/40 = 2.5%. Thus the success rate is 1 - 2.5% = 97.5%.

The expected value of success for Fund 3 is therefore: E(X) = p = 0.975 and the variance is V(X) = p(1-p) = 0.975*0.025 = 0.024375. The confidence interval for p is (0.950, 0.999).

Results rationale: Over 40 trial runs, the large fund seems to emerge as the safest fund to invest with a failure rate of 2.5%. Since all hedge funds trade at similar trading volumes if a given trade is successful and consider each arbitrage trade with the same probabilities, it is reasonable that there is a higher likelihood that the large hedge fund would be able to retain average ending equity over 50% of its original equity level.

Test Case 1 – 20 Trials and 221 Trading Days

This test case involves turning off convergence trades while forcing all hedge funds to greedily always consider doing either a volatility trade or interest swap trade.

Fund 1 - Small Fund: There are 5 trial runs in which failure occurred. Therefore, the failure rate in 20 trials for Fund 1 is: 5/20 = 25%. Thus the success rate is 1 - 25% = 75%.

The expected value of success for Fund 1 is therefore: E(X) = p = 0.75 and the variance is V(X) = p(1-p) = 0.75*0.25 = 0.1875. The confidence interval for p is (0.653, 0.8468).

Fund 2 - Medium Fund: There are 4 trial runs in which failure occurred. Therefore, the failure rate in 20 trials for Fund 2 is: 4/20 = 20%. Thus the success rate is 1 - 20% = 80%.

The expected value of success for Fund 2 is there for: E(X) = p = 0.80 and the variance is V(X) = p(1-p) = 0.80*.20 = 0.16. The confidence interval for p is (0.71, 0.889).

Fund 3- Large Fund: There are 8 trial runs in which failure occurred. Therefore, the failure rate in 20 trials for Fund 3 is: 8/20 = 40%. Thus the success rate is 1 - 40% = 60%.

The expected value of success for Fund 3 is there for: E(X) = p = 0.6 and the variance is V(X) = p(1-p)= 0.6*0.4= 0.24. The confidence interval for p is (0.4904, 0.7095).

Results rationale: Over 20 trial runs, the medium fund seems to emerge as the safest fund to invest with a failure rate of 20%. By removing the convergence trade and removing the probability thresholds on the other two arbitrage trades for all hedges, the test results suggests that the medium fund's moderate level of aggressive investment behavior (its action probability threshold is between the other two hedge funds) is optimal under the subjected conditions. Since all hedge funds trade at similar trading volumes if a given trade is successful and consider each arbitrage trade with the same probabilities, it is reasonable that the small hedge fund would converge more quickly to the failure threshold of 50% because of its lower initial equity.

Furthermore, the large fund takes upon the most volatility and therefore incurs a higher chance of losses.

Test Case 2 – 20 Trials, 221 Trading Days, and 100 Investors

This test case retains all conditions of the prior sensitivity test while increasing the default number of investors to 100. This increase in non-linear complexity may induce more dramatic equity fluctuations.

Fund 1 - Small Fund: There are 6 trial runs in which failure occurred. Therefore, the failure rate in 20 trials for Fund 1 is: 6/20 = 30%. Thus the success rate is 1 - 30% = 70%.

The expected value of success for Fund 1 is therefore: $E(X) = p = 0.70$ and the variance is $V(X) = p(1-p) = 0.70*0.30 = 0.21$. The confidence interval for p is (0.5975, 0.802469).

Fund 2 - Medium Fund: There are 5 trial runs in which failure occurred. Therefore, the failure rate in 20 trials for Fund 1 is: 5/20 = 25%. Thus the success rate is 1 - 25% = 75%.

The expected value of success for Fund 2 is therefore: $E(X) = p = 0.75$ and the variance is $V(X) = p(1-p) = 0.75*0.25 = 0.1875$. The confidence interval for p is (0.653, 0.8468).

Fund 3 - Large Fund: There are 7 trial runs in which failure occurred. Therefore, the failure rate in 20 trials for Fund 1 is: 7/20 = 35%. Thus the success rate is 1 - 35% = 65%.

The expected value of success for Fund 3 is therefore: $E(X) = p = .65$ and the variance is $V(X) = p(1-p) = 0.65*0.35= 0.2275$. The confidence interval for p is (0.5433, 0.7566).

Results rationale: Over 20 trial runs, the medium fund seems to emerge as the safest fund to invest with a failure rate of 25%. By removing the convergence trade and removing the probability thresholds on the other two arbitrage trades for all hedges, the test results suggests that the medium fund's moderate level of aggressive investment behavior (its action probability threshold is between the other two hedge funds') is optimal under the subjected conditions. Even with the addition of 50 more investors, the medium fund still shows the highest success rate. Similarly to the previous test case, since all hedge funds trade at similar trading volumes if a given trade is successful and consider each arbitrage trade with the same probabilities, it is reasonable that the small hedge fund would converge more quickly to the failure threshold of 50% because of its lower initial equity. Furthermore, the large fund takes upon the most volatility and therefore incurs a higher chance of losses.

Below is the table of all Bernoulli Confidence Intervals for p:

First batch		
Small Fund	**Medium Fund**	**Large Fund**
(0.49, .7095)	(.5975, .8025)	(0.8329, .967)
Second Batch		
Small Fund	**Medium Fund**	**Large Fund**
(.817, .92317)	(.7935, .90645)	(.950, .999)
First Sensitivity Test		
Small Fund	**Medium Fund**	**Large Fund**
(.653, .8468)	(.71, .889)	(.4904, .7095)
Second Sensitivity Test		
Small Fund	**Medium Fund**	**Large Fund**
(.5975, .802469)	(.653, .8468)	(.5433, .7566)

Table 18 - Bernoulli Confidence Intervals

4. Conclusions and Future Work

4.1 Model Analysis Conclusions

After developing the hedge fund model, methods were developed to generate results. First, two batch runs with 20 (baseline) and 40 trials respectively were run. The goal was to examine and estimate the range of returns by the three hedge funds. In these two cases, the model was run for 58 trading days (due to data availability for on & off the run credit spreads). Then, two additional test cases were run to gauge how the funds equity may change due to the absence of treasury convergence trades, greedily considering volatility trades and interest rate swaps, increasing the model timespan to 221 trading days, and increasing the number of investors. The rationale for these two test cases is to take a closer look on how hedge funds behave in a risk-seeking manner and what their returns may look like under more non-linear complexity. Ultimately, the goal for these batch run results is to accomplish reasonable first-order analysis.

Given the results of the first two batch runs, increasing the number of trials reduces the length of the confidence interval as expected. That means in the 40 trials batch run, there was a better estimate of returns for the three hedge funds. Moving on to the test cases, there are also two batch runs, each with 20 trials. However, for the second batch run, the number of investors was increased to 100. This action adds an extra dimension of non-linear complexity into the market. One striking result is that the batch run with 100 investors generates a lower return estimates than the one with default number of investors. One possibility is that more investors offers other hedge funds more opportunities for volatility trading, leading to more possible risky positions. Also, because of the hedge funds' characteristic that was set to be more risk seeking, hedge funds and investors will compete with each other for profit opportunities. This shows that by changing the initial conditions, different results can be obtained with the model.

Next, the VaR method was introduced to analyze model results. With the assumption that daily returns are normally distributed, the industry standard VaR has gained its popularity because of its simplicity in generating a single number to quantify the risk level. People find this method very easy to grasp and understand, especially in the finance industry and in government regulation. As a result, the conventional VaR was compared to a 10-day ABM estimated VaR (via Monte Carlo simulation). However, as explained earlier in the VaR analysis section, in both the baseline and test case, the small and medium hedge funds have 1-days losses which are large. The volatility seems to be much higher than what was assumed with using the conventional VaR approach. As the hedge funds' trading strategies are modeled after LTCM and since LTCM had similar equity levels to the medium hedge fund in the ABM model, the model provides insight into how non-linear complexity increased risk for LTCM.

As for examining success and failure rates based on average ending results over a trading period, a Bernoulli distribution is applied; with p a success and 1-p a failure. All the success and failure rates are compared among the four batch runs, both under baseline and test case conditions. For the baseline batch runs, it is a result that the large hedge fund appears to be the safest bet for investors to invest. Given the large hedge fund's initial portfolio value, it takes more losses to converge towards the 50% threshold cutoff point for failure.

However, when the Bernoulli distribution is applied to get the success and failure rate for all three hedge funds under the test cases, a surprising result was that the medium size fund appeared as the safest bet for investors to invest. Given the risk-seeking and aggressive characteristic of all three funds, medium size fund seems to be an optimal choice to pick among all three. This could be impacted by two factors: one, all hedge funds execute the same trading volumes, and two, each hedge fund has a different probability action threshold for considering any kind of trade.

In conclusion, although there are many assumptions this ABM hedge fund model, these assumptions are closely based on real conditions in the market. Despite that, this ABM study provides a baseline model of multiple arbitrage trading strategies upon which could be easily expanded for future use cases with influences from the historic LTCM failure in 1998.

4.2 Possible Model Expansions

There are two main avenues for model expansion in the future: technology and financial logic.

Technology options include:

1) Introduce inheritance in Java Repast code to remove static object type checking.

2) Enable better debug console messages for system fixes.

3) Determine how to best automate batch procedures in Repast.

4) Consider machine learning techniques for trading decisions.

Financial options includes:

1) Expand beyond three arbitrage strategies for hedge funds for research and application: The purpose of this model was to understand if ABM could show that if a hedge fund utilized LTCM strategies, failure could follow, and therefore only the main LTCM arbitrage strategies were used. However, LTCM is one out of many hedge funds that existed in the past. To make the model more useful, other trading strategies should be included in the model.

2) Ensure interaction between investors and banks: economies could be considered as connected as market prices and actions affect all agents. Currently, bank actions and investor actions may not affect investors and banks respectively, creating an unrealistic divide between investors and banks. Adding this interaction will increase economy connectivity.

3) Track portfolio positions over a period of time.

4) The US Securities and Exchange Commission could be added to the model in a future release: as more types of trading and more agent types are added to the model, more regulation should be introduced to mirror US trading regulation. Adding the SEC will add more realism to the model.

5) The ABM VaR and Bernoulli methods can be considered as two metrics for use in a hedge fund risk mitigation framework.

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Appendix B - Inputs

1. Hedge fund equity: the large hedge fund has an initial equity of $10 billion, the medium hedge fund with $5 billion, and the small hedge fund with $1 billion

2. Start date: January 1, 2011

3. Decide action threshold: 0.30 for the small fund, 0.60 for the medium fund, and 0.90 for the large fund, 0.95 (all other agent types)

4. Perform strategy thresholds (three separate discrete distributions) for hedge fund:
    a. [0.0, 0.30]: Convergence trade
    b. (0.3, 0.60]: Interest Rate Swap
    c. (0.6, 0.90]: Volatility Trade

5. Interest rate swap type choice threshold for hedge funds:
    a. [0, 0.5): 3-year, semi-annual payments (6 payments total)
    b. [0.5, 1]: 2-year, quarterly payments (8 payments total)

6. Interest rate swap decision threshold for interest rate swaps: 0.90

7. Bank loan decision threshold for hedge fund loan requests: 0.95

8. Bank loan decision threshold for bank overnight loan requests: 0.45

9. Bank decision threshold to ask for overnight loan from other bank: 0.5

10. LIBOR and LIBOR Forward rates:

Date	LIBOR Current Rate (Spot Rate)	LIBOR Annual Forward Rate
1/5/2011	0.3029	0.3028
4/5/2011	0.3029	0.3821
7/5/2011	0.3447	0.4619
10/5/2011	0.3873	0.5766
1/5/2012	0.4379	0.7576
4/5/2012	0.5036	0.9827
7/5/2012	0.5854	1.2522

