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

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1 Purpose

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 a large population 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. 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 tool for studying and predicting the emergence of risk events associated with a failed (total collapse and liquidation) 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 hedge fund and its associated entities 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 and its associated entities. 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 riskier 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.

[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 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 arbitrage in the interest-rate swap[5] 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) 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 (i.e. the model may show that LTCM'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 by extreme portfolio value loss when capital lost exceeds capital required to cover losses. VaR traditionally computes a probability of when a certain capital requirement level is not exceeded within a set number of business days. The complement of that event is the probability of failure that will be compared against the failure rate derived from the ABM model. If the ABM model clearly demonstrates a higher likelihood of extreme events to include heavy portfolio loss for a LTCM-like hedge fund

[5] A derivative in which counterparties exchange one of the party's financial instruments for those of the other party's instruments

[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)

when compared to traditional approaches such as VaR, the proposed ABM model can become a 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 and 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 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 a failed hedge fund along with other relevant entities. The failed hedge fund chosen for modelling is Long Term Capital Management (LTCM).

2.1 Problem-solving Methodology

The LTCM model will be 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 largely on the Cross Industry Standard Process for Data Mining (CRISP-DM) generalizes the way forward in model implementation.

1) Understand Market Context
The market context will center around LTCM, its hedge fund competitors, miscellaneous investors, banks, and regulators. LTCM shall use a fixed income arbitrage strategy with a mix of other investment strategies, while its competitors may use the same mix of strategies but at different levels of risk behavior exhibited by parameters such as a leverage ratio. Behavior from the hedge funds shall exhibit various trading strategies to include convergence trades, interest rate swaps, and volatility trades. For example, they long a bond with 29 year ¾ maturity date and short a 30 year bond. LTCM may make use of relatively stable bonds in the US, Europe, and Japan. Other associated agents such as lending banks and investors will come into play and interact with the hedge fund agents.

2) Collect Appropriate Data

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

The George Mason Bloomberg terminal shall be the main source of data for setting initial parameters in the ABM system to reflect real-time conditions around January 1997. Most of the financial instruments will come from fixed-income instruments. A full set of data on those chosen instruments from January 1997 to December 1998 will be critical in establishing a historically based VaR for comparison to the results of the ABM model.

3) Specify Agent Types
Type may include but not are limited to LTCM, other hedge fund competitors, institutional and wealthy individual investors, lending banks, and the US Federal Reserve. The study aims to populate the ABM system with a number of agents (between 50 and 100). Each agent shall have optional input parameters -- to include but not are limited to leverage ratios, bank capital requirements, etc -- in order to understand sensitivity of model output to input.

4) Specify Associated Rules
Each agent type shall have a set of well-defined rules that describes its behavior. For instance, LTCM should have a rule defined for handling long trades and one for short trades. Stochastic distributions shall also be 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. For instance, a 'network' context may show visual connections between two agents to represent a change such as a purchase or sale of investments. In addition, the visual position of the agent may indicate a loss or gain in trading position.

6) Analyze Model Results
Repast easily presents data results in graphical or spreadsheet form. The kind of results may include but is not limited to aggregated loss or gains of a particular agent type.

7) Form Insights and Finalize Conclusion
Each model run will begin in January 1997 and will be set for a length of approximately two years until December 1998. All agents will adhere to its own set of specified behavioral rules, and the collective interactions of all agents may potentially form an overall emerging pattern at the end of each run. Each run may yield a new insight, giving another opportunity to refine the model to reach an appropriate conclusion. It also may lead to other opportunities such as randomly introducing policy changes or "financial jolts" to the system. Taking the aggregated results over all runs as a Monte Carlo simulation, the likelihood of heavy capital losses for our LTCM hedge fund agent shall be compared to the probability complement from VaR.

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 chosen to be specified constitutes an appropriate set of entities required for a realistic LTCM financial model.

4. Results from the LTCM model can be extended to other financial institutions.

Constraints for this study include:

1. The period of performance for this study is 29 August 2013 to 5 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 one real (i.e. LTCM) failed hedge fund 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 Staffing

Erik Halseth - Professional career is in consulting conducting data analytics based on open source technologies. He has an undergraduate degree in computer science, and is currently finishing his master's degree in operations research.

