Financial Engineering:
Agent-based Modeling
Final Presentation

OR 699
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Agenda

- Background
- Technical Approach and Conceptual Model
- Results
- Conclusions and Future Work

Background

Capability Gap

- Neoclassical Economics - most widely taught form of economics
  - Basic Assumptions of Neoclassical Economics
    - People have rational preferences among outcomes that can be identified and associated with a value
    - Individuals maximize utility and firms maximize profits
    - People act independently on the basis of full and relevant (perfect) information
  - Trades are also conducted through a centralized auctioneer

- While assumptions make economic system mathematically simpler, they do not hold all the time

- Agent-Based Modeling (ABM) may be used to study whether good economic designs can be discovered by modeling economic systems from the ground up

Study Purpose and Scope

- Study the feasibility of ABM to predict the emergence of risk events centered around a hedge fund

- Chosen financial entity acting as a blueprint: failed hedge fund
  - Modeling the global economy is infeasible due to size
  - Hedge funds previously have had more relaxed regulatory requirements than mutual funds, and therefore can engage in more risky trading behavior
  - Use Long Term Capital Management (LTCM) as a template for hedge fund strategies
    - LTCM was a hedge fund which collapsed in 1998, requiring a $3.65 billion recapitalization from 14 financial institutions

- If successful, the ABM model becomes an experimental playground and code baseline for hedge fund risk

Stakeholders

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

- Second-order stakeholders: those which could potentially use the results of this study
  - Finance academic societies that are interested in assessing the utility of an ABM approach to quantifying financial risk
  - Interested academic and practicing economists, sociologists, mathematicians, etc.
  - The size of the second-order body of stakeholders is undefined and possibly large
  - Results of the study will be prepared such that a second-order stakeholder can understand and use the results as they need

Technical Approach and Conceptual Model

Methodology

- Understand the market context
  - Research LTCM
    - LTCM trading strategies
    - How LTCM interacted with investors and banks
    - Ultimately how LTCM failed
- Intermediate steps include data collection, agent specification, modeling, verification, and evaluation
- End by deploying the model so that it can be effectively run with adjustment to initial parameters
- ABM-inspired Monte Carlo Simulation
  - Leveraged the Repast Symphony open source ABM toolkit to simulate a run of our hedge fund interaction
  - Recording results over a large batch of runs will result in a Monte Carlo simulation driven by non-linear agent interaction

Model Structure

- Agent types
  - Hedge funds (3)
  - Banks (5)
  - Investors (50)
  - Regulator (1)
    - Modeled after the US Federal Reserve

- Actions agents can perform, for example:
  - Execute and update trading strategies
  - Request loans
  - Grant loans
  - Do nothing
  - Agent actions are also dependent on a discrete probability distribution

- Agent parameters, for example:
  - Equity
  - Net asset value
  - Deposit base

Hedge Fund Agents

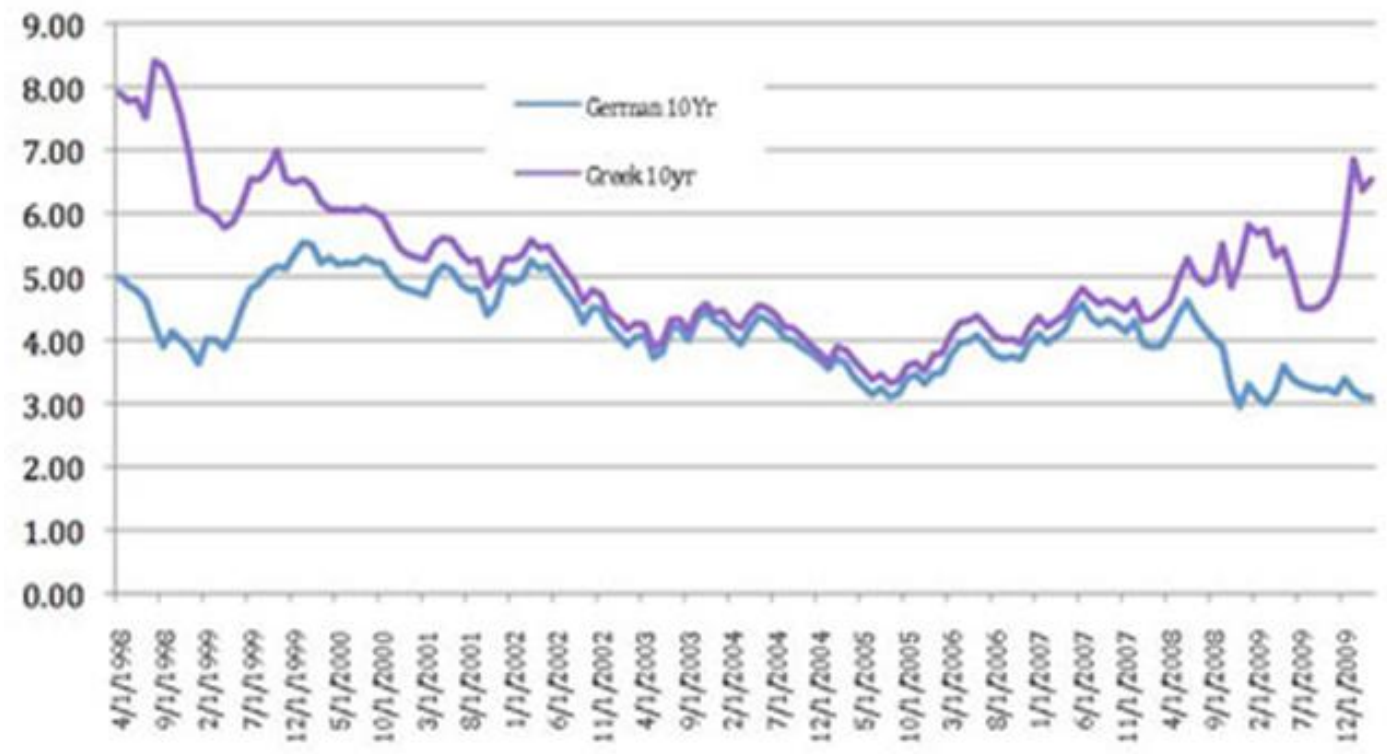
- Hedge funds are primarily interested in taking advantage of arbitrage opportunities in the market
  - Therefore require high leverage, or borrowed capital from banks, to perform high-volume trading to make a profit

- Arbitrage can take many forms, and hedge funds have developed different trades as a result

- The trades that hedge funds use in the model are
  - Convergence trades
  - Interest rate swaps
  - Volatility trades

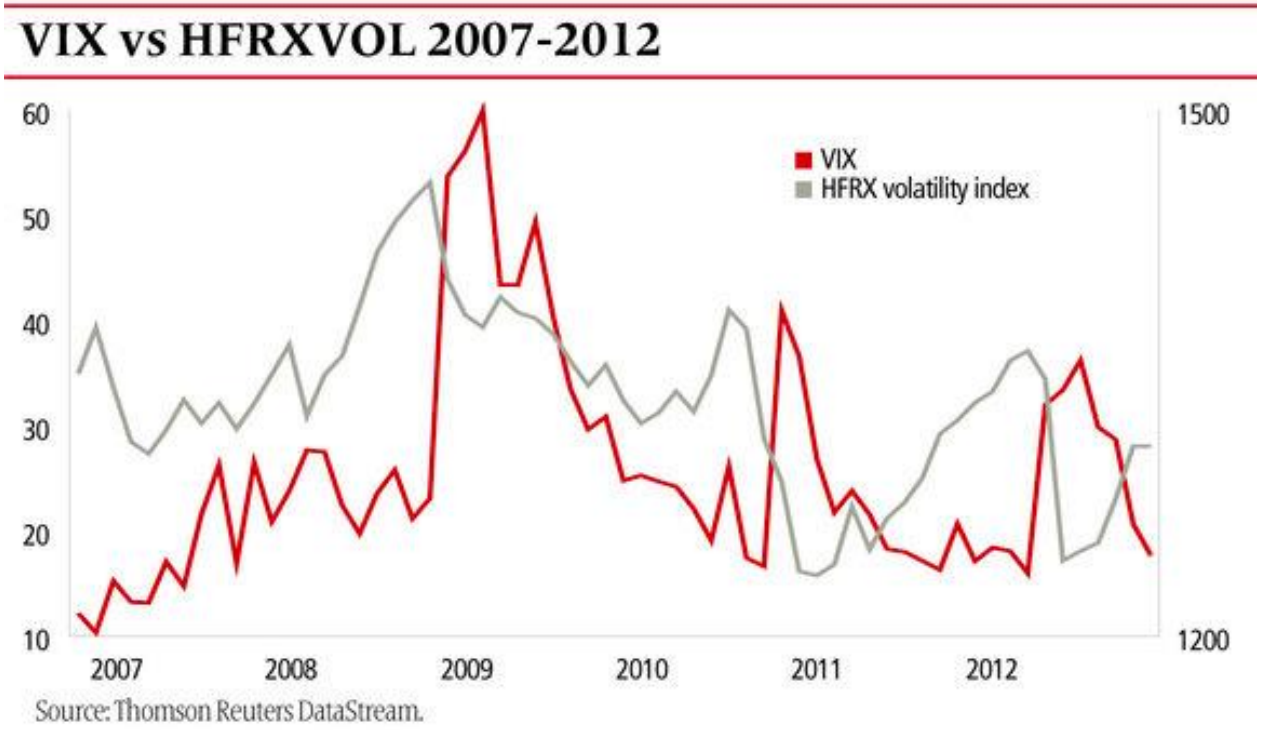
- At instantiation, hedge fund agents have empty portfolios and a certain amount of equity