10/5/2012	0.6848	1.5335

11. Discount rates and reserve requirements

Date	Discount Rate	Reserve Requirement
12/31/2010	0.75	3
1/3/2011	0.75	3
1/4/2011	0.75	3
1/5/2011	0.75	3
1/6/2011	0.75	3
1/7/2011	0.75	3
1/10/2011	0.75	3
1/11/2011	0.75	3
1/12/2011	0.75	3
1/13/2011	0.75	3
1/14/2011	0.75	3
1/17/2011	0.75	3
1/18/2011	0.75	3
1/19/2011	0.75	3
1/20/2011	0.75	3
1/21/2011	0.75	3
1/24/2011	0.75	3
1/25/2011	0.75	3
1/26/2011	0.75	3
1/27/2011	0.75	3
1/28/2011	0.75	3
1/31/2011	0.75	3
2/1/2011	0.75	3

2/2/2011	0.75	3
2/3/2011	0.75	3
2/4/2011	0.75	3
2/7/2011	0.75	3
2/8/2011	0.75	3
2/9/2011	0.75	3
2/10/2011	0.75	3
2/11/2011	0.75	3
2/14/2011	0.75	3
2/15/2011	0.75	3
2/16/2011	0.75	3
2/17/2011	0.75	3
2/18/2011	0.75	3
2/21/2011	0.75	3
2/22/2011	0.75	3
2/23/2011	0.75	3
2/24/2011	0.75	3
2/25/2011	0.75	3
2/28/2011	0.75	3
3/1/2011	0.75	3
3/2/2011	0.75	3
3/3/2011	0.75	3
3/4/2011	0.75	3
3/7/2011	0.75	3
3/8/2011	0.75	3
3/9/2011	0.75	3
3/10/2011	0.75	3

3/11/2011	0.75	3
3/14/2011	0.75	3
3/15/2011	0.75	3
3/16/2011	0.75	3
3/17/2011	0.75	3
3/18/2011	0.75	3
3/21/2011	0.75	3
3/22/2011	0.75	3
3/23/2011	0.75	3
3/24/2011	0.75	3
3/25/2011	0.75	3
3/28/2011	0.75	3
3/29/2011	0.75	3
3/30/2011	0.75	3
3/31/2011	0.75	3
4/1/2011	0.75	3
4/4/2011	0.75	3
4/5/2011	0.75	3
4/6/2011	0.75	3
4/7/2011	0.75	3
4/8/2011	0.75	3
4/11/2011	0.75	3
4/12/2011	0.75	3
4/13/2011	0.75	3
4/14/2011	0.75	3
4/15/2011	0.75	3
4/18/2011	0.75	3

4/19/2011	0.75	3
4/20/2011	0.75	3
4/21/2011	0.75	3
4/22/2011	0.75	3
4/25/2011	0.75	3
4/26/2011	0.75	3
4/27/2011	0.75	3
4/28/2011	0.75	3
4/29/2011	0.75	3
5/2/2011	0.75	3

12. US 30-year treasury rates

Date	Rate
12/31/2010	4.334134
1/3/2011	4.397118
1/4/2011	4.410604
1/5/2011	4.543869
1/6/2011	4.511155
1/7/2011	4.48459
1/10/2011	4.461099
1/11/2011	4.487552
1/12/2011	4.531015
1/13/2011	4.49839
1/14/2011	4.530073
1/17/2011	4.528098
1/18/2011	4.562982
1/19/2011	4.527116

1/20/2011	4.609268
1/21/2011	4.565032
1/24/2011	4.557043
1/25/2011	4.489638
1/26/2011	4.586148
1/27/2011	4.569089
1/28/2011	4.528229
1/31/2011	4.571147
2/1/2011	4.616534
2/2/2011	4.619591
2/3/2011	4.664479
2/4/2011	4.72754
2/7/2011	4.696457
2/8/2011	4.76521
2/9/2011	4.710985
2/10/2011	4.764206
2/11/2011	4.687577
2/14/2011	4.671146
2/15/2011	4.661498
2/16/2011	4.679813
2/17/2011	4.668216
2/18/2011	4.683622
2/21/2011	4.683611
2/22/2011	4.603061
2/23/2011	4.582214
2/24/2011	4.54174
2/25/2011	4.496041

2/28/2011	4.500659
3/1/2011	4.479355
3/2/2011	4.566065
3/3/2011	4.619133
3/4/2011	4.596262
3/7/2011	4.621944
3/8/2011	4.663176
3/9/2011	4.606672
3/10/2011	4.498628
3/11/2011	4.548035
3/14/2011	4.5349
3/15/2011	4.454234
3/16/2011	4.355262
3/17/2011	4.435811
3/18/2011	4.416647
3/21/2011	4.45137
3/22/2011	4.436688
3/23/2011	4.447663
3/24/2011	4.482646
3/25/2011	4.500207
3/28/2011	4.494623
3/29/2011	4.544055
3/30/2011	4.502019
3/31/2011	4.507584
4/1/2011	4.485262
4/4/2011	4.475998
4/5/2011	4.50379

4/6/2011	4.594937
4/7/2011	4.615875
4/8/2011	4.641698
4/11/2011	4.654192
4/12/2011	4.57497
4/13/2011	4.542924
4/14/2011	4.548548
4/15/2011	4.468413
4/18/2011	4.456418
4/19/2011	4.431626
4/20/2011	4.465601
4/21/2011	4.473853
4/22/2011	4.464606
4/25/2011	4.455378
4/26/2011	4.390523
4/27/2011	4.452603
4/28/2011	4.414126
4/29/2011	4.396789
5/2/2011	4.378647

13. Historic US 30-year treasury rates

11/4/1991	8.222
11/4/1992	7.709
11/4/1993	6.789
11/4/1994	7.108
11/4/1995	7.156
11/4/1996	6.646

11/4/1997	6.675
11/4/1998	5.713
11/4/1999	5.692
11/4/2000	6.035
11/4/2001	5.538
11/4/2002	5.342
11/4/2003	4.896
11/4/2004	5.064
11/4/2005	4.601
11/4/2006	4.878
11/4/2007	4.862
11/4/2008	4.453
11/4/2009	3.9
11/4/2010	4.263
11/4/2011	4.112
11/4/2012	2.943
11/4/2013	3.287

14. Historic LIBOR Average

11/04/91	6.79539
11/04/92	4.35784
11/04/93	3.74382
11/04/94	5.07806
11/04/95	6.48379
11/04/96	5.75826
11/04/97	6.01728

11/04/98	5.68905
11/04/99	5.53533
11/04/00	6.84096
11/04/01	4.47244
11/04/02	2.3207
11/04/03	1.37237
11/04/04	1.90005
11/04/05	3.74619
11/04/06	5.2556
11/04/07	5.24856
11/04/08	3.38194
11/04/09	1.80622
11/04/10	0.96186
11/04/11	0.78687
11/04/12	1.04444
11/04/13	0.72482

15. Bond and yield rates

8/8/2013	99.58984375	5/9/2013	97.296875	2.29296875	8/8/2013	3.647	3.673	-2.5905	2.5905
8/9/2013	99.8203125	5/10/2013	95.7265625	4.09375	8/9/2013	3.635	3.665	-3	3
8/12/2013	98.9296875	5/13/2013	95.0390625	3.890625	8/12/2013	3.684	3.713	-2.8966	2.8966
8/13/2013	97.5859375	5/14/2013	93.9296875	3.65625	8/13/2013	3.76	3.79	-2.9897	2.9897
8/14/2013	97.7109375	5/15/2013	94.5703125	3.140625	8/14/2013	3.753	3.783	-3.0116	3.0116
8/15/2013	96.7265625	5/16/2013	95.6640625	1.0625	8/15/2013	3.809	3.841	-3.1718	3.1718
8/16/2013	96.0390625	5/17/2013	94.3671875	1.671875	8/16/2013	3.849	3.882	-3.3489	3.3489
8/19/2013	95.1640625	5/20/2013	94.1953125	0.96875	8/19/2013	3.9	3.933	-3.3421	3.3421
8/20/2013	95.9609375	5/21/2013	95.0390625	0.921875	8/20/2013	3.853	3.887	-3.4123	3.4123
8/21/2013	94.8203125	5/22/2013	93.3984375	1.421875	8/21/2013	3.92	3.952	-3.1782	3.1782
8/22/2013	95.65625	5/23/2013	93.9296875	1.7265625	8/22/2013	3.871	3.904	-3.2745	3.2745
8/23/2013	97.0234375	5/24/2013	94.2734375	2.75	8/23/2013	3.792	3.824	-3.2234	3.2234

8/26/2013	97.4921875	5/27/2013	94.2734375	3.21875	8/26/2013	3.765	3.797	-3.2154	3.2154
8/27/2013	98.78125	5/28/2013	91.546875	7.234375	8/27/2013	3.693	3.725	-3.2116	3.2116
8/28/2013	98.0078125	5/29/2013	92.5546875	5.453125	8/28/2013	3.736	3.767	-3.0835	3.0835
8/29/2013	98.3828125	5/30/2013	92.4609375	5.921875	8/29/2013	3.715	3.744	-2.9423	2.9423
8/30/2013	98.6484375	5/31/2013	92.3125	6.3359375	8/30/2013	3.7	3.729	-2.888	2.888
9/3/2013	96.9765625	6/4/2013	91.7421875	5.234375	9/3/2013	3.795	3.824	-2.8995	2.8995
9/4/2013	96.9296875	6/5/2013	92.9140625	4.015625	9/4/2013	3.797	3.826	-2.8356	2.8356
9/5/2013	95.40625	6/6/2013	92.9453125	2.4609375	9/5/2013	3.886	3.914	-2.8007	2.8007
9/6/2013	95.734375	6/7/2013	91.3359375	4.3984375	9/6/2013	3.867	3.895	-2.7975	2.7975
9/9/2013	95.9609375	6/10/2013	90.7109375	5.25	9/9/2013	3.853	3.88	-2.7007	2.7007
9/10/2013	95.2578125	6/11/2013	91.6875	3.5703125	9/10/2013	3.895	3.924	-2.9783	2.9783
9/11/2013	95.9375	6/12/2013	90.7109375	5.2265625	9/11/2013	3.855	3.884	-2.8788	2.8788
9/12/2013	95.96875	6/13/2013	91.6484375	4.3203125	9/12/2013	3.853	3.883	-2.9642	2.9642
9/13/2013	96.2734375	6/14/2013	91.859375	4.4140625	9/13/2013	3.835	3.867	-3.1281	3.1281
9/16/2013	95.7265625	6/17/2013	91.03125	4.6953125	9/16/2013	3.867	3.898	-3.0977	3.0977
9/17/2013	96.3203125	6/18/2013	91.2109375	5.109375	9/17/2013	3.833	3.865	-3.2076	3.2076
9/18/2013	97.8046875	6/19/2013	89.9765625	7.828125	9/18/2013	3.748	3.779	-3.1233	3.1233
9/19/2013	96.8359375	6/20/2013	88.2421875	8.59375	9/19/2013	3.803	3.834	-3.0728	3.0728
9/20/2013	97.546875	6/21/2013	87.078125	10.46875	9/20/2013	3.762	3.794	-3.1644	3.1644
9/23/2013	98.1953125	6/24/2013	87.6640625	10.53125	9/23/2013	3.725	3.756	-3.0894	3.0894
9/24/2013	99.1796875	6/25/2013	86.4140625	12.765625	9/24/2013	3.67	3.701	-3.0435	3.0435
9/25/2013	99.1796875	6/26/2013	87.1328125	12.046875	9/25/2013	3.67	3.702	-3.1454	3.1454
9/26/2013	98.71875	6/27/2013	87.8828125	10.8359375	9/26/2013	3.696	3.728	-3.2047	3.2047
9/27/2013	98.8828125	6/28/2013	88.46875	10.4140625	9/27/2013	3.687	3.719	-3.2595	3.2595
9/30/2013	98.90625	7/1/2013	88.84375	10.0625	9/30/2013	3.686	3.719	-3.298	3.298
10/1/2013	98.328125	7/2/2013	88.9296875	9.3984375	10/1/2013	3.718	3.751	-3.288	3.288
10/2/2013	98.609375	7/3/2013	88.5859375	10.0234375	10/2/2013	3.702	3.735	-3.3055	3.3055
10/3/2013	98.5078125	7/4/2013	88.5859375	9.921875	10/3/2013	3.708	3.74	-3.2296	3.2296
10/4/2013	98.2890625	7/5/2013	84.9453125	13.34375	10/4/2013	3.72	3.752	-3.1908	3.1908
10/7/2013	98.7890625	7/8/2013	86.2421875	12.546875	10/7/2013	3.692	3.725	-3.2622	3.2622
10/8/2013	98.8203125	7/9/2013	86.0078125	12.8125	10/8/2013	3.69	3.722	-3.1492	3.1492
10/9/2013	97.9765625	7/10/2013	85.96875	12.0078125	10/9/2013	3.738	3.77	-3.2133	3.2133
10/10/2013	98.03125	7/11/2013	86.3046875	11.7265625	10/10/2013	3.735	3.768	-3.2811	3.2811
10/11/2013	97.796875	7/12/2013	86.375	11.421875	10/11/2013	3.748	3.78	-3.1584	3.1584
10/15/2013	97.0625	7/16/2013	87.0390625	10.0234375	10/15/2013	3.79	3.823	-3.3018	3.3018
10/16/2013	98.265625	7/17/2013	87.2109375	11.0546875	10/16/2013	3.722	3.754	-3.2556	3.2556