Toan Bui - Has an undergraduate degree in Financial Math and Financial Econ and is currently finishing his master’s degree in operations research with concentration in financial engineering.

Callie Beagley - Professional career is in consulting as an operations research analyst for government clients. She has an undergraduate degree in applied mathematics, and is currently finishing her master’s degree in systems engineering with concentration in Command, Control, Communications, Computing, and Intelligence (C4I).

2.4 Work Breakdown Structure and Schedule

Level 1 Tasks	Level 2 Tasks	Level 3 Tasks	Date Start	Date Finish
1 Develop ABM LTCM Model	1.1 Conduct Literature Review	1.1.1 Review Agent-based Modeling Literature	9/2/2013	10/4/2013
		1.1.2 Review Repast Literature	9/2/2013	10/4/2013
		1.1.3 Review General Economic/Finance Literature	9/2/2013	10/4/2013
		1.1.4 Review Long Term Capital Management Literature	9/2/2013	10/4/2013
	1.2 Develop LTCM Repast Model	1.2.1 Develop Conceptual LTCM Model (Storyboard, preliminary algorithms)	9/25/2013	10/10/2013
		1.2.2 Specify LTCM Model in Repast (Verify and Validate while Developing)	10/10/2013	10/28/2013
		1.2.3 Conduct LTCM Model Runs	10/29/2013	10/30/2013
		1.2.4 Conduct Data Analysis on Run Results	11/1/2013	11/3/2013
		1.2.5 Develop Way-Ahead (Excursions) for LTCM Model	11/3/2013	11/8/2013
	1.3 Develop LTCM Model Deliverables and Documentation	1.3.1 Develop LTCM Proposal and Proposal Presentation	9/12/2013	9/22/2013
		1.3.2 Develop	10/4/2013	10/10/2013

		Status Report		
		1.3.3 Develop IPR	10/11/2013	10/17/2013
		1.3.4 Develop ABM LTCM Final Report and Presentation	11/15/2013	11/21/2013
		1.3.6 Develop Financial Engineering Project Website	10/25/2013	11/21/2013
	1.4 Milestones	1.4.1 Proposal and Proposal Presentation Due	9/22/2013	9/22/2013
		1.4.2 Status Report Due	10/10/2013	10/10/2013
		1.4.3 IPR Due	10/17/2013	10/17/2013
		1.4.4 Final Report Due	11/21/2013	11/21/2013
		1.4.5 Final Presentation Due	12/5/2013	12/5/2013
		1.4.6 Website Due	12/5/2013	12/5/2013
		1.4.7 Final ACE LTCM Model Due	12/5/2013	12/5/2013
		1.4.8 Weekly Meetings with Dr. Chang	Recurring weekly starting 19 Sep	

2.5 Risk Management and Quality Assurance

Risk management is defined as “the continuing process to identify, analyze, evaluate, and treat loss exposures and monitor risk control and financial resources to mitigate the adverse effects of loss” (marquette.edu). Utilizing this definition, the primary risk for this project is schedule slippage due to conceptual model development (i.e. issues developing algorithms for implementation) and model specification. The mitigation strategy for schedule slippage for the conceptual model is meeting weekly with the study sponsor, Dr. Chang, and through thorough literature research and strong teamwork. The mitigation strategy for model specification is to

reduce the likelihood of single-point-of-failure by all team members participating in model specification and maintaining proper model change control and backup procedures.

Quality assurance is defined as “the planned and systematic activities implemented in a quality system so that quality requirements for a product or service will be fulfilled” (asq.org). To this end, the quality assurance strategy for this study is three-fold. First, weekly meetings with the study sponsor, Dr. Chang, will be held to ensure sponsor expectations are met. Secondly, teamwork will ensure that all study deliverables are consistent and are of the best quality possible. Third, the LTCM model will be developed using a code-test-code-test process, ensuring that all algorithms specified in code are verified and validated during development.

3 Deliverables List

1. Proposal and Proposal Presentation
2. Status Report
3. IPR
4. Final Report
5. Final Presentation
6. ABM LTCM Model
7. Financial Engineering Project Website

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