Convergence Trade



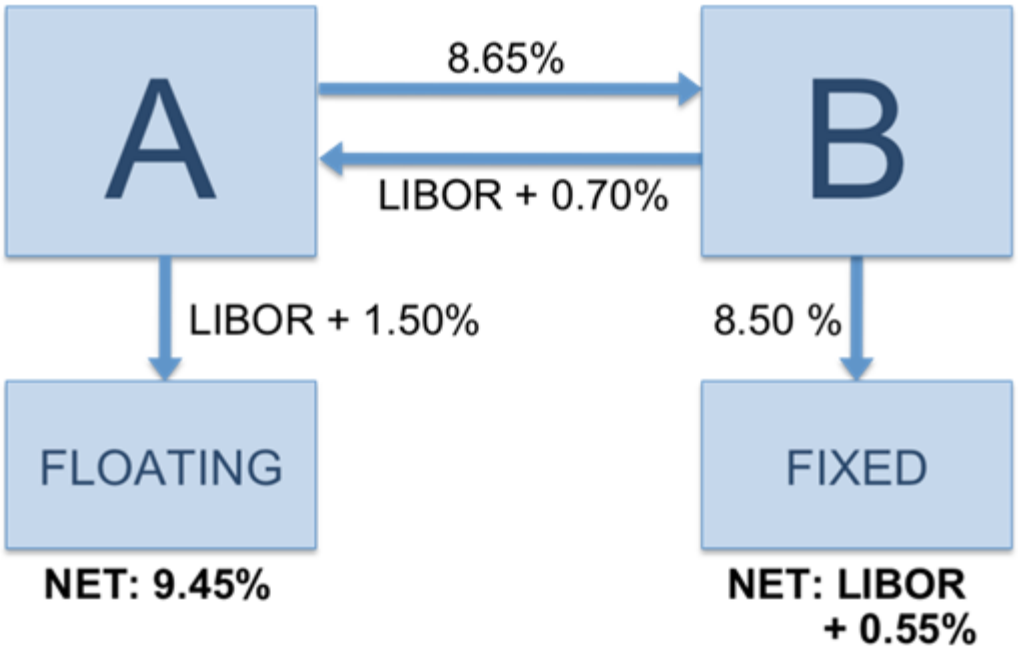
Source: http://www.forbes.com/2010/05/28/deutsche-mark-euro-intelligent-investing-turkish-lira.html

Volatility Trade



Source: http://www.risk.net/IMG/540/250540/volarb3-0312-580x358.jpg?1362538562

Interest Rate Swap



Party A is currently paying floating rate, but wants to pay fixed rate. Party B is currently paying fixed rate, but wants to pay floating rate. By entering into an interest rate swap, the net result is that each party can swap their existing obligation for their desired obligation.

Source: http://en.wikipedia.org/wiki/Interest_rate_swap

Agent-to-Agent Interactions Summation Matrix

	Hedge Fund	Banks	Investors	Regulators
Hedge Fund	1) Volatility trade 2) Treasury convergence (assuming that 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

Assumptions

- Human behavior and cognition can be approximated and simulated using a set of rules specified in Repast
- 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
- The final set of agents specified constitutes an appropriate set of entities required for a realistic ABM financial model.
- Results from the ABM model can be extended to other financial institutions
- Each agent can take multiple actions per day among other agents
- 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
- 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
- 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

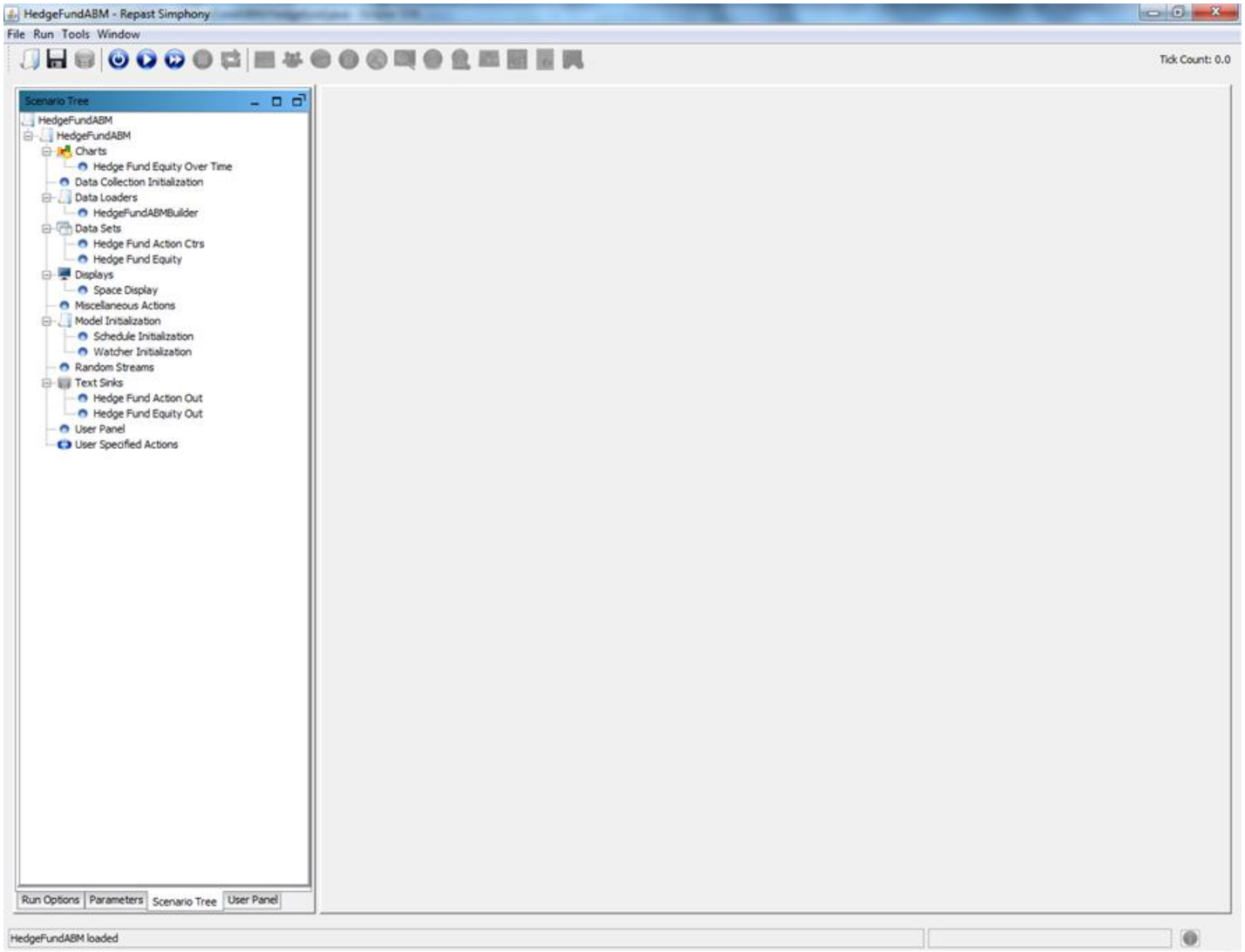
Assumptions

- 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
- 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 agen
- Bank overnight loan requests can be realistically modeled as comparing a uniform random variable between 0 and 1 to a threshold value.
- 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
- The reserve requirement can be modeled as a single percentage of deposit base set at 3%
- Hedge fund to bank interactions can be realistically modeled without modeling margin calls