10/17/2013	99.3828125	7/18/2013	86.3671875	13.015625	10/17/2013	3.659	3.692	-3.3167	3.3167
10/18/2013	99.6953125	7/19/2013	87.453125	12.2421875	10/18/2013	3.642	3.675	-3.3242	3.3242
10/21/2013	99.171875	7/22/2013	87.6328125	11.5390625	10/21/2013	3.671	3.704	-3.3754	3.3754
10/22/2013	100.28125	7/23/2013	87.1796875	13.1015625	10/22/2013	3.609	3.643	-3.3927	3.3927
10/23/2013	100.53125	7/24/2013	86.0390625	14.4921875	10/23/2013	3.596	3.629	-3.3347	3.3347
10/24/2013	100.234375	7/25/2013	86.1328125	14.1015625	10/24/2013	3.612	3.647	-3.4803	3.4803
10/25/2013	100.4375	7/26/2013	86.4609375	13.9765625	10/25/2013	3.601	3.636	-3.557	3.557
10/28/2013	100.109375	7/29/2013	85.5859375	14.5234375	10/28/2013	3.619	3.654	-3.5317	3.5317
10/29/2013	100.2109375	7/30/2013	85.4609375	14.75	10/29/2013	3.613	3.647	-3.4238	3.4238
10/30/2013	99.6953125	7/31/2013	86.21875	13.4765625	10/30/2013	3.642	3.676	-3.4699	3.4699
10/31/2013	99.7421875	8/1/2013	84.3046875	15.4375	10/31/2013	3.639	3.674	-3.4929	3.4929

16. France CAC rates

12/31/2010	3804.780029	21801838
1/3/2011	3900.860107	72025040
1/4/2011	3916.030029	109202040
1/5/2011	3904.610107	116335656
1/6/2011	3904.419922	124397112
1/7/2011	3865.580078	113235544
1/10/2011	3802.030029	123907960
1/11/2011	3861.919922	135100816
1/12/2011	3945.070068	177690192
1/13/2011	3974.830078	185024704
1/14/2011	3983.280029	136628704
1/17/2011	3975.409912	79477608
1/18/2011	4012.679932	138535888
1/19/2011	3976.709961	151931584
1/20/2011	3964.840088	171667264
1/21/2011	4017.449951	189639424
1/24/2011	4033.209961	113053168

1/25/2011	4019.620117	149305888
1/26/2011	4049.070068	159649344
1/27/2011	4059.570068	155312400
1/28/2011	4002.320068	159516400
1/31/2011	4005.5	149667424
2/1/2011	4072.620117	145716592
2/2/2011	4066.530029	135369120
2/3/2011	4036.590088	132587792
2/4/2011	4047.209961	125922000
2/7/2011	4090.800049	135168720
2/8/2011	4108.27002	150037776
2/9/2011	4090.73999	148466688
2/10/2011	4095.139893	274587168
2/11/2011	4101.310059	225951392
2/14/2011	4096.620117	179200160
2/15/2011	4110.339844	145990608
2/16/2011	4151.259766	181543712
2/17/2011	4152.310059	178320944
2/18/2011	4157.140137	166152128
2/21/2011	4097.410156	123263664
2/22/2011	4050.27002	170506784
2/23/2011	4013.120117	160225472
2/24/2011	4009.639893	198786128
2/25/2011	4070.379883	129429880
2/28/2011	4110.350098	130304128
3/1/2011	4067.149902	156607504
3/2/2011	4034.320068	168907664

3/3/2011	4060.76001	234355872
3/4/2011	4020.209961	163440720
3/7/2011	3990.409912	160394688
3/8/2011	4015.909912	145232896
3/9/2011	3993.810059	158263152
3/10/2011	3963.98999	148831200
3/11/2011	3928.679932	149965824
3/14/2011	3878.040039	199882736
3/15/2011	3780.850098	301915904
3/16/2011	3696.560059	240015456
3/17/2011	3786.209961	213430768
3/18/2011	3810.219971	240579328
3/21/2011	3904.449951	155323280
3/22/2011	3892.709961	140866400
3/23/2011	3913.72998	116755880
3/24/2011	3968.840088	132218016
3/25/2011	3972.379883	100944544
3/28/2011	3976.949951	121680720
3/29/2011	3987.800049	113657696
3/30/2011	4024.439941	124535128
3/31/2011	3989.179932	127460384
4/1/2011	4054.76001	150409904
4/4/2011	4042.919922	100169616
4/5/2011	4041.73999	116996224
4/6/2011	4048.159912	134534480
4/7/2011	4028.300049	125786200
4/8/2011	4061.909912	99894816

4/11/2011	4038.699951	96334632
4/12/2011	3976.600098	136738384
4/13/2011	4006.22998	125471768
4/14/2011	3970.389893	141820352
4/15/2011	3974.47998	128157672
4/18/2011	3881.23999	177310656
4/19/2011	3908.580078	122201760
4/20/2011	4004.620117	145177168
4/21/2011	4021.879883	117981696
4/22/2011		
4/25/2011		
4/26/2011	4045.290039	117611040
4/27/2011	4067.719971	136070240
4/28/2011	4104.899902	132981608
4/29/2011	4106.919922	88112384
5/2/2011	4108.77002	73176632

17. France CAC call rates

Strike Date	Strike	Ticker	Bid	Ask	Last	IVM	DM	Volm	OInt
15-Nov-11	4250	CAC 11 C4250	68.90000153	71.09999847	69.81999969	13.27663136	0.629498243	77	4316
15-Nov-11	4275	CAC 11 C4275	52.70000076	54.29999924	53.15999985	12.73479271	0.545793056	285	307
15-Nov-11	4300	CAC 11 C4300	38.5	40	39.31000137	12.338727	0.454161882	230	5474
15-Nov-11	4325	CAC 11 C4325	26.79999924	28	27.40999985	11.94016838	0.359647036	31	152
15-Nov-11	4350	CAC 11 C4350	17.79999924	18.79999924	18.25	11.63844013	0.270162582	1174	4617
20-Dec-12	4200	CAC 12 C4200	135.3000031	137.8000031	136.6499939	14.31364441	0.639264286	0	7428
20-Dec-12	4250	CAC 12 C4250	102.5999985	104.0999985	103.2600021	13.74785328	0.555310726	11	3260
20-Dec-12	4300	CAC 12 C4300	73.40000153	74.80000305	74.20999908	13.08788586	0.460220307	228	6272

20-Dec-12	4350	CAC 12 C4350	49.90000153	51	50.36000061	12.55269623	0.361624777	97	9639
20-Dec-12	4400	CAC 12 C4400	31.89999962	33	32.33000183	12.06479073	0.267153263	174	6946
17-Jan-12	4200	CAC 1/14 C4200	155.8000031	160.1999969	157.6999969	14.39450264	0.616394579	25	251
17-Jan-12	4250	CAC 1/14 C4250	123.5	127.4000015	124.8499985	13.83346367	0.548846304	26	52
17-Jan-12	4300	CAC 1/14 C4300	94.5	98.30000305	96.11000061	13.3176527	0.473615646	25	583
17-Jan-12	4350	CAC 1/14 C4350	69.80000305	73.30000305	71.65000153	12.83805275	0.395476669	35	2418
17-Jan-12	4400	CAC 1/14 C4400	49.29999924	52.5	51.18999863	12.41786385	0.318545312	25	1557
21-Mar-12	4200	CAC 3/14 C4200	210	215.3000031	212.9600067	15.96524048	0.590469599	0	2538
22-Mar-12	4250	CAC 3/14 C4250	179	184	181.9199982	15.56432533	0.544085264	0	329
23-Mar-12	4300	CAC 3/14 C4300	150.3000031	155	152.5299988	15.1509285	0.494428635	0	1122
24-Mar-12	4350	CAC 3/14 C4350	124.5	128.8000031	126.5599976	14.78430939	0.44333598	0	121
25-Mar-12	4400	CAC 3/14 C4400	101.6999969	105.5	103.5400009	14.42161846	0.391871601	0	1203
20-Jun-12	4200	CAC 6/14 C4200	203.8000031	209.6999969	206.5800018	16.29374504	0.490906805	30	155
20-Jun-12	4250	CAC 6/14 C4250	178.1000061	182.3999939	180.7899933	16.00173187	0.454857409	0	341
20-Jun-12	4300	CAC 6/14 C4300	154.3999939	158.3999939	157.1999969	15.70722961	0.417822659	0	48
20-Jun-12	4350	CAC 6/14 C4350	132.8000031	137.6000061	135.6100006	15.46425343	0.380714267	0	3
20-Jun-12	4400	CAC 6/14 C4400	113.4000015	117.8000031	115.9800034	15.23131847	0.343759745	0	315
19-Sep-12	4200	CAC 9/14 C4200	251.6999969	258.7000122	256.4899902	17.14332962	0.497940838	0	122
19-Sep-12	4250	CAC 9/14 C4250	225.5	232.5	230.4100037	16.86912346	0.468190283	0	50
19-Sep-12	4300	CAC 9/14 C4300	201.1000061	208.1000061	205.9199982	16.54203606	0.437755078	0	0
19-Sep-12	4350	CAC 9/14 C4350	178.8000031	184.8000031	182.8899994	16.29857445	0.407481998	0	0
19-Sep-12	4400	CAC 9/14 C4400	158	163.8000031	161.8500061	16.12428856	0.378169924	0	80

18. France CAC put rates

Strike Date	Strike	Ticker	Bid	Ask	Last	IVM	DM	Volm	OInt
15-Nov-11	4250	CAC 11 P4250	26.20000076	27.39999962	26.81999969	12.78959942	- 0.365167975	281	2234

15-Nov-11	4275	CAC 11 P4275	34.5	35.79999924	35.15999985	12.31604671	-0.451199681	37	175
15-Nov-11	4300	CAC 11 P4300	45.20000076	46.79999924	46.31000137	11.90688992	-0.545705914	36	150
15-Nov-11	4325	CAC 11 P4325	58.09999847	60.20000076	59.40999985	11.62208366	-0.642105103	0	64
15-Nov-11	4350	CAC 11 P4350	73.69999695	76.40000153	75.25	11.15486336	-0.737076879	0	104
20-Dec-11	4200	CAC 12 P4200	53.40000153	54.79999924	54.16999817	14.1437254	-0.355828732	2	4130
20-Dec-11	4250	CAC 12 P4250	69.80000305	71.5	70.76000214	13.50370979	-0.440588027	41	1373
20-Dec-11	4300	CAC 12 P4300	90.59999847	92.59999847	91.70999908	12.86543941	-0.534553409	0	570
20-Dec-11	4350	CAC 12 P4350	116.5999985	119.3000031	117.8399963	12.38767815	-0.634844005	6	23
20-Dec-11	4400	CAC 12 P4400	148.3999939	151.6000061	149.8000031	11.80601883	-0.733988345	0	3070
17-Jan-12	4200	CAC 1/14 P4200	73.80000305	77.40000153	75.73999786	14.21968079	-0.378155112	25	94
17-Jan-12	4250	CAC 1/14 P4250	91	94.90000153	92.87000275	13.67054081	-0.446798623	25	75
17-Jan-12	4300	CAC 1/14 P4300	111.6999969	116.0999985	114.0999985	13.12281513	-0.520975471	25	82
17-Jan-12	4350	CAC 1/14 P4350	137.1999969	141.1999969	139.6100006	12.64895916	-0.600636601	30	92
17-Jan-12	4400	CAC 1/14 P4400	165.1999969	171.1999969	169.1300049	12.26879406	-0.678698301	0	0
21-Mar-12	4200	CAC 3/14 P4200	125.3000031	129.8000031	128.0399933	15.81484795	-0.404600561	0	2821
21-Mar-12	4250	CAC 3/14 P4250	144.8000031	148.6999969	146.9600067	15.43808174	-0.450994283	0	1364
21-Mar-12	4300	CAC 3/14 P4300	165.8000031	170	167.5200043	15.01802826	-0.500387251	0	77
21-Mar-12	4350	CAC 3/14 P4350	188.8999939	194	191.4900055	14.64740944	-0.551110268	15	38
21-Mar-12	4400	CAC 3/14 P4400	215.8000031	222.6000061	218.4199982	14.31235981	-0.603504121	0	65
20-Jun-12	4200	CAC 6/14 P4200	222.8999939	228.1999969	225.5399933	16.18057823	-0.478599608	0	110
20-Jun-12	4250	CAC 6/14 P4250	246.8000031	252.6000061	249.6600037	15.89225578	-0.515508473	0	289
20-Jun-12	4300	CAC 6/14 P4300	272.6000061	278.6000061	275.980011	15.59383869	-0.552517474	0	0
20-Jun-12	4350	CAC 6/14 P4350	300.2999878	307.2000122	304.2999878	15.40060234	-0.589856327	20	20
20-Jun-12	4400	CAC 6/14 P4400	330.3999939	337.7000122	334.5700073	15.09393883	-0.627506137	0	0
19-Sep-12	4200	CAC 9/14 P4200	274.7999878	281	278.9299927	17.00028419	-0.470716834	0	120
19-Sep-12	4250	CAC 9/14 P4250	298.5	305.5	302.7000122	16.73054886	-0.500017822	0	20

19-Sep-12	4300	CAC 9/14 P4300	323.5	331.5	328.0700073	16.47167587	-0.530312061	0	20
19-Sep-12	4350	CAC 9/14 P4350	350.7000122	358.7000122	354.8999939	16.22534561	-0.560474873	0	0
19-Sep-12	4400	CAC 9/14 P4400	379.5	387.5	383.7200012	16.03430748	-0.590723336	0	1

19. Germany DAX rates

12/30/2010	6914.189941	43679800
12/31/2010		
1/3/2011	6989.740234	61893344
1/4/2011	6975.350098	87666600
1/5/2011	6939.819824	117146456
1/6/2011	6981.390137	91236440
1/7/2011	6947.839844	92626936
1/10/2011	6857.060059	93168240
1/11/2011	6941.569824	115261968
1/12/2011	7068.779785	122558976
1/13/2011	7075.109863	160370256
1/14/2011	7075.700195	125094016
1/17/2011	7078.060059	79250944
1/18/2011	7143.450195	121753312
1/19/2011	7082.759766	110037280
1/20/2011	7024.27002	154430112
1/21/2011	7062.419922	173923200
1/24/2011	7067.77002	121574080
1/25/2011	7059.009766	122876888
1/26/2011	7127.350098	109512536
1/27/2011	7155.580078	113485728
1/28/2011	7102.799805	96022824

1/31/2011	7077.47998	93018512
2/1/2011	7184.27002	117370304
2/2/2011	7183.669922	114244744
2/3/2011	7193.680176	105094536
2/4/2011	7216.209961	94076888
2/7/2011	7283.620117	93208560
2/8/2011	7323.240234	98994728
2/9/2011	7320.899902	81830768
2/10/2011	7340.279785	105397336
2/11/2011	7371.200195	96099008
2/14/2011	7396.629883	70608152
2/15/2011	7400.040039	101585936
2/16/2011	7414.299805	122451696
2/17/2011	7405.509766	112234432
2/18/2011	7426.810059	122191784
2/21/2011	7321.810059	100847928
2/22/2011	7318.350098	121301928
2/23/2011	7194.600098	118025256
2/24/2011	7130.5	137571200
2/25/2011	7185.169922	114084736
2/28/2011	7272.319824	101476224
3/1/2011	7223.299805	112183016
3/2/2011	7181.120117	111173240
3/3/2011	7225.959961	95319688
3/4/2011	7178.899902	97469000
3/7/2011	7161.930176	86672160
3/8/2011	7164.75	144200448

3/9/2011	7131.799805	129975848
3/10/2011	7063.089844	131966392
3/11/2011	6981.490234	141440576
3/14/2011	6866.629883	170820224
3/15/2011	6647.660156	284493344
3/16/2011	6513.839844	202701008
3/17/2011	6656.879883	146282944
3/18/2011	6664.399902	252620560
3/21/2011	6816.120117	218423472
3/22/2011	6780.970215	119681576
3/23/2011	6804.450195	95709848
3/24/2011	6933.580078	103543232
3/25/2011	6946.359863	80873792
3/28/2011	6938.629883	72637488
3/29/2011	6934.439941	93219920
3/30/2011	7057.149902	100538824
3/31/2011	7041.310059	96956496
4/1/2011	7179.810059	103281992
4/4/2011	7175.330078	79303040
4/5/2011	7175.310059	104296176
4/6/2011	7215.109863	153826800
4/7/2011	7178.779785	125935480
4/8/2011	7217.02002	117314968
4/11/2011	7204.859863	108180272
4/12/2011	7102.910156	147621024
4/13/2011	7177.970215	182479456
4/14/2011	7146.560059	134294784

4/15/2011	7178.290039	187054256
4/18/2011	7026.850098	164025696
4/19/2011	7039.310059	130665200
4/20/2011	7249.189941	142620176
4/21/2011	7295.490234	115549992
4/22/2011		
4/25/2011		
4/26/2011	7356.509766	83584912
4/27/2011	7404.950195	107732744
4/28/2011	7475.220215	138746864
4/29/2011	7514.459961	91919024

20. Germany DAX call rates

Strike Date	Strike	Ticker	Bid	Ask	Last	IVM	DM	Volm	OInt
15-Nov-11	8950	DAX 11 C8950	129.6999969	133.6999969	135.3000031	12.3088522	0.631001532	40	2499
15-Nov-11	9000	DAX 11 C9000	97.30000305	100.8000031	102.1999969	11.80011272	0.545619965	562	11454
15-Nov-11	9050	DAX 11 C9050	69.80000305	72.69999695	74	11.39363956	0.451326519	754	3857
15-Nov-11	9100	DAX 11 C9100	47.59999847	50.29999924	51.09999847	11.10172272	0.354338229	2382	8418
15-Nov-11	9150	DAX 11 C9150	31.20000076	33.20000076	33.70000076	10.5604077	0.27739692	1774	6857
20-Dec-11	8950	DAX 12 C8950	215.6999969	219.6000061	220.8999939	13.32428932	0.575876594	139	1701
20-Dec-11	9000	DAX 12 C9000	184.8000031	188.3999939	189.6999969	12.98776436	0.531011522	1618	59950
20-Dec-11	9050	DAX 12 C9050	156.3999939	159.6999969	160.8000031	12.67976284	0.48431322	82	2142
20-Dec-11	9100	DAX 12 C9100	130.1999969	133.6000061	134.5	12.40425301	0.436358035	129	8228
20-Dec-11	9150	DAX 12 C9150	107	110.1999969	110.9000015	12.15275383	0.386937678	242	4644
17-Jan-12	8950	DAX 1/14 C8950	263.5	268.2999878	268.7999878	13.52999115	0.565219343	4	161
17-Jan-12	9000	DAX 1/14 C9000	232.8999939	237.3000031	238.1000061	13.26606846	0.530516505	5	4772
17-Jan-12	9050	DAX 1/14 C9050	204.1999969	208.1000061	209.1000061	13.01964474	0.493808538	2	578

17-Jan-12	9100	DAX 1/14 C9100	177.8000031	181.1999969	182.3000031	12.7617054	0.456732482	4	457
17-Jan-12	9150	DAX 1/14 C9150	153.3000031	156.3999939	157.3999939	12.54586506	0.417529523	22	728
21-Mar-12	8950	DAX 3/14 C8950	379.1000061	384.7999878	385.2000122	15.17435169	0.557060003	0	34
21-Mar-12	9000	DAX 3/14 C9000	349.2999878	353.8999939	355	14.96440792	0.53295821	332	21613
21-Mar-12	9050	DAX 3/14 C9050	320.7999878	325.1000061	326.2000122	14.78487682	0.50886184	776	1042
21-Mar-12	9100	DAX 3/14 C9100	293.8999939	297.2999878	298.5	14.58152103	0.484972984	0	829
21-Mar-12	9150	DAX 3/14 C9150	267.7999878	271.1000061	272.2999878	14.40199471	0.459656566	0	172
20-Jun-12	8950	DAX 6/14 C8950	506.7000122	516.7999878	513.9000244	16.07303659	0.560981729	0	142
20-Jun-12	9000	DAX 6/14 C9000	477	486.5	484	16.05862427	0.538848341	2252	12350
20-Jun-12	9050	DAX 6/14 C9050	448.2000122	457.2999878	455.1000061	15.73023542	0.52605987	310	169
20-Jun-12	9100	DAX 6/14 C9100	420.3999939	429.2999878	427.3999939	15.71724224	0.503759027	2	1388
20-Jun-12	9150	DAX 6/14 C9150	393.5	402.2000122	400.3999939	15.41230513	0.489887089	0	43
19-Sep-12	8950	DAX 9/14 C8950	615.0999756	629.5999756	624.5	16.77966741	0.562839362	0	20
19-Sep-12	9000	DAX 9/14 C9000	585.7999878	600	595	16.63620994	0.54877418	0	196
19-Sep-12	9050	DAX 9/14 C9050	557.2999878	571	566.5	16.49235865	0.534484279	0	10
19-Sep-12	9100	DAX 9/14 C9100	529.4000244	542.9000244	538.4000244	16.35067391	0.519986405	0	10
19-Sep-12	9150	DAX 9/14 C9150	502.3999939	515.5999756	511.3999939	16.2130061	0.505305262	0	10
19-Dec-12	8800	DAX 12/14 C8800	805	824.5999756	818.7000122	17.95142365	0.597895026	1	2760
19-Dec-12	8900	DAX 12/14 C8900	744.5999756	762.9000244	757.5999756	17.68653297	0.57482481	0	3031
19-Dec-12	9000	DAX 12/14 C9000	687.2999878	703.4000244	698.7000122	17.37988472	0.550801516	1502	16651
19-Dec-12	9100	DAX 12/14 C9100	633.2000122	646.5	642.5	17.16406822	0.526872456	0	701
19-Dec-12	9200	DAX 12/14 C9200	579.4000244	592.5999756	588.7999878	16.89853477	0.501322865	0	1967
19-Jun-12	8800	DAX 6/15 C8800	993.9000244	1016.400024	1007.700012	18.86478806	0.599025726	0	10
19-Jun-12	8900	DAX 6/15 C8900	936.7999878	957	948.4000244	18.59404978	0.58379467	0	1
19-Jun-12	9000	DAX 6/15 C9000	878.2999878	899.5	890.7000122	18.4312706	0.562097311	0	11
19-Jun-12	9100	DAX 6/15 C9100	821.7000122	844	835	18.21306229	0.542683125	0	58