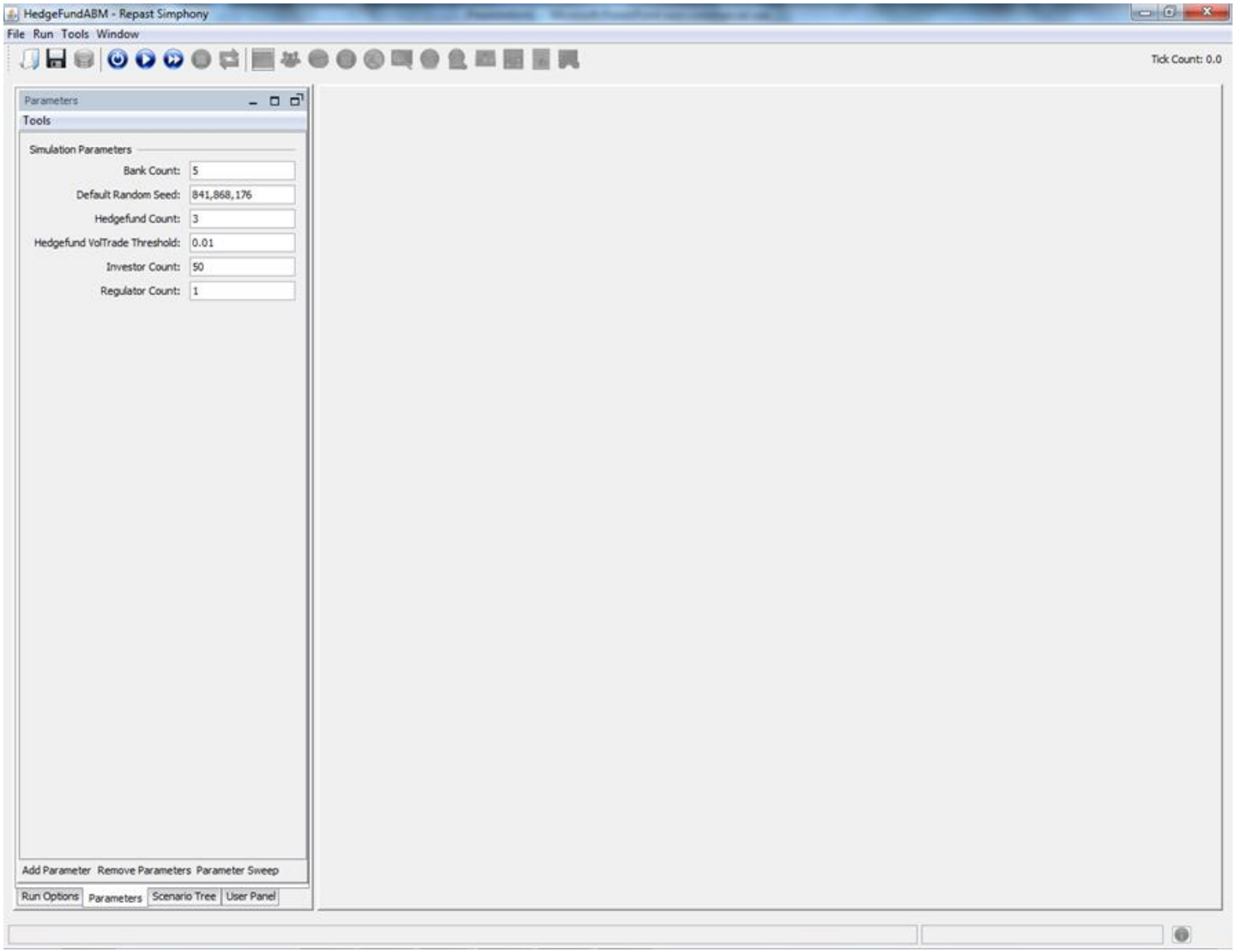
Assumptions

- 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
- Interest rates for loans can be realistically modeled as the current US 30-year treasury rate
- Convergence trades in this model already assume the counterparty has already accepted the other side of the long and short positions
- Volatility trading execution based on standard deviation of past log returns constitutes a reasonable forecast
- The contrarian and value trades can be realistically modeled using fixed values for December 2013 call and put options
- 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
- 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
- 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
- Once a hedge fund passes $0 in equity, the hedge fund stops trading