19-Jun-12	9200	DAX 6/15 C9200	767.9000244	790.2999878	781.5	17.99017143	0.523637295	0	55
18-Dec-12	8600	DAX 12/15 C8600	1253.300049	1354.400024	1304.5	20.04470816	0.637156459	0	1832
18-Dec-12	8800	DAX 12/15 C8800	1142.199951	1223.199951	1182.5	19.6361156	0.607173263	0	1001
18-Dec-12	9000	DAX 12/15 C9000	1032	1108	1066.599976	19.2876264	0.576104622	0	3020
18-Dec-12	9200	DAX 12/15 C9200	922.9000244	998.7999878	957.4000244	18.89832067	0.543990981	0	38
18-Dec-12	9400	DAX 12/15 C9400	819.7999878	895.7000122	855.4000244	18.51387705	0.510990696	0	848
17-Jun-12	8600	DAX 6/16 C8600	1363.5	1564.599976	1464.599976	21.79486993	0.623597751	0	0
17-Jun-12	8800	DAX 6/16 C8800	1244.599976	1445.599976	1345.5	21.36311772	0.597892083	0	0
17-Jun-12	9000	DAX 6/16 C9000	1130.900024	1331.900024	1231.5	20.94447611	0.571362437	0	0
17-Jun-12	9200	DAX 6/16 C9200	1022.400024	1223.400024	1123.800049	20.53508385	0.544087696	0	0
17-Jun-12	9400	DAX 6/16 C9400	919.2999878	1120.199951	1021.799988	20.13568417	0.516169733	0	0

21. Germany DAX put rates

Strike Date	Strike	Ticker	Bid	Ask	Last	IVM	DM	Volm	OInt
15-Nov-11	8950	DAX 11 P8950	54.79999924	57.09999847	53.79999924	12.34525681	-0.368507922	882	3575
15-Nov-11	9000	DAX 11 P9000	71.69999695	74.69999695	70.69999695	11.85361767	-0.454096645	507	6509
15-Nov-11	9050	DAX 11 P9050	93.80000305	96.80000305	92.5	11.39273643	-0.549944103	170	775
15-Nov-11	9100	DAX 11 P9100	120.6999969	126.6999969	119.5999985	11.13558006	-0.644324124	10	201
15-Nov-11	9150	DAX 11 P9150	153.8999939	158	152.1999969	11.9914289	-0.697534464	2	33
20-Dec-11	8950	DAX 12 P8950	139	141.6999969	138.3999939	13.332798	-0.424033672	71	3714
20-Dec-11	9000	DAX 12 P9000	157.8999939	161.3000031	157.1999969	13.0050354	-0.468558609	168	9200
20-Dec-11	9050	DAX 12 P9050	179.1000061	182.6999969	178.3000031	12.71925831	-0.515443683	18	270
20-Dec-11	9100	DAX 12 P9100	202.8999939	206.8000031	202	12.43438053	-0.563342273	23	522
20-Dec-11	9150	DAX 12 P9150	229.3999939	233.6000061	228.5	12.14615154	-0.613108397	0	65
17-Jan-12	8950	DAX 1/14 P8950	181.3999939	185.3999939	180.8000031	13.367136	-0.432740897	1	180
17-Jan-12	9000	DAX 1/14 P9000	200.6000061	204.6999969	200.1000061	13.10390186	-0.469220728	736	834

17-Jan-12	9050	DAX 1/14 P9050	221.6000061	225.6999969	221.1000061	12.83856964	-0.505490303	0	224
17-Jan-12	9100	DAX 1/14 P9100	244.3999939	248.8999939	244.1999969	12.59771442	-0.544730604	3	198
17-Jan-12	9150	DAX 1/14 P9150	269.3999939	274.2000122	269.2999878	12.36291027	-0.583699226	15	14
21-Mar-12	8950	DAX 3/14 P8950	290.7000122	294.2000122	290	14.99263763	-0.443434954	0	115
21-Mar-12	9000	DAX 3/14 P9000	310.6000061	314.2000122	309.8999939	14.80192566	-0.466219902	2	1956
21-Mar-12	9050	DAX 3/14 P9050	331.7999878	335.3999939	331	14.5846777	-0.490678906	6	96
21-Mar-12	9100	DAX 3/14 P9100	353.8999939	357.7999878	353.2999878	14.39624596	-0.515799344	5	101
21-Mar-12	9150	DAX 3/14 P9150	377.3999939	383	377.1000061	14.22793198	-0.54127574	10	126
20-Jun-12	8950	DAX 6/14 P8950	400.2999878	408	401.1000061	15.91549484	-0.438732512	0	25
20-Jun-12	9000	DAX 6/14 P9000	420.5	428.2999878	421.5	15.58755016	-0.461016923	15	2193
20-Jun-12	9050	DAX 6/14 P9050	441.6000061	449.5	442.5	15.59607071	-0.47395961	0	50
20-Jun-12	9100	DAX 6/14 P9100	463.5	472	464.7000122	15.26856136	-0.497704953	0	51
20-Jun-12	9150	DAX 6/14 P9150	486.1000061	495.1000061	487.6000061	15.28505883	-0.5104191	0	1
19-Sep-12	8950	DAX 9/14 P8950	499.8999939	510.6000061	502.7999878	16.64609715	-0.43697318	0	0
19-Sep-12	9000	DAX 9/14 P9000	520.5	531.0999756	523.2000122	16.50887999	-0.451143223	0	10
19-Sep-12	9050	DAX 9/14 P9050	541.9000244	552.2999878	544.5999756	16.37202117	-0.465530126	0	100
19-Sep-12	9100	DAX 9/14 P9100	563.5999756	574.5999756	566.4000244	16.23565429	-0.480120469	0	0
19-Sep-12	9150	DAX 9/14 P9150	586.0999756	600.2000122	589.2000122	16.13828682	-0.494767293	0	0
19-Dec-12	8800	DAX 12/14 P8800	527.9000244	540.7000122	532.5	17.46021461	-0.401790738	0	2251
19-Dec-12	8900	DAX 12/14 P8900	567	579.9000244	571.0999756	17.20923805	-0.425469369	0	3060
19-Dec-12	9000	DAX 12/14 P9000	608.2999878	621.5	612.2999878	16.96202278	-0.449284971	1751	8180
19-Dec-12	9100	DAX 12/14 P9100	651.5999756	665.5999756	655.2999878	16.69822311	-0.474094659	0	323
19-Dec-12	9200	DAX 12/14 P9200	696.7999878	712.5999756	701.2999878	16.44595909	-0.500258982	0	64
19-Jun-12	8800	DAX 6/15 P8800	657.4000244	678.7000122	664.9000244	17.84088707	-0.400399655	0	400
19-Jun-12	8900	DAX 6/15 P8900	697.7999878	719.5	705	17.69230315	-0.416392872	0	1
19-Jun-12	9000	DAX 6/15 P9000	739.4000244	760.7000122	746.7999878	17.43891335	-0.439549595	0	71

19-Jun-12	9100	DAX 6/15 P9100	781.5999756	804.5	791.0999756	17.22838211	-0.459496737	0	0
19-Jun-12	9200	DAX 6/15 P9200	829.2999878	850.0999756	836.5	17.01963425	-0.480299801	0	50
18-Dec-12	8600	DAX 12/15 P8600	678.0999756	768.7000122	711.7000122	18.93637362	-0.361159463	0	2500
18-Dec-12	8800	DAX 12/15 P8800	755.7000122	846.2999878	788	18.57341571	-0.392750849	0	1101
18-Dec-12	9000	DAX 12/15 P9000	839.2000122	929.9000244	870.5	18.21424363	-0.425555249	0	704
18-Dec-12	9200	DAX 12/15 P9200	928.7000122	1019.5	959.7000122	17.85496331	-0.459437755	0	0
18-Dec-12	9400	DAX 12/15 P9400	0	0	1056.099976	0	0	0	0
17-Jun-12	8600	DAX 6/16 P8600	719.0999756	919.7999878	813.5	17.96930688	-0.376737541	0	0
17-Jun-12	8800	DAX 6/16 P8800	798.2000122	998.7999878	891.9000244	17.57705121	-0.407501535	0	0
17-Jun-12	9000	DAX 6/16 P9000	882.5	1083.199951	975.5	17.18082221	-0.439511369	0	0
17-Jun-12	9200	DAX 6/16 P9200	972	1172.800049	1065.400024	16.77488712	-0.472721987	0	0
17-Jun-12	9400	DAX 6/16 P9400	0	0	1160.900024	0	0	0	0

22. SPX 500 rates

12/31/2010	1257.636	4.27E+08
1/3/2011	1271.87	8.5E+08
1/4/2011	1270.196	8.27E+08
1/5/2011	1276.563	7.98E+08
1/6/2011	1273.852	8.65E+08
1/7/2011	1271.502	8.49E+08
1/10/2011	1269.753	7.36E+08
1/11/2011	1274.482	7.12E+08
1/12/2011	1285.955	7.35E+08
1/13/2011	1283.759	7.4E+08
1/14/2011	1293.245	8.54E+08
1/17/2011		

1/18/2011	1295.02	9.88E+08
1/19/2011	1281.918	8.3E+08
1/20/2011	1280.257	9.57E+08
1/21/2011	1283.347	1.05E+09
1/24/2011	1290.835	7.45E+08
1/25/2011	1291.18	8.28E+08
1/26/2011	1296.633	8.34E+08
1/27/2011	1299.541	7.8E+08
1/28/2011	1276.344	1.02E+09
1/31/2011	1286.121	9.33E+08
2/1/2011	1307.592	8.27E+08
2/2/2011	1304.029	7.15E+08
2/3/2011	1307.102	7.69E+08
2/4/2011	1310.87	7.03E+08
2/7/2011	1319.052	6.84E+08
2/8/2011	1324.573	6.53E+08
2/9/2011	1320.879	7.45E+08
2/10/2011	1321.868	9.12E+08
2/11/2011	1329.146	7.7E+08
2/14/2011	1332.322	6.67E+08
2/15/2011	1328.014	7.21E+08
2/16/2011	1336.322	7.67E+08
2/17/2011	1340.427	6.98E+08
2/18/2011	1343.014	1E+09
2/21/2011		
2/22/2011	1315.445	1.02E+09
2/23/2011	1307.398	1.03E+09

2/24/2011	1306.099	9.21E+08
2/25/2011	1319.883	7.19E+08
2/28/2011	1327.224	9.51E+08
3/1/2011	1306.332	9.09E+08
3/2/2011	1308.44	7.92E+08
3/3/2011	1330.969	8.15E+08
3/4/2011	1321.153	8.12E+08
3/7/2011	1310.131	8.22E+08
3/8/2011	1321.818	7.66E+08
3/9/2011	1320.025	6.86E+08
3/10/2011	1295.106	8.96E+08
3/11/2011	1304.281	7.26E+08
3/14/2011	1296.388	7.51E+08
3/15/2011	1281.872	1.02E+09
3/16/2011	1256.876	1.17E+09
3/17/2011	1273.715	8.41E+08
3/18/2011	1279.205	1.48E+09
3/21/2011	1298.383	7.87E+08
3/22/2011	1293.769	6.24E+08
3/23/2011	1297.543	6.89E+08
3/24/2011	1309.661	6.92E+08
3/25/2011	1313.802	6.52E+08
3/28/2011	1310.193	5.95E+08
3/29/2011	1319.443	5.92E+08
3/30/2011	1328.26	6.81E+08
3/31/2011	1325.827	8.2E+08
4/1/2011	1332.413	7.36E+08

4/4/2011	1332.874	5.93E+08
4/5/2011	1332.634	6.63E+08
4/6/2011	1335.54	7.36E+08

23. SPX 500 call rates

Strike Date	Strike	Ticker	Bid	Ask	Last	IVM	DM	Volm	OInt
16-Nov-11	1745	SPX 11/16/13 C1745	20.70000076	20.89999962	23.14999962	12.26103973	0.597185552	277	9160
16-Nov-11	1750	SPX 11/16/13 C1750	17.5	17.60000038	19.5	11.8868866	0.553096771	13621	76331
16-Nov-11	1755	SPX 11/16/13 C1755	14.60000038	14.69999981	16.70000076	11.53291035	0.505530715	1022	5222
16-Nov-11	1760	SPX 11/16/13 C1760	11.89999962	12	13.56999969	11.29166508	0.455619067	1079	26741
16-Nov-11	1765	SPX 11/16/13 C1765	9.600000381	9.699999809	10.97999954	10.89781094	0.402958959	269	24740
21-Dec-11	1745	SPX 12/21/13 C1745	34.59999847	34.79999924	37.04999924	12.85400009	0.542342246	25	16465
21-Dec-11	1750	SPX 12/21/13 C1750	31.70000076	31.89999962	34	12.70344067	0.518270552	12480	77132
21-Dec-11	1755	SPX 12/21/13 C1755	28.79999924	29	31	12.54543591	0.493439287	12089	9858
21-Dec-11	1760	SPX 12/21/13 C1760	26.10000038	26.29999924	29.89999962	12.30068874	0.467758507	8622	18790
21-Dec-11	1765	SPX 12/21/13 C1765	23.60000038	23.79999924	26.5	12.18120193	0.442676961	1072	11262
31-Dec-11	1745	SPXQ 12/31/13 C1745	37.90000153	38.09999847	37.40000153	13.00102806	0.536743104	0	10
31-Dec-11	1750	SPXQ 12/31/13 C1750	35	35.20000076	37.40000153	12.76557255	0.514865577	379	19963
31-Dec-11	1755	SPXQ 12/31/13 C1755	32.09999847	32.29999924	38.20000076	12.66804695	0.492347151	6	0
31-Dec-11	1760	SPXQ 12/31/13 C1760	29.39999962	29.60000038	35.34999847	12.47925949	0.469433099	63	831
31-Dec-11	1765	SPXQ 12/31/13 C1765	26.79999924	27	32.34000015	12.22281742	0.447481126	10	3
18-Jan-12	1745	SPX 1/18/14 C1745	43.20000076	43.40000153	48	13.25997353	0.531661391	43	614

18-Jan-12	1750	SPX 1/18/14 C1750	40.20000076	40.40000153	41.95000076	13.04228497	0.513315856	5013	25466
18-Jan-12	1760	SPX 1/18/14 C1760	34.70000076	34.90000153	36	12.721632	0.473766357	4	10443
18-Jan-12	1770	SPX 1/18/14 C1770	29.5	29.70000076	34.97000122	12.38647938	0.433965266	84	1105
18-Jan-12	1775	SPX 1/18/14 C1775	27.10000038	27.29999924	29	12.29611969	0.413782805	566	13195
22-Feb-12	1740	SPX 2/22/14 C1740	54.90000153	55.09999847	57.04999924	13.89395332	0.533403873	20	225
22-Feb-12	1750	SPX 2/22/14 C1750	49	49.20000076	50.88000107	13.65011311	0.50330919	2	2353
22-Feb-12	1760	SPX 2/22/14 C1760	43.40000153	43.59999847	46.34999847	13.30294418	0.47307086	412	25
22-Feb-12	1775	SPX 2/22/14 C1775	35.79999924	36	41.5	12.93364048	0.423326671	156	1446
22-Feb-12	1780	SPX 2/22/14 C1780	33.40000153	33.59999847	36.84999847	12.78956223	0.40779385	62	22
22-Mar-12	1700	SPX 3/22/14 C1700	88	88.19999695	92.5	15.33111477	0.622487664	310	20896
22-Mar-12	1725	SPX 3/22/14 C1725	71.30000305	71.5	78.09999847	14.65991783	0.565148592	54	19193
22-Mar-12	1750	SPX 3/22/14 C1750	56.20000076	56.40000153	59.54999924	14.03951168	0.502214074	2715	27505
22-Mar-12	1775	SPX 3/22/14 C1775	42.79999924	43	44.20000076	13.39180565	0.432770789	901	12348
22-Mar-12	1800	SPX 3/22/14 C1800	31.39999962	31.60000038	34.86999893	12.82292938	0.36039564	506	33325
31-Mar-12	1700	SPXQ 3/31/14 C1700	89.80000305	90	89.69999695	15.44046783	0.617655337	0	876
31-Mar-12	1725	SPXQ 3/31/14 C1725	73.30000305	73.5	78.19999695	14.73454285	0.562382162	10	835
31-Mar-12	1750	SPXQ 3/31/14 C1750	58.20000076	58.40000153	60.90000153	14.09802818	0.502073824	17	2844
31-Mar-12	1775	SPXQ 3/31/14 C1775	44.79999924	45	44.5	13.52647495	0.434758425	0	85
31-Mar-12	1800	SPXQ 3/31/14 C1800	33.40000153	33.59999847	41.40000153	12.9867382	0.36684075	0	1220
21-Jun-12	1700	SPX 6/21/14 C1700	105.1999969	105.4000015	114.8000031	15.97826672	0.588409662	0	21958
21-Jun-12	1725	SPX 6/21/14 C1725	89.40000153	89.59999847	89	15.44437885	0.543366849	0	9963
21-Jun-12	1750	SPX 6/21/14 C1750	74.80000305	75	76	14.93081474	0.495483071	303	18251
21-Jun-12	1775	SPX 6/21/14 C1775	61.40000153	61.59999847	67.5	14.38295746	0.445615172	300	7031
21-Jun-12	1800	SPX 6/21/14 C1800	49.40000153	49.59999847	52	13.90436268	0.393645912	200	17499

30-Jun-12	1700	SPXQ 6/30/14 C1700	106.1999969	106.4000015	100.8000031	15.97784328	0.58568579	0	5
30-Jun-12	1725	SPXQ 6/30/14 C1725	90.59999847	90.80000305	85.09999847	15.42051601	0.542452753	0	1
30-Jun-12	1750	SPXQ 6/30/14 C1750	76	76.19999695	71.25	14.98006439	0.496495038	0	1
30-Jun-12	1775	SPXQ 6/30/14 C1775	62.79999924	63	41.5	14.48702049	0.446424305	0	38
30-Jun-12	1800	SPXQ 6/30/14 C1800	50.90000153	51.09999847	35.79999924	13.99716377	0.396597207	0	19
20-Sep-12	1700	SPX 9/20/14 C1700	120.5	120.6999969	129.3000031	16.58449745	0.568707943	0	5231
20-Sep-12	1725	SPX 9/20/14 C1725	105.3000031	105.5	103	16.07508469	0.531793654	0	1919
20-Sep-12	1750	SPX 9/20/14 C1750	91	91.19999695	98.69999695	15.63890362	0.493277401	0	4083
20-Sep-12	1775	SPX 9/20/14 C1775	77.69999695	77.90000153	80.90000153	15.21365833	0.452764779	102	1705
20-Sep-12	1800	SPX 9/20/14 C1800	65.59999847	65.80000305	68	14.80415535	0.410361052	600	2126

24. SPX 500 put rates

Strike Date	Strike	Ticker	Bid	Ask	Last	IVM	DM	Volm	OInt
16-Nov-11	1745	SPX 11/16/13 P1745	12	12.10000038	10.97999954	11.01097298	-0.391953021	48	2837
16-Nov-11	1750	SPX 11/16/13 P1750	13.80000019	13.89999962	12.39999962	10.52309799	-0.440110505	5820	30618
16-Nov-11	1755	SPX 11/16/13 P1755	15.89999962	16	14.35000038	10.25309753	-0.49372384	575	767
16-Nov-11	1760	SPX 11/16/13 P1760	18.20000076	18.29999924	16.5	9.897236824	-0.550671339	1715	2783
16-Nov-11	1765	SPX 11/16/13 P1765	20.79999924	21	18.89999962	9.647989273	-0.609228849	562	1112
21-Dec-11	1745	SPX 12/21/13 P1745	28.70000076	28.89999962	25.5	12.049119	-0.453437388	1	15088
21-Dec-11	1750	SPX 12/21/13 P1750	30.70000076	30.89999962	30	11.82506466	-0.478675157	9997	55004
21-Dec-11	1755	SPX 12/21/13 P1755	32.79999924	33	32	11.68727875	-0.504691958	12285	9293
21-Dec-11	1760	SPX 12/21/13 P1760	35.09999847	35.29999924	31.89999962	11.44173908	-0.532471061	10333	20067

21-Dec-11	1765	SPX 12/21/13 P1765	37.59999847	37.79999924	36.25	11.19860554	-0.560650885	1037	10874
31-Dec-11	1745	SPXQ 12/31/13 P1745	32.59999847	32.79999924	35.5	12.13279533	-0.459292024	0	1
31-Dec-11	1750	SPXQ 12/31/13 P1750	34.70000076	34.90000153	33.5	12.04178619	-0.482012153	310	4877
31-Dec-11	1755	SPXQ 12/31/13 P1755	36.90000153	37.09999847	0	11.82068825	-0.505828857	0	0
31-Dec-11	1760	SPXQ 12/31/13 P1760	39.09999847	39.29999924	36.70000076	11.64983177	-0.529933929	1	0
31-Dec-11	1765	SPXQ 12/31/13 P1765	41.59999847	41.79999924	0	11.50431347	-0.554398239	0	0
18-Jan-12	1745	SPX 1/18/14 P1745	38.5	38.70000076	35.34999847	12.52440262	-0.463709831	0	63
18-Jan-12	1750	SPX 1/18/14 P1750	40.59999847	40.79999924	35.70000076	12.30430412	-0.482833356	5285	13290
18-Jan-12	1760	SPX 1/18/14 P1760	45	45.20000076	39.29999924	12.03631878	-0.523648202	91	1792
18-Jan-12	1770	SPX 1/18/14 P1770	49.90000153	50.09999847	47.20000076	11.66287804	-0.567530036	0	278
18-Jan-12	1775	SPX 1/18/14 P1775	52.5	52.70000076	50	11.50207901	-0.589456558	66	542
22-Feb-12	1740	SPX 2/22/14 P1740	48.79999924	49	44.54999924	13.28025818	-0.460110754	168	268
22-Feb-12	1750	SPX 2/22/14 P1750	52.90000153	53.09999847	51.56999969	13.03626919	-0.490714163	32	6469
22-Feb-12	1760	SPX 2/22/14 P1760	57.29999924	57.5	55	12.71656704	-0.523763478	430	21
22-Feb-12	1775	SPX 2/22/14 P1775	64.59999847	64.80000305	60.54999924	12.22762012	-0.575172186	30	371
22-Feb-12	1780	SPX 2/22/14 P1780	67.30000305	67.5	62.54999924	12.07863998	-0.592651784	70	10
22-Mar-12	1700	SPX 3/22/14 P1700	43.59999847	43.79999924	40.45000076	14.78803158	-0.366853178	374	16196
22-Mar-12	1725	SPX 3/22/14 P1725	51.90000153	52.09999847	48.90000153	14.05891418	-0.42634511	4	10102
22-Mar-12	1750	SPX 3/22/14 P1750	61.79999924	62	58.29999924	13.46850586	-0.491678387	3751	12043
22-Mar-12	1775	SPX 3/22/14 P1775	73.40000153	73.59999847	69.29000092	12.80833435	-0.564091921	4	3186
22-Mar-12	1800	SPX 3/22/14 P1800	87	87.19999695	82.15000153	12.2765646	-0.638177276	6	2124
31-Mar-12	1700	SPXQ 3/31/14 P1700	45.90000153	46.09999847	43.02999878	14.86267471	-0.371020526	0	543
31-Mar-12	1725	SPXQ 3/31/14 P1725	54.20000076	54.40000153	52	14.19893932	-0.428755432	0	1343
31-Mar-12	1750	SPXQ	64.09999847	64.30000305	70.63999939	13.57972813	-	0	225