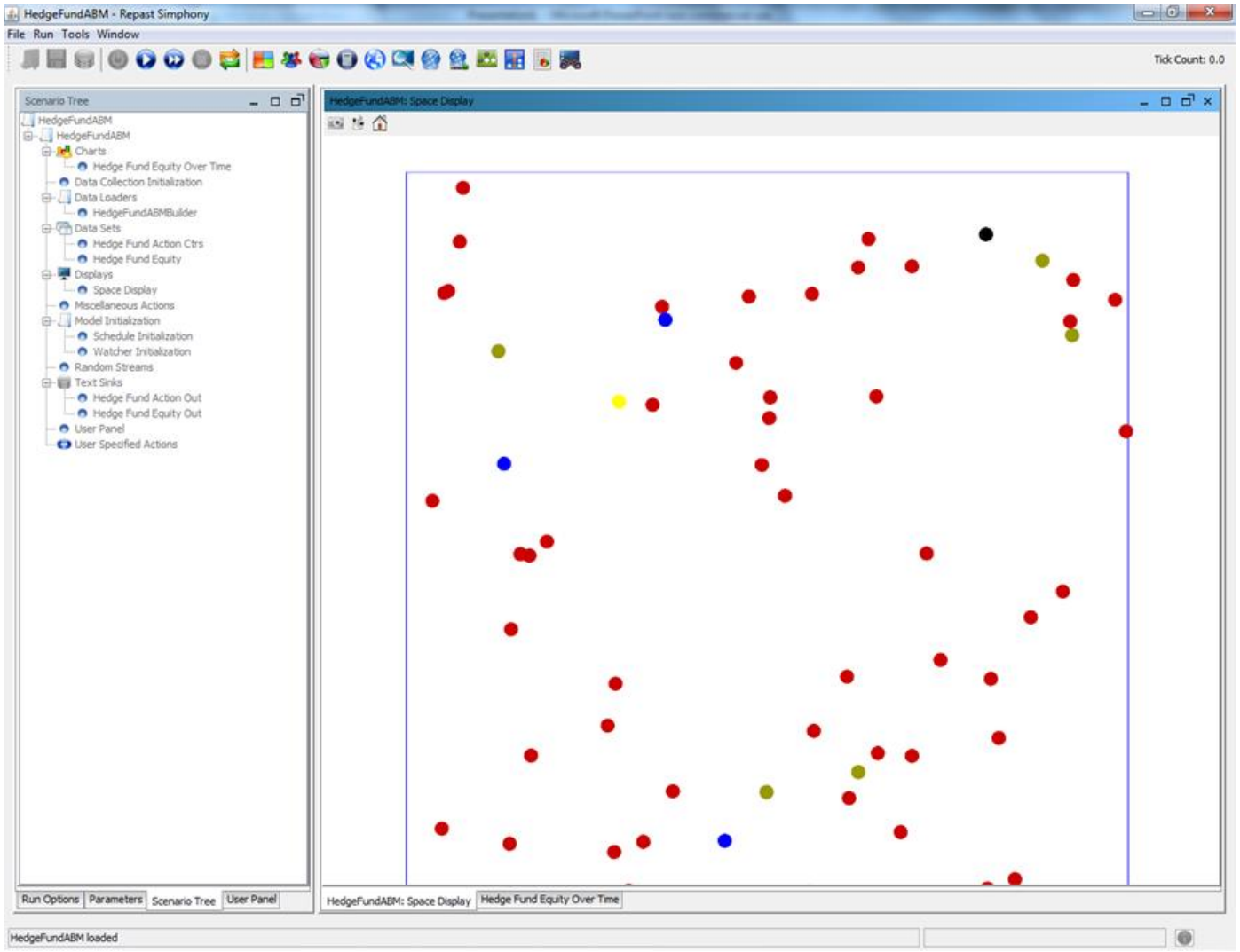
Model at Launch



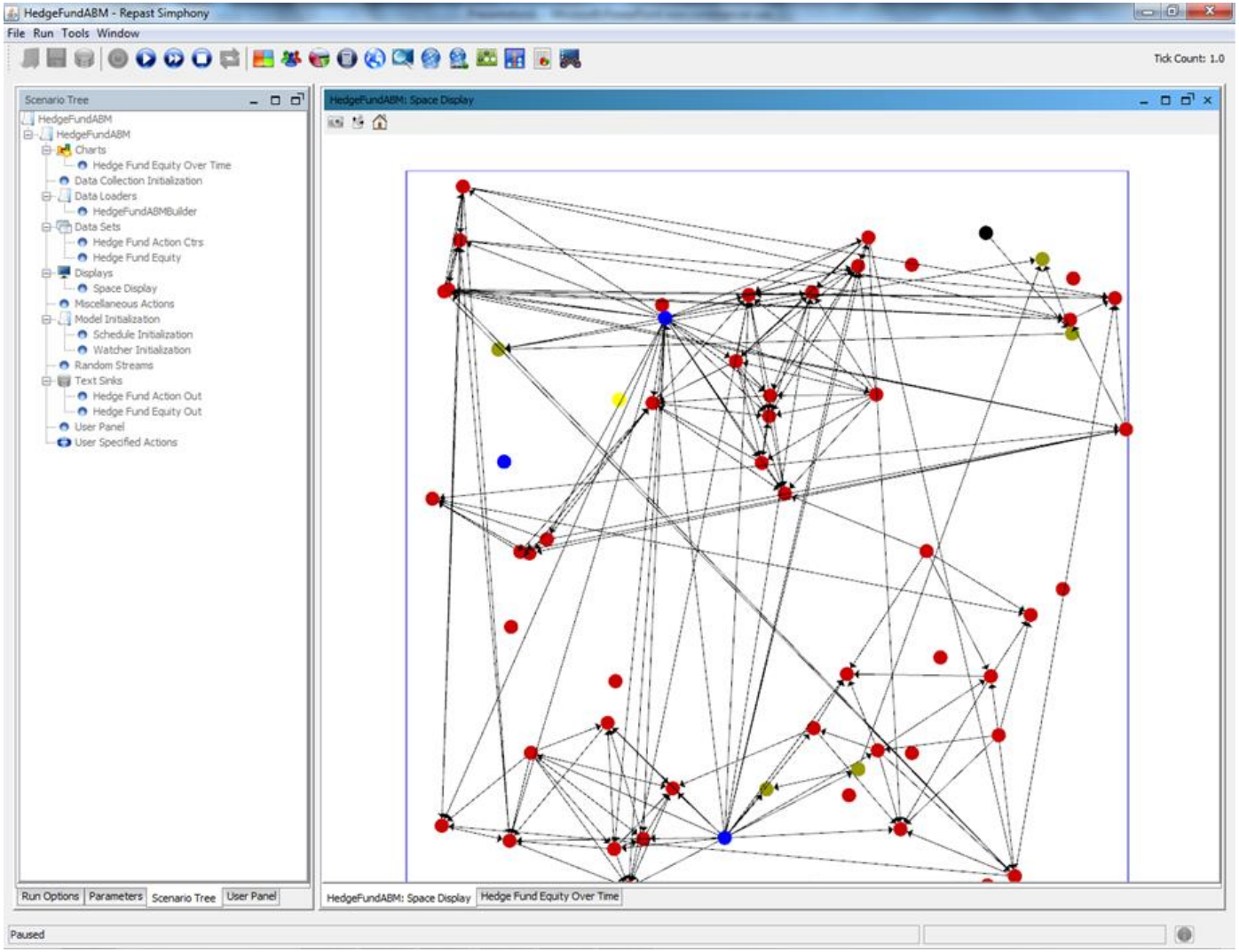
Model at Launch



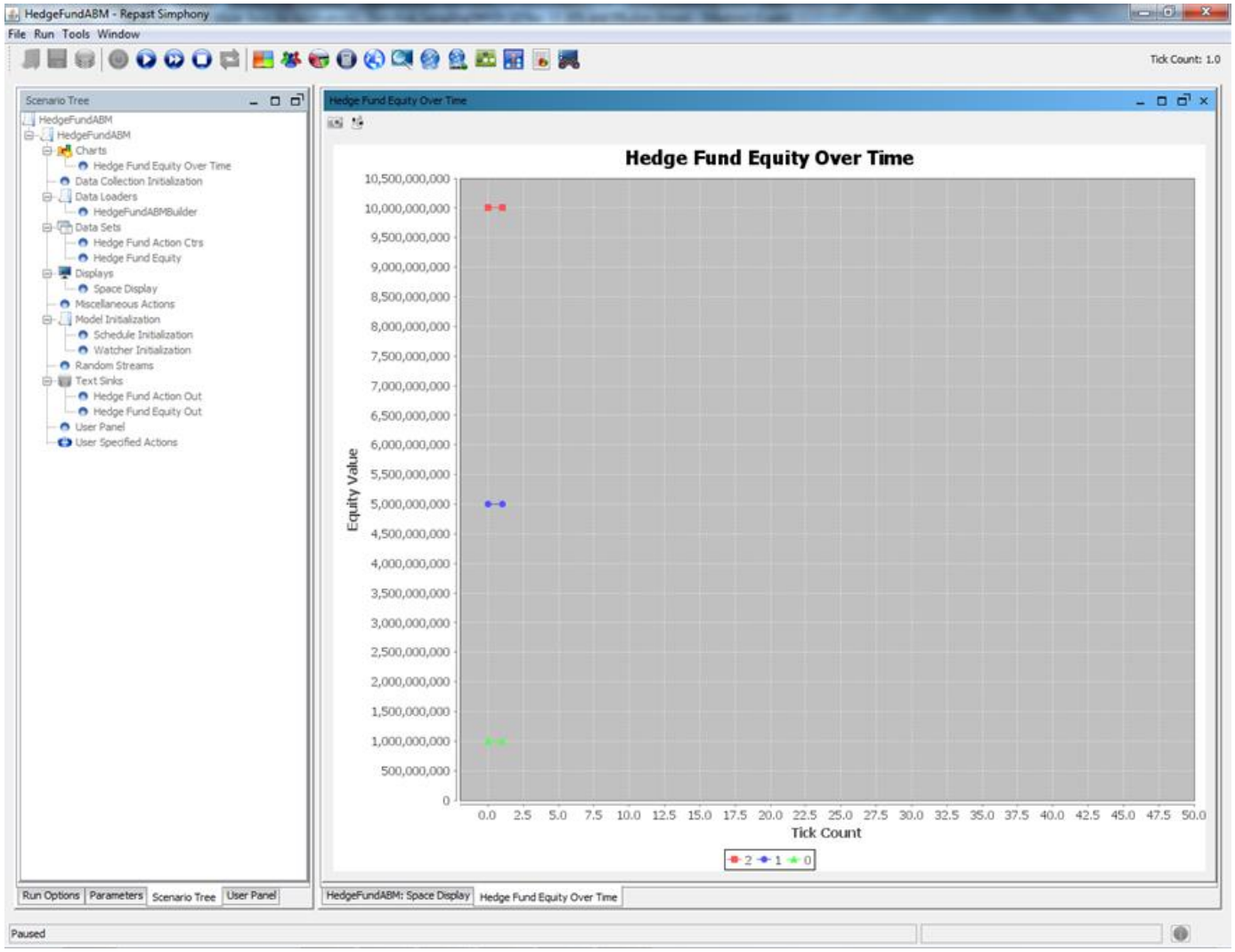
Model at Load



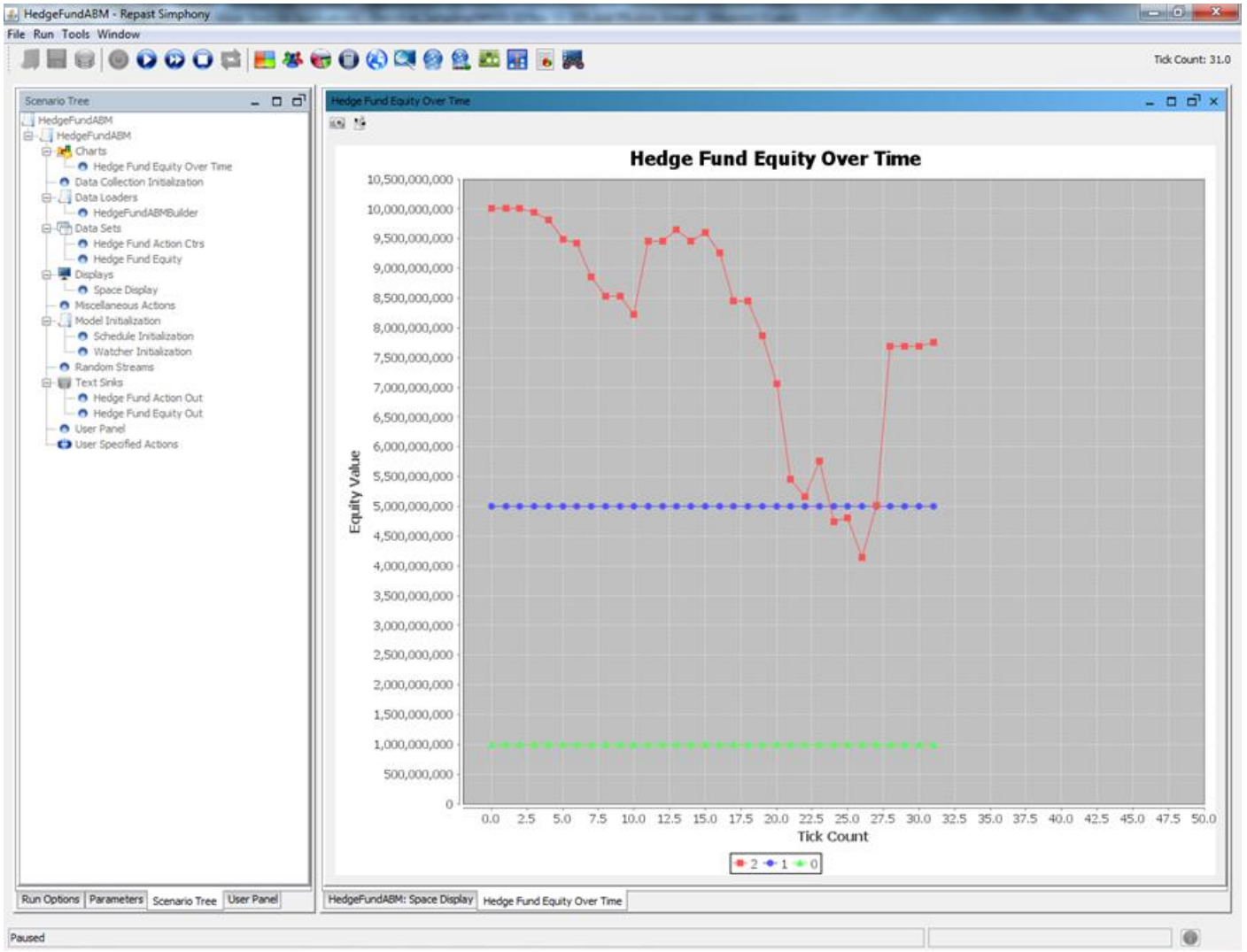
Model After 1 Tick (1 Day)



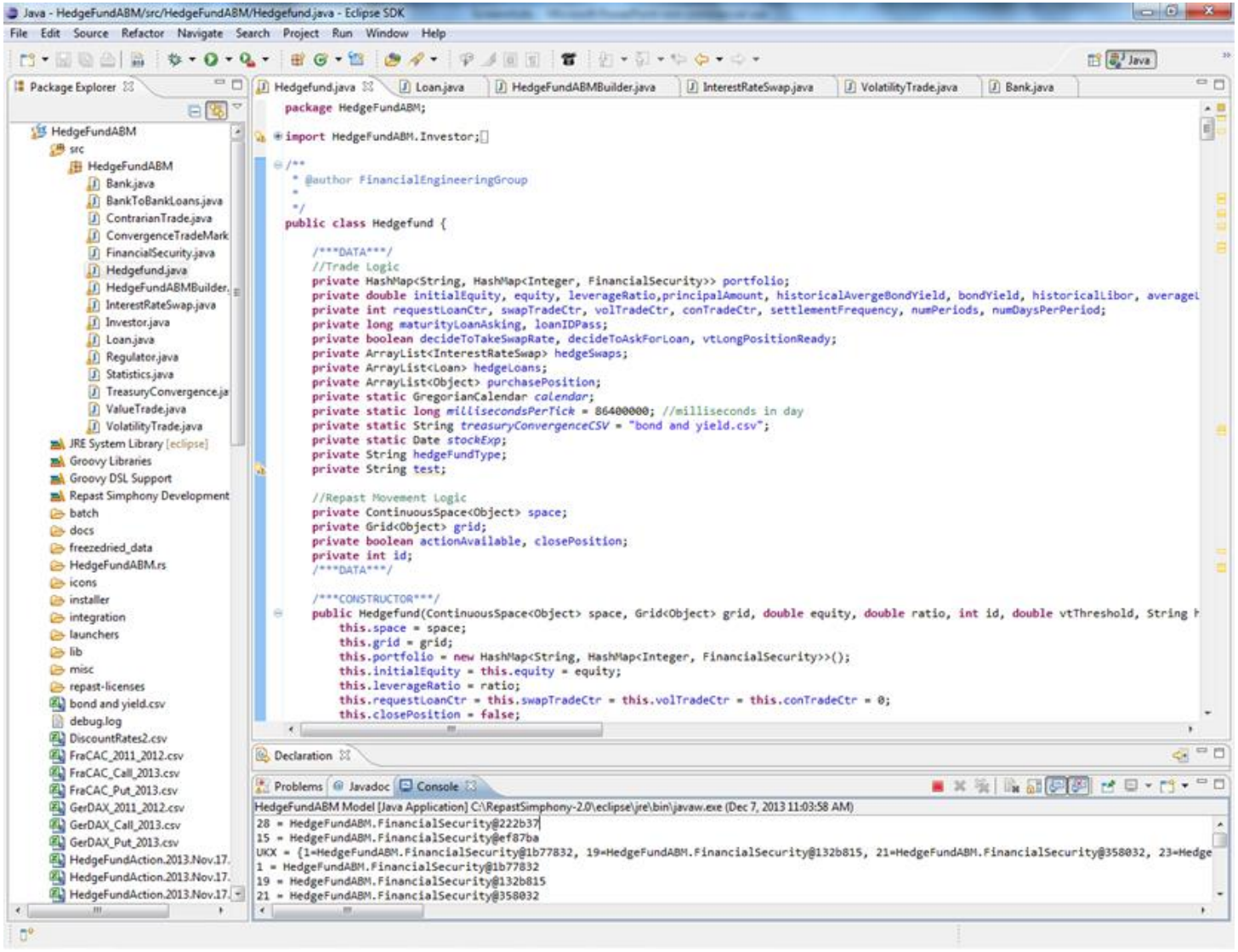
Model After 1 Tick (1 Day)



Model After 32 Ticks (32 Days)



Model In Repast



Results

Run Setup

- Three hedge funds are examined, each with a different initial portfolio value
  - The large hedge fund has an initial equity of $10 billion
  - The medium hedge fund has an initial equity of $5 billion
  - The small hedge fund has an initial equity of $1 billion

- Run cases:
  - Baseline: 58 days with 20 trials (replications)
  - Baseline 40: 58 days with 40 trials
  - Test Case 1: 221 trading days, removal of convergence trades, and greedily consider volatility trades and interest rate swaps
  - Test case 2: Test Case 1 conditions plus 100 investors

- Eliminate dependency and perform I.I.D. approximation
  - The equity is averaged at the end of each trial for each case
  - Then computed the average for the case over all trials for each case
  - Compute variances, standard deviations, and confidence intervals for each case

Run Results

	Case			
	Baseline	**Baseline (40)**	**Test Case 1**	**Test Case 2**
Number of trials	20	40	20	20
Number of trading days	58	58	221	221
Small hedge fund average equity	0.7 Billion	0.9 Billion	1.3 Billion	1.0 Billion
Medium hedge fund average equity	3.8 Billion	4.2 Billion	4.5 Billion	4.1 Billion
Large hedge fund average equity	8.4 Billion	9.1 Billion	7.0 Billion	6.6 Billion
Small hedge fund confidence interval	(0.5 Billion, 0.9 Billion)	(0.8 Billion, 1.0 Billion)	(1.1 Billion, 1.4 Billion)	(1.02 Billion, 1.02 Billion)
Medium hedge fund confidence interval	(3.0 Billion, 4.6 Billion)	(3.7 Billion, 4.6 Billion)	(4.3 Billion, 4.7 Billion)	(4.0 Billion, 4.2 Billion)
Large hedge fund confidence interval	(7.4 Billion, 9.3 Billion)	(8.5 Billion, 9.8 Billion)	(6.5 Billion, 7.6 Billion)	(6.2 Billion, 7.0 Billion)

Value At Risk (VaR)

- Used extensively to estimate at what loss level is such that we are X% confident it will not be exceeded in N business days
  - 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

- VaR assumed daily returns are normally distributed when estimating the risk level

- Assuming a daily volatility fluctuating from 0.5% to 5%, the table below shows the 10-day, 99% VaR calculations for the three hedge funds using traditional VaR computations

	Small Fund	Medium Fund	Large Fund	
	1 Billion	5 Billion	10 Billion	
Volatility Level				
0.5%	36.8 Million	184.2 Million	368.4 Million	3.68%
1.0%	73.7 Million	368.4 Million	736.8 Million	7.37%
1.5%	110.5 Million	552.6 Million	1,105.2 Million	11.05%
2.0%	147.4 Million	736.8 Million	1,473.6 Million	14.74%
2.5%	184.2 Million	921.0 Million	1,842.0 Million	18.42%
3.0%	221.0 Million	1,105.2 Million	2,210.4 Million	22.10%
3.5%	257.9 Million	1,289.4 Million	2,578.8 Million	25.79%
4.0%	294.7 Million	1,473.6 Million	2,947.2 Million	25.79%
4.5%	331.6 Million	1,657.8 Million	3,315.6 Million	29.47%
5.0%	368.4 Million	1,842.0 Million	3,684.1 Million	33.16%

Estimating VaR with ABM

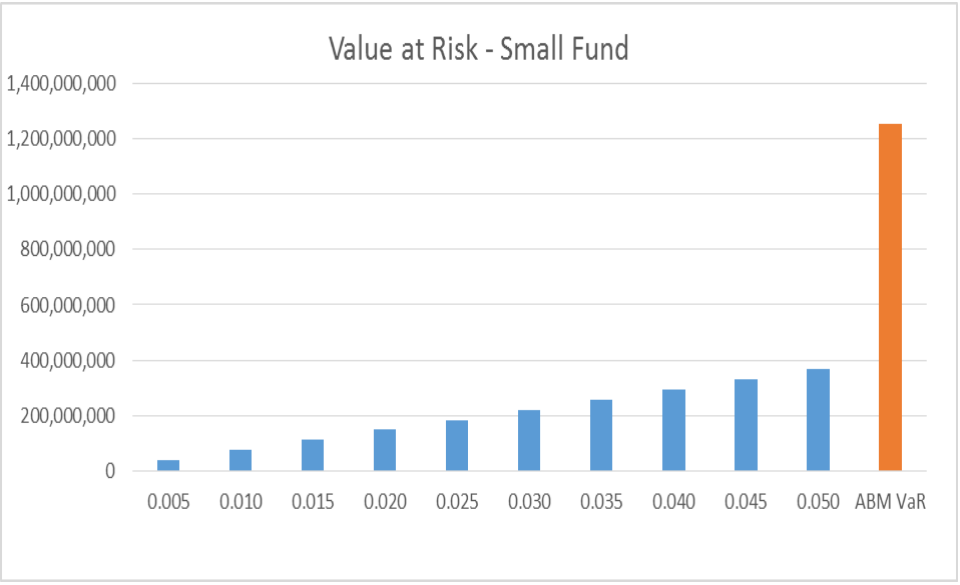
- Used two cases to show estimation of VaR with model results
  - Baseline (20 trials)
  - Test Case 1

- Method (using Baseline numbers)
  - As there are 20 trials each with 58 trading days, there are roughly 1200 points of daily equity change data
  - Rank these from largest loss to lowest loss
  - Find the 1% point that represents the loss on a single day, then multiply by the square root of 10 to get a 10-day VaR

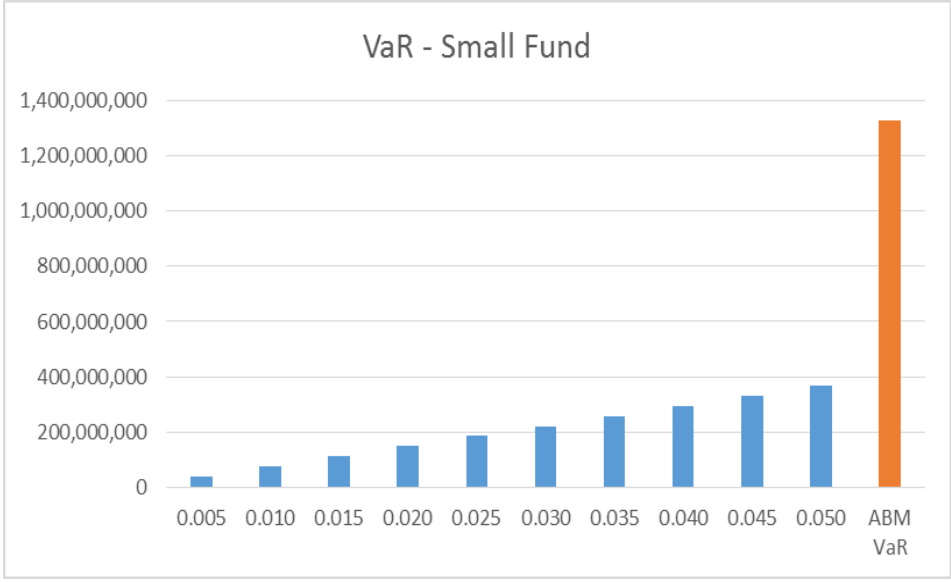
	Small Fund	Medium Fund	Large Fund
Baseline VaR	1,256.0 Million	8,948.1 Million	4,810.7 Million
Test Case 1 VaR	1,330.0 Million	11,185.1 Million	5,120.4 Million

VaR Comparison – Small Hedge Fund

Baseline (20)



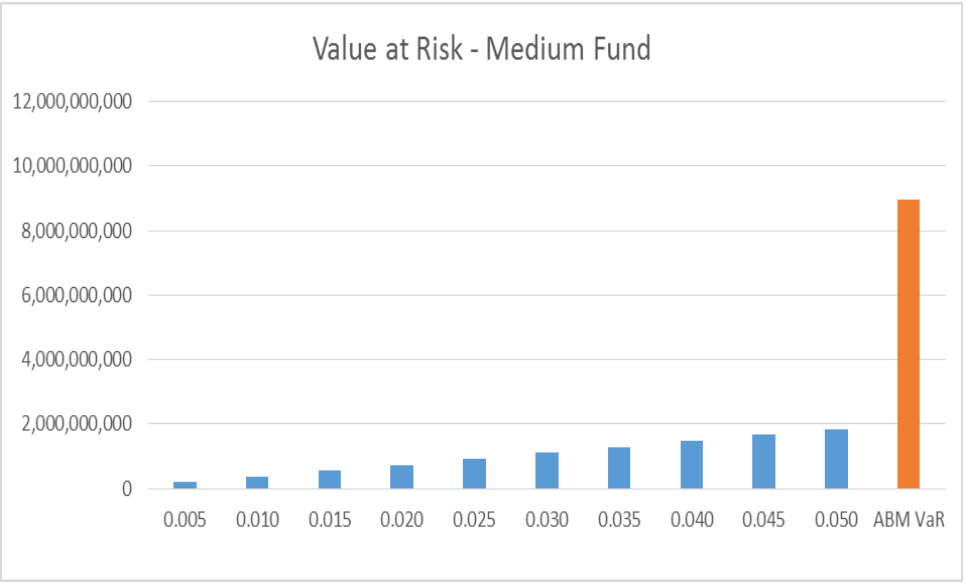
Test Case 1



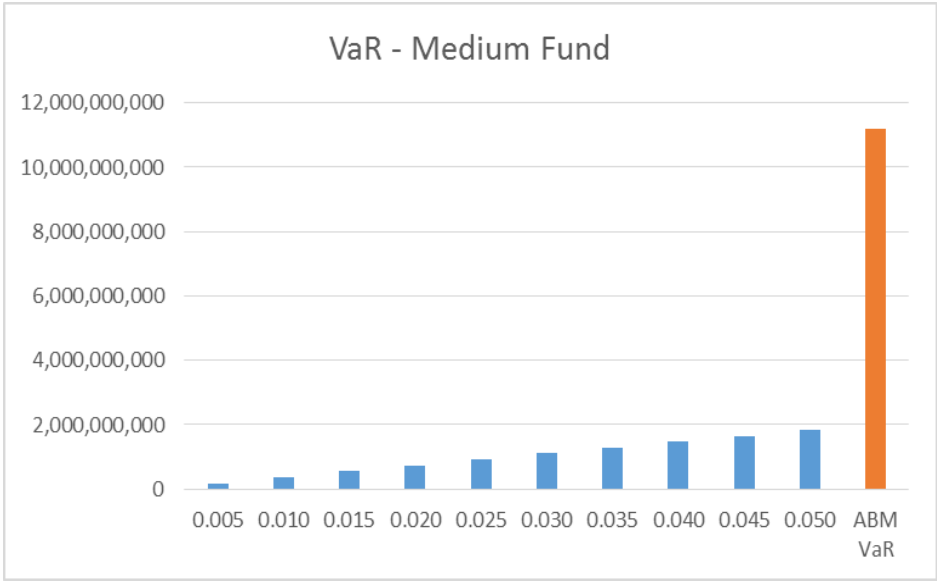
Note: Blue bars are VaR estimates using the traditional computations (slide 28), and the orange bar is the VaR as estimated using model results

VaR Comparison – Medium Hedge Fund

Baseline (20)



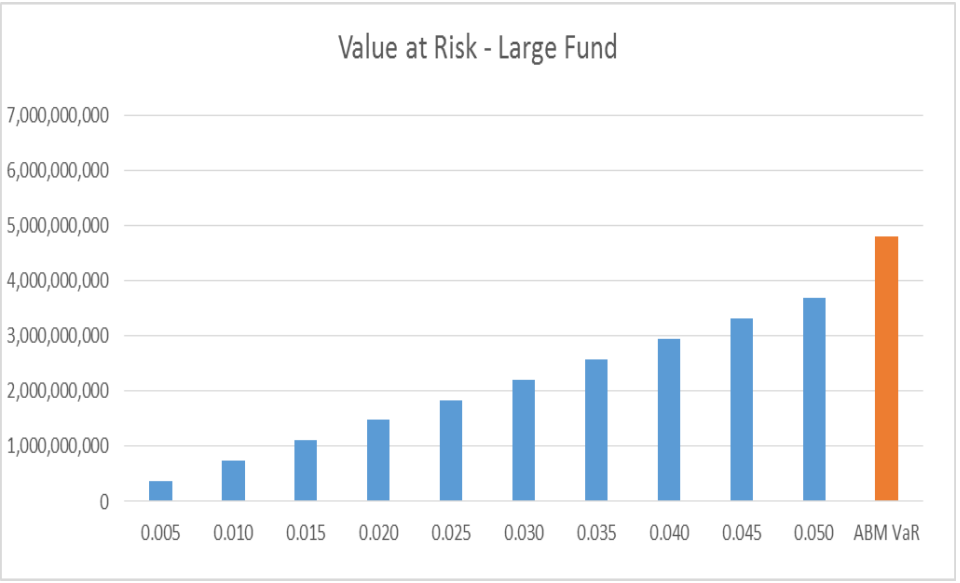
Test Case 1



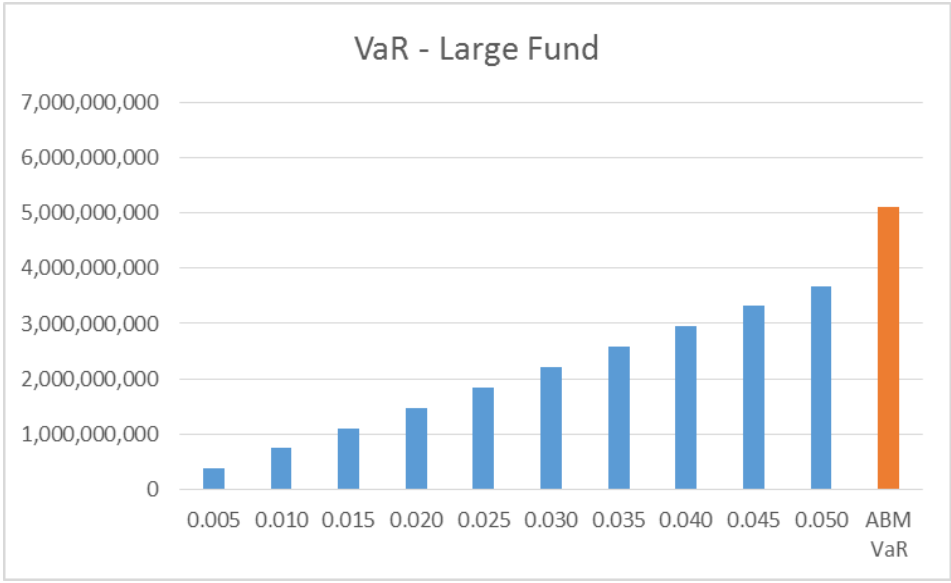
Note: Blue bars are VaR estimates using the traditional computations (slide 28), and the orange bar is the VaR as estimated using model results

VaR Comparison – Large Hedge Fund

Baseline (20)



Test Case 1



Note: Blue bars are VaR estimates using the traditional computations (slide 28), and the orange bar is the VaR as estimated using model results

Bernoulli Analysis

- Apply Bernoulli discrete probability distribution to analyze the failure classification of trial averages for each hedge fund

- Define failure as a hedge fund losing more than 50% of initial equity
  - Assuming that hedge funds require at most 50% of its equity be invested, then at most 50% of its investment can be lost

	Small Fund Success Rate	Small Fund Success Rate Confidence Interval	Medium Fund Success Rate	Medium Fund Success Rate Confidence Interval	Large Fund Success Rate	Large Fund Success Rate Confidence Interval
Baseline (20)	60%	(49%, 71%)	70%	(59.8%, 80.3%)	90%	(83.3%, 96.7%)
Baseline (40)	87%	(81.7%, 92.3%)	85%	(79.4%, 90.6%)	98%	(95%, 99.9%)
Test Case 1	75%	(65.3%, 84.7%)	80%	(71%, 88.9%)	60%	(49%, 71%)
Test Case 2	70%	(59.8%, 80.2%)	75%	(65.3%, 84.7%)	65%	(54.3%, 75.7%)

Conclusions and Future Work

Conclusions

- Created a baseline model with three financial trading strategies
  - Can easily change the initial parameters (such as number of agents) to conduct multiple analyses
- The model allows for analysis of how financial trading strategies affect risk
  - Using the same trading strategies as LTCM as in the Baseline Case, the small and medium hedge funds have large losses
    - LTCM has equity around 4 Billion dollars – roughly the size equal to the medium hedge fund
  - Small and medium hedge fund equity levels appear to be similar to a fat-tailed walk
- Model can be expanded with future research work and experiments

Future Work

- There are many extensions which could be added to the model in order to make it more realistic and applicable to other analyses

- These extensions are classified as technology upgrades and financial logic upgrades
  - Technology upgrades
    - Introduce inheritance in Java Repast code to remove static object type checking
    - Enable better debug console messages for system fixes
    - Determine how to automate batch procedures in Repast
    - Consider machine learning for trading decisions
  - Financial logic upgrades
    - 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
      - To make the model more useful, other trading strategies should be included in the model to reflect other hedge fund trading strategies
    - 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 the economy connectedness

Future Work

- Track portfolio positions over a period of time
- 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 to the model will add more realism to the model

Questions?

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https://sites.google.com/site/fesysor699fall2013/

Backup

Sensitivity Run 2 Results

- Applying the t-test to calculate the Confidence Interval, the confidence interval table is derived

	Confidence Interval	
Fund 1	Fund 2	Fund 3
(1024786599.74, 1029830551.62)	(3976061000.11,4235497913.13)	(6164869226.37, 6999516183.41)

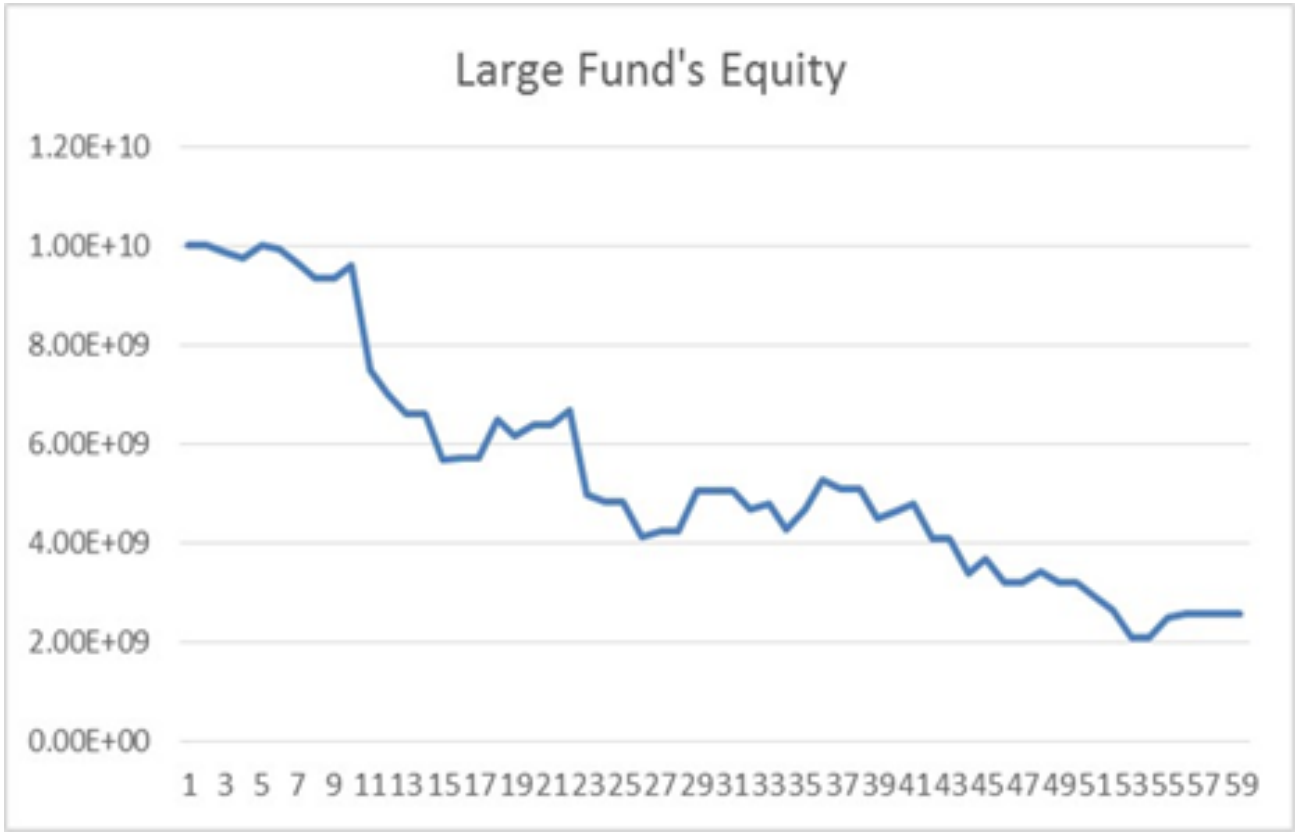
- According to the results, the small hedge fund will have a success rate of 70% and a failure rate of 30%
  - Confidence interval is (0.5975, 0.802469)
- According to the results, the medium hedge fund will have a success rate of 75% and a failure rate of 25%
  - Confidence interval is (0.653, 0.8468)
- According to the results, the large hedge fund will have a success rate of 65% and a failure rate of 35%
  - Confidence interval is (0.5433, 0.7566)