		3/31/14 P1750					0.491427064		
31-Mar-12	1775	SPXQ 3/31/14 P1775	75.69999695	75.90000153	0	12.93192101	-0.56078732	0	0
31-Mar-12	1800	SPXQ 3/31/14 P1800	89.19999695	89.40000153	92.59999847	12.41629791	-0.631671965	0	6
21-Jun-12	1700	SPX 6/21/14 P1700	67.69999695	67.90000153	62.5	15.51567936	-0.399085134	91	13332
21-Jun-12	1725	SPX 6/21/14 P1725	76.80000305	77	74.59999847	14.98971367	-0.443829477	0	1834
21-Jun-12	1750	SPX 6/21/14 P1750	87.09999847	87.30000305	83.5	14.48731804	-0.493346721	300	5762
21-Jun-12	1775	SPX 6/21/14 P1775	98.69999695	98.90000153	92	13.97143364	-0.544522345	306	856
21-Jun-12	1800	SPX 6/21/14 P1800	111.5999985	111.8000031	105.8199997	13.47990894	-0.599018693	0	101
30-Jun-12	1700	SPXQ 6/30/14 P1700	69.19999695	69.40000153	108	15.55302715	-0.40091902	0	1
30-Jun-12	1725	SPXQ 6/30/14 P1725	78.5	78.69999695	101	15.01841831	-0.445205599	0	2
30-Jun-12	1750	SPXQ 6/30/14 P1750	88.90000153	89.09999847	0	14.51125908	-0.492439419	0	0
30-Jun-12	1775	SPXQ 6/30/14 P1775	100.5	100.6999969	95.69999695	14.05864906	-0.542970479	0	1
30-Jun-12	1800	SPXQ 6/30/14 P1800	113.5999985	113.8000031	181.5500031	13.5475502	-0.59591037	0	10
20-Sep-12	1700	SPX 9/20/14 P1700	89.59999847	89.80000305	85.40000153	16.17646408	-0.413676471	561	3565
20-Sep-12	1725	SPX 9/20/14 P1725	99.30000305	99.5	109.8000031	15.72896862	-0.451131463	0	350
20-Sep-12	1750	SPX 9/20/14 P1750	109.9000015	110.0999985	105.8000031	15.29559231	-0.491308063	0	3356
20-Sep-12	1775	SPX 9/20/14 P1775	121.5999985	121.8000031	119	14.84005356	-0.53265202	0	57
20-Sep-12	1800	SPX 9/20/14 P1800	134.3999939	134.6000061	176.6000061	14.44274044	-0.574880183	0	4

25. United Kingdom (UK) FTSE rates

12/31/2010	5899.94	2.05E+08
1/3/2011		2048
1/4/2011	6013.87	9.72E+08
1/5/2011	6043.86	9.86E+08

1/6/2011	6019.51	8.62E+08
1/7/2011	5984.33	7.89E+08
1/10/2011	5956.3	6.75E+08
1/11/2011	6014.03	8.75E+08
1/12/2011	6050.72	1.04E+09
1/13/2011	6023.88	9.43E+08
1/14/2011	6002.07	8.64E+08
1/17/2011	5985.7	6.12E+08
1/18/2011	6056.43	8.88E+08
1/19/2011	5976.7	9.08E+08
1/20/2011	5867.91	1.09E+09
1/21/2011	5896.25	1.18E+09
1/24/2011	5943.85	9.85E+08
1/25/2011	5917.71	1.05E+09
1/26/2011	5969.21	9.05E+08
1/27/2011	5965.08	8.53E+08
1/28/2011	5881.37	9.96E+08
1/31/2011	5862.94	9.49E+08
2/1/2011	5957.82	9.9E+08
2/2/2011	6000.07	9.1E+08
2/3/2011	5983.34	1.06E+09
2/4/2011	5997.38	7.88E+08
2/7/2011	6051.03	7.24E+08
2/8/2011	6091.33	8.85E+08
2/9/2011	6052.29	1.02E+09
2/10/2011	6020.01	8.42E+08
2/11/2011	6062.9	8.59E+08

2/14/2011	6060.09	6.33E+08
2/15/2011	6037.08	8.94E+08
2/16/2011	6085.27	8.9E+08
2/17/2011	6087.38	1.04E+09
2/18/2011	6082.99	8.15E+08
2/21/2011	6014.8	6.36E+08
2/22/2011	5996.76	7.83E+08
2/23/2011	5923.53	9.22E+08
2/24/2011	5919.98	9.71E+08
2/25/2011	6001.2	8.56E+08
2/28/2011	5994.01	1.04E+09
3/1/2011	5935.76	9.11E+08
3/2/2011	5914.89	9.1E+08
3/3/2011	6005.09	8.29E+08
3/4/2011	5990.39	7.4E+08
3/7/2011	5973.78	7.25E+08
3/8/2011	5974.76	8.38E+08
3/9/2011	5937.3	7.71E+08
3/10/2011	5845.29	9.76E+08
3/11/2011	5828.67	7.95E+08
3/14/2011	5775.24	8.41E+08
3/15/2011	5695.28	1.33E+09
3/16/2011	5598.23	1.15E+09
3/17/2011	5696.11	9.51E+08
3/18/2011	5718.13	1.55E+09
3/21/2011	5786.09	7.63E+08
3/22/2011	5762.71	7.87E+08

3/23/2011	5795.88	9.25E+08
3/24/2011	5880.87	8.76E+08
3/25/2011	5900.76	6.7E+08
3/28/2011	5904.49	5.3E+08
3/29/2011	5932.17	6.69E+08
3/30/2011	5948.3	9.11E+08
3/31/2011	5908.76	1.07E+09
4/1/2011	6009.92	9.46E+08
4/4/2011	6016.98	6.63E+08
4/5/2011	6007.06	6.97E+08
4/6/2011	6041.13	8.19E+08
4/7/2011	6007.37	7.11E+08
4/8/2011	6055.75	6.28E+08
4/11/2011	6053.44	6.91E+08
4/12/2011	5964.47	7.72E+08
4/13/2011	6010.44	7.09E+08
4/14/2011	5963.8	6.83E+08
4/15/2011	5996.01	7.82E+08
4/18/2011	5870.08	8.02E+08
4/19/2011	5896.87	6.22E+08
4/20/2011	6022.26	6.89E+08
4/21/2011	6018.3	7.43E+08
4/22/2011		
4/25/2011		
4/26/2011	6069.36	5.62E+08
4/27/2011	6068.16	7.27E+08
4/28/2011	6069.9	7.45E+08

4/29/2011		200560
5/2/2011		

26. UK FTSE call rates

Strike Date	Strike	Ticker	Bid	Ask	Last	IVM	DM	Volm	OInt
15-Nov-11	6675	UKX 11 C6675	76	79.5	78.5	10.38154697	0.622244239	16	3771
15-Nov-11	6700	UKX 11 C6700	60.5	63.5	62.5	10.09217262	0.555107296	595	13527
15-Nov-11	6725	UKX 11 C6725	47	49.5	48	9.821645737	0.482309729	37	3536
15-Nov-11	6750	UKX 11 C6750	36	38	37	9.683997154	0.407040894	907	6552
15-Nov-11	6775	UKX 11 C6775	26	28.5	27	9.558302879	0.33307609	74	2094
20-Dec-11	6675	UKX 12 C6675	134	138.5	136.5	12.14678955	0.553435802	0	147
20-Dec-11	6700	UKX 12 C6700	119.5	123.5	122	11.91635799	0.521592081	42	27926
20-Dec-11	6725	UKX 12 C6725	106	110	108	11.73583412	0.487692028	3	192
20-Dec-11	6750	UKX 12 C6750	94	97	95.5	11.59998035	0.453080326	306	9807
20-Dec-11	6775	UKX 12 C6775	81	85	83.5	11.47130775	0.41778478	757	167
17-Jan-12	6650	UKX 1/14 C6650	182	187	184.5	12.36990833	0.575084329	0	8316
17-Jan-12	6700	UKX 1/14 C6700	152	156	154	12.04430485	0.52372241	17	4865
17-Jan-12	6750	UKX 1/14 C6750	124.5	129	127	11.74858761	0.469144672	79	766
17-Jan-12	6800	UKX 1/14 C6800	100.5	105	102.5	11.4839716	0.413339585	0	199
17-Jan-12	6850	UKX 1/14 C6850	80	84	82	11.24499798	0.356911391	30	2885
21-Feb-12	6650	UKX 2/14 C6650	205	214	212.5	12.98308182	0.543075383	0	0
21-Feb-12	6700	UKX 2/14 C6700	176.5	184.5	182.5	12.70567322	0.502067626	21	180
21-Feb-12	6750	UKX 2/14 C6750	150	158	155.5	12.44030094	0.458717614	0	0
21-Feb-12	6800	UKX 2/14 C6800	126.5	134.5	132	12.19878483	0.415428311	0	35
21-Feb-12	6850	UKX 2/14 C6850	105.5	113.5	112	11.98964596	0.371232182	0	0
21-Mar-12	6600	UKX 3/14 C6600	253	258	256.5	13.76020908	0.552829444	0	15652

22-Mar-12	6650	UKX 3/14 C6650	223.5	229	227	13.51557255	0.518288255	0	0
23-Mar-12	6700	UKX 3/14 C6700	196	201	198.5	13.23876286	0.482910007	15	8367
24-Mar-12	6800	UKX 3/14 C6800	147.5	152	150	12.82570362	0.408147305	54	8273
25-Mar-12	6850	UKX 3/14 C6850	126.5	130.5	128.5	12.62930298	0.371159166	37	625
20-Jun-12	6500	UKX 6/14 C6500	360	370.5	365	15.06250763	0.563531697	0	7247
20-Jun-12	6600	UKX 6/14 C6600	300.5	310.5	305.5	14.58114243	0.513564587	78	7202
20-Jun-12	6700	UKX 6/14 C6700	247.5	256	252	14.19288158	0.46161443	0	5177
20-Jun-12	6800	UKX 6/14 C6800	201.5	208.5	205.5	13.82464886	0.408010513	155	3883
20-Jun-12	6900	UKX 6/14 C6900	160.5	166.5	160.5	13.47734833	0.353679478	3	531
19-Sep-12	6500	UKX 9/14 C6500	400	412.5	400	15.45353794	0.539060235	0	14
19-Sep-12	6600	UKX 9/14 C6600	344.5	355	350	15.06973839	0.497306615	0	388
19-Sep-12	6700	UKX 9/14 C6700	293.5	302.5	298	14.71250153	0.454077154	0	19
19-Sep-12	6800	UKX 9/14 C6800	247	256	254	14.39375591	0.410488904	0	674
19-Sep-12	6900	UKX 9/14 C6900	206	215	210.5	14.12186146	0.366579622	0	177
19-Dec-12	6500	UKX 12/14 C6500	443	453.5	451.5	15.72480392	0.525243938	0	13920
19-Dec-12	6600	UKX 12/14 C6600	388.5	399	394	15.40284729	0.488922089	250	10686
19-Dec-12	6700	UKX 12/14 C6700	338	348.5	343.5	15.11091805	0.451631397	575	3304
19-Dec-12	6800	UKX 12/14 C6800	291.5	301	296.5	14.82994938	0.409466028	0	5802
19-Dec-12	6900	UKX 12/14 C6900	249	259.5	254.5	14.71051598	0.386486053	0	0

27. UK FTSE put rates

Strike Date	Strike	Ticker	Bid	Ask	Last	IVM	DM	Volm	OInt
15-Nov-11	6675	UKX 11 P6675	37	39	38	10.23068523	-0.373351991	233	1251
15-Nov-11	6700	UKX 11 P6700	46.5	48	47	9.960562706	-0.441889614	827	7504
15-Nov-11	6725	UKX 11 P6725	57	59.5	57.5	9.826431274	-0.515544653	56	372
15-Nov-11	6750	UKX 11 P6750	70.5	73	71.5	9.586946487	-0.592291534	60	243