Run Results

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

- This table shows the average for each fund in 20 trials
  - Fund 1 represents the small hedge fund, Fund 2 represents the medium size hedge fund, and Fund 3 represents the large hedge fund

Run Results



- This graphic shows an example of equity fluctuations during a simulation run

Run Results

- After the average of each trial is found, the average is found for all of them

Average of all 20 trials		
Trial 1	Trial 2	Trial 3
719050566.2	3846225387	8420190149

- Apply the batching procedure

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	94455419.08	382,946,633.52	502,746,907.95

- As 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 interval table is derived

Confidence Interval		
Fund 1	Fund 2	Fund 3
(521355374.03, 916745758.31)	(3044718083.15, 4647732691.(	(7367940871.03, 9472439427.73)

- According to the run results, the small hedge fund will have a success rate of 60% and a failure rate of 40%
  - Confidence interval is (0.49, 0.7095)

- According to the run results, the medium hedge fund will have a success rate of 70% and a failure rate of 30%
  - Confidence interval is (0.5975, 0.8025)

- According to the run results, the large hedge fund will have a success rate of 90% and a failure rate of 10%
  - Confidence interval is (0.8329, 0.967)

Run Results

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

- This table shows the average for each fund in 40 trials
  - Fund 1 represents the small hedge fund, Fund 2 represents the medium size hedge fund, and Fund 3 represents the large hedge fund

Run Results

- After the average of each trial is found, the average is found for all of them

Averages of 40 Trials		
925833002.06	4191323403.26	9127130030.06

- 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

- Applying the t-test to calculate the Confidence Interval, the confidence interval table is derived

Confidence Interval		
Fund 1	Fund 2	Fund 3
(8255633214, 1026102683)	(3745239164, 4637407642)	(8485360103, 9768899958)

- According to the results, the small hedge fund will have a success rate of 87% and a failure rate of 13%
  - Confidence interval is (0.817, 0.92317)
- According to the results, the medium hedge fund will have a success rate of 85% and a failure rate of 15%
  - Confidence interval is (0.7935, 0.90645)
- According to the results, the large hedge fund will have a success rate of 97.5% and a failure rate of 2.5%
  - Confidence interval is (0.950, 0.999)

Sensitivity Run Setup

- Sensitivity Run 1:
  - Turn off convergence trades so that the simulation runs past 58 trading days to full year while forcing hedge funds to always consider the other two trading strategies
- Rationale for run:
  - Allows for analysis of hedge fund trading strategies long-term
- Sensitivity Run 2:
  - Maintain changes in sensitivity run 1, and also increase number of investors to 100
- Rationale for run:
  - Increase non-linearity of the model and understand this aspect of the non-linearity on model results
- For both sensitivity runs, execute a single batch test of 20 trials

Sensitivity Run 1 Results

Trial Averages		
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

- This table shows the average for each fund in 20 trials
  - Column 1 represents the small hedge fund, column 2 represents the medium size hedge fund, and column 3 represents the large hedge fund

Sensitivity Run 1 Results

- After the average of each trial is found, the average is found for all of them

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

- Applying the t-test to calculate the Confidence Interval, the confidence interval table is derived

	Confidence Interval	
Fund 1	Fund 2	Fund 3
(1153729640.44, 1358919779.61)	(4297951168.91, 4706773879.43)	(6451185928.43, 7582134953.26)

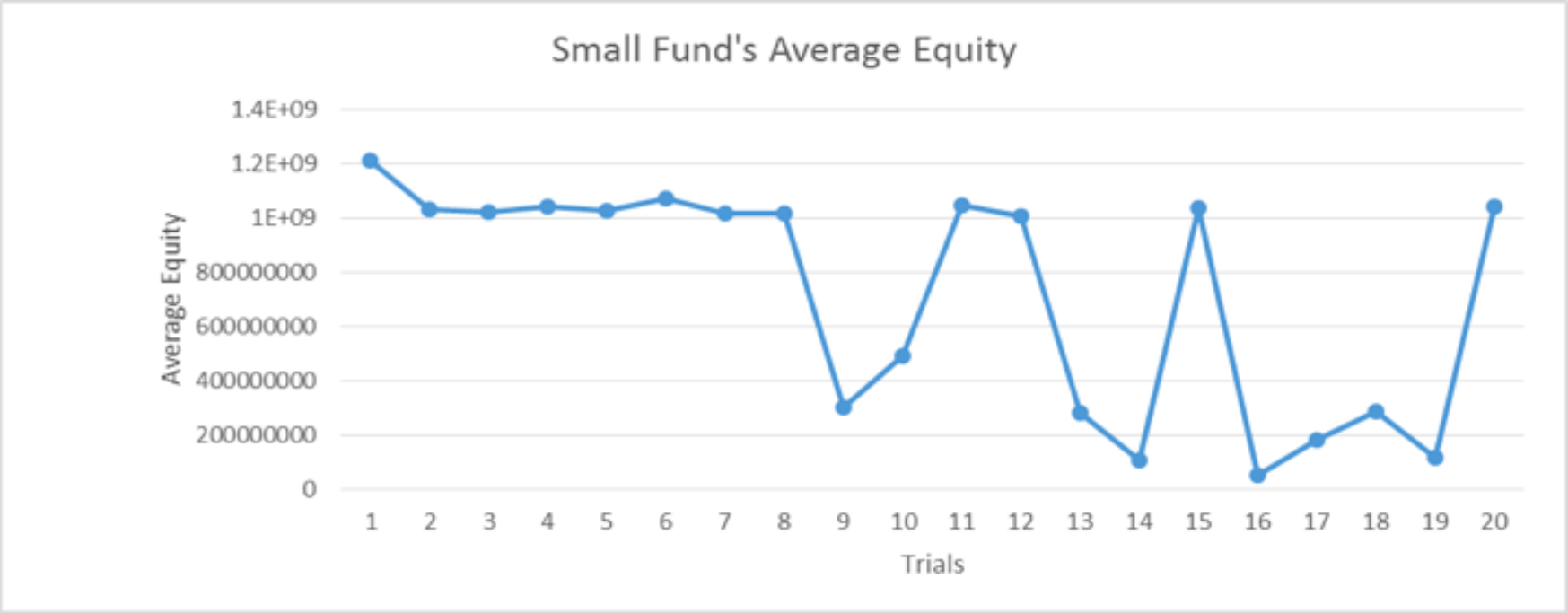
- According to the results, the small hedge fund will have a success rate of 75% and a failure rate of 25%
  - Confidence interval is (0.653, 0.8468)
- According to the results, the medium hedge fund will have a success rate of 80% and a failure rate of 20%
  - Confidence interval is (0.71, 0.889)
- According to the results, the large hedge fund will have a success rate of 60% and a failure rate of 40%
  - Confidence interval is (0.4904, 0.7095)

Sensitivity Run 2 Results