15-Nov-11	6775	UKX 11 P6775	85.5	89	86.5	9.396229744	-0.6658476	76	62
20-Dec-11	6675	UKX 12 P6675	101.5	105	103	11.95467567	-0.442064017	0	271
20-Dec-11	6700	UKX 12 P6700	112	115.5	113.5	11.78641415	-0.474353373	2002	6283
20-Dec-11	6725	UKX 12 P6725	123.5	127	124.5	11.63574409	-0.508632064	16	71
20-Dec-11	6750	UKX 12 P6750	135	139	137	11.50403214	-0.544427812	23	852
20-Dec-11	6775	UKX 12 P6775	148	152.5	150	11.34626961	-0.578911781	0	10
17-Jan-12	6650	UKX 1/14 P6650	120	123.5	121.5	12.14027977	-0.420239955	0	8296
17-Jan-12	6700	UKX 1/14 P6700	139	143.5	141.5	11.81787682	-0.47327891	15	4671
17-Jan-12	6750	UKX 1/14 P6750	162	166.5	163.5	11.5687027	-0.527401388	56	368
17-Jan-12	6800	UKX 1/14 P6800	187.5	192	189.5	11.22647953	-0.584418952	0	211
17-Jan-12	6850	UKX 1/14 P6850	216.5	221	219	11.02194977	-0.642000556	0	0
21-Feb-12	6650	UKX 2/14 P6650	169	177	173.5	12.91732597	-0.448851854	0	0
21-Feb-12	6700	UKX 2/14 P6700	190	198	193.5	12.59074974	-0.490945429	27	3
21-Feb-12	6750	UKX 2/14 P6750	213	222.5	216.5	12.35850716	-0.533331096	0	0
21-Feb-12	6800	UKX 2/14 P6800	239.5	248.5	242.5	12.18857479	-0.576732397	0	23
21-Feb-12	6850	UKX 2/14 P6850	268.5	277.5	273	11.99915409	-0.62005204	0	0
21-Mar-12	6600	UKX 3/14 P6600	194.5	199	196.5	13.70315838	-0.43353036	79	12746
21-Mar-12	6650	UKX 3/14 P6650	215	219.5	217	13.43220043	-0.468726665	0	21
21-Mar-12	6700	UKX 3/14 P6700	237	242	238.5	13.22552872	-0.504353344	14	798
21-Mar-12	6800	UKX 3/14 P6800	287.5	293	289.5	12.7372818	-0.579191446	2	178
21-Mar-12	6850	UKX 3/14 P6850	316.5	322	318.5	12.53640747	-0.616700053	0	0
20-Jun-12	6500	UKX 6/14 P6500	258.5	267.5	263	14.98904705	-0.413938373	0	6962
20-Jun-12	6600	UKX 6/14 P6600	298.5	307.5	303	14.53303719	-0.464001805	78	6035
20-Jun-12	6700	UKX 6/14 P6700	343.5	353.5	349	14.11533356	-0.516600311	0	2857
20-Jun-12	6800	UKX 6/14 P6800	395.5	406	402.5	13.73707581	-0.570739508	5	220
20-Jun-12	6900	UKX 6/14 P6900	454	466	466	13.41748905	-0.623654485	0	26

19-Sep-12	6500	UKX 9/14 P6500	340.5	351	350.5	15.42761803	-0.430483997	0	72
19-Sep-12	6600	UKX 9/14 P6600	383.5	394	391.5	15.02761364	-0.472564876	0	257
19-Sep-12	6700	UKX 9/14 P6700	430.5	443	439	14.70277214	-0.51551348	0	72
19-Sep-12	6800	UKX 9/14 P6800	483.5	496	494.5	14.38765812	-0.559408128	0	39
19-Sep-12	6900	UKX 9/14 P6900	541	554.5	550.5	14.11889362	-0.602327526	0	0
19-Dec-12	6500	UKX 12/14 P6500	414	424.5	419	15.74400616	-0.437549263	0	12640
19-Dec-12	6600	UKX 12/14 P6600	458.5	469	461	15.43259621	-0.473413587	0	9976
19-Dec-12	6700	UKX 12/14 P6700	507	517.5	510	15.10459137	-0.510443807	575	3229
19-Dec-12	6800	UKX 12/14 P6800	560	570.5	562	14.80174923	-0.548641026	0	250
19-Dec-12	6900	UKX 12/14 P6900	617	627.5	619.5	14.35965767	-0.592099695	0	0

28. Bond and yield rates

8/8/2013	99.58984375	5/9/2013	97.296875	2.29296875	8/8/2013	3.647	3.673	-2.5905	2.5905
8/9/2013	99.8203125	5/10/2013	95.7265625	4.09375	8/9/2013	3.635	3.665	-3	3
8/12/2013	98.9296875	5/13/2013	95.0390625	3.890625	8/12/2013	3.684	3.713	-2.8966	2.8966
8/13/2013	97.5859375	5/14/2013	93.9296875	3.65625	8/13/2013	3.76	3.79	-2.9897	2.9897
8/14/2013	97.7109375	5/15/2013	94.5703125	3.140625	8/14/2013	3.753	3.783	-3.0116	3.0116
8/15/2013	96.7265625	5/16/2013	95.6640625	1.0625	8/15/2013	3.809	3.841	-3.1718	3.1718
8/16/2013	96.0390625	5/17/2013	94.3671875	1.671875	8/16/2013	3.849	3.882	-3.3489	3.3489
8/19/2013	95.1640625	5/20/2013	94.1953125	0.96875	8/19/2013	3.9	3.933	-3.3421	3.3421
8/20/2013	95.9609375	5/21/2013	95.0390625	0.921875	8/20/2013	3.853	3.887	-3.4123	3.4123
8/21/2013	94.8203125	5/22/2013	93.3984375	1.421875	8/21/2013	3.92	3.952	-3.1782	3.1782
8/22/2013	95.65625	5/23/2013	93.9296875	1.7265625	8/22/2013	3.871	3.904	-3.2745	3.2745
8/23/2013	97.0234375	5/24/2013	94.2734375	2.75	8/23/2013	3.792	3.824	-3.2234	3.2234
8/26/2013	97.4921875	5/27/2013	94.2734375	3.21875	8/26/2013	3.765	3.797	-3.2154	3.2154
8/27/2013	98.78125	5/28/2013	91.546875	7.234375	8/27/2013	3.693	3.725	-3.2116	3.2116
8/28/2013	98.0078125	5/29/2013	92.5546875	5.453125	8/28/2013	3.736	3.767	-3.0835	3.0835
8/29/2013	98.3828125	5/30/2013	92.4609375	5.921875	8/29/2013	3.715	3.744	-2.9423	2.9423
8/30/2013	98.6484375	5/31/2013	92.3125	6.3359375	8/30/2013	3.7	3.729	-2.888	2.888
9/3/2013	96.9765625	6/4/2013	91.7421875	5.234375	9/3/2013	3.795	3.824	-2.8995	2.8995
9/4/2013	96.9296875	6/5/2013	92.9140625	4.015625	9/4/2013	3.797	3.826	-2.8356	2.8356

9/5/2013	95.40625	6/6/2013	92.9453125	2.4609375	9/5/2013	3.886	3.914	-2.8007	2.8007
9/6/2013	95.734375	6/7/2013	91.3359375	4.3984375	9/6/2013	3.867	3.895	-2.7975	2.7975
9/9/2013	95.9609375	6/10/2013	90.7109375	5.25	9/9/2013	3.853	3.88	-2.7007	2.7007
9/10/2013	95.2578125	6/11/2013	91.6875	3.5703125	9/10/2013	3.895	3.924	-2.9783	2.9783
9/11/2013	95.9375	6/12/2013	90.7109375	5.2265625	9/11/2013	3.855	3.884	-2.8788	2.8788
9/12/2013	95.96875	6/13/2013	91.6484375	4.3203125	9/12/2013	3.853	3.883	-2.9642	2.9642
9/13/2013	96.2734375	6/14/2013	91.859375	4.4140625	9/13/2013	3.835	3.867	-3.1281	3.1281
9/16/2013	95.7265625	6/17/2013	91.03125	4.6953125	9/16/2013	3.867	3.898	-3.0977	3.0977
9/17/2013	96.3203125	6/18/2013	91.2109375	5.109375	9/17/2013	3.833	3.865	-3.2076	3.2076
9/18/2013	97.8046875	6/19/2013	89.9765625	7.828125	9/18/2013	3.748	3.779	-3.1233	3.1233
9/19/2013	96.8359375	6/20/2013	88.2421875	8.59375	9/19/2013	3.803	3.834	-3.0728	3.0728
9/20/2013	97.546875	6/21/2013	87.078125	10.46875	9/20/2013	3.762	3.794	-3.1644	3.1644
9/23/2013	98.1953125	6/24/2013	87.6640625	10.53125	9/23/2013	3.725	3.756	-3.0894	3.0894
9/24/2013	99.1796875	6/25/2013	86.4140625	12.765625	9/24/2013	3.67	3.701	-3.0435	3.0435
9/25/2013	99.1796875	6/26/2013	87.1328125	12.046875	9/25/2013	3.67	3.702	-3.1454	3.1454
9/26/2013	98.71875	6/27/2013	87.8828125	10.8359375	9/26/2013	3.696	3.728	-3.2047	3.2047
9/27/2013	98.8828125	6/28/2013	88.46875	10.4140625	9/27/2013	3.687	3.719	-3.2595	3.2595
9/30/2013	98.90625	7/1/2013	88.84375	10.0625	9/30/2013	3.686	3.719	-3.298	3.298
10/1/2013	98.328125	7/2/2013	88.9296875	9.3984375	10/1/2013	3.718	3.751	-3.288	3.288
10/2/2013	98.609375	7/3/2013	88.5859375	10.0234375	10/2/2013	3.702	3.735	-3.3055	3.3055
10/3/2013	98.5078125	7/4/2013	88.5859375	9.921875	10/3/2013	3.708	3.74	-3.2296	3.2296
10/4/2013	98.2890625	7/5/2013	84.9453125	13.34375	10/4/2013	3.72	3.752	-3.1908	3.1908
10/7/2013	98.7890625	7/8/2013	86.2421875	12.546875	10/7/2013	3.692	3.725	-3.2622	3.2622
10/8/2013	98.8203125	7/9/2013	86.0078125	12.8125	10/8/2013	3.69	3.722	-3.1492	3.1492
10/9/2013	97.9765625	7/10/2013	85.96875	12.0078125	10/9/2013	3.738	3.77	-3.2133	3.2133
10/10/2013	98.03125	7/11/2013	86.3046875	11.7265625	10/10/2013	3.735	3.768	-3.2811	3.2811
10/11/2013	97.796875	7/12/2013	86.375	11.421875	10/11/2013	3.748	3.78	-3.1584	3.1584
10/15/2013	97.0625	7/16/2013	87.0390625	10.0234375	10/15/2013	3.79	3.823	-3.3018	3.3018
10/16/2013	98.265625	7/17/2013	87.2109375	11.0546875	10/16/2013	3.722	3.754	-3.2556	3.2556
10/17/2013	99.3828125	7/18/2013	86.3671875	13.015625	10/17/2013	3.659	3.692	-3.3167	3.3167
10/18/2013	99.6953125	7/19/2013	87.453125	12.2421875	10/18/2013	3.642	3.675	-3.3242	3.3242
10/21/2013	99.171875	7/22/2013	87.6328125	11.5390625	10/21/2013	3.671	3.704	-3.3754	3.3754
10/22/2013	100.28125	7/23/2013	87.1796875	13.1015625	10/22/2013	3.609	3.643	-3.3927	3.3927
10/23/2013	100.53125	7/24/2013	86.0390625	14.4921875	10/23/2013	3.596	3.629	-3.3347	3.3347
10/24/2013	100.234375	7/25/2013	86.1328125	14.1015625	10/24/2013	3.612	3.647	-3.4803	3.4803
10/25/2013	100.4375	7/26/2013	86.4609375	13.9765625	10/25/2013	3.601	3.636	-3.557	3.557

10/28/2013	100.109375	7/29/2013	85.5859375	14.5234375	10/28/2013	3.619	3.654	-3.5317	3.5317
10/29/2013	100.2109375	7/30/2013	85.4609375	14.75	10/29/2013	3.613	3.647	-3.4238	3.4238
10/30/2013	99.6953125	7/31/2013	86.21875	13.4765625	10/30/2013	3.642	3.676	-3.4699	3.4699
10/31/2013	99.7421875	8/1/2013	84.3046875	15.4375	10/31/2013	3.639	3.674	-3.4929	3.4929

29. The acceptance rate for a volatility trade deal once it is executed is .90.

30. For all hedge funds, there are three possible and distinct trade volumes in a volatility trade: 50,000 shares, 100,000 shares, and 250,000 shares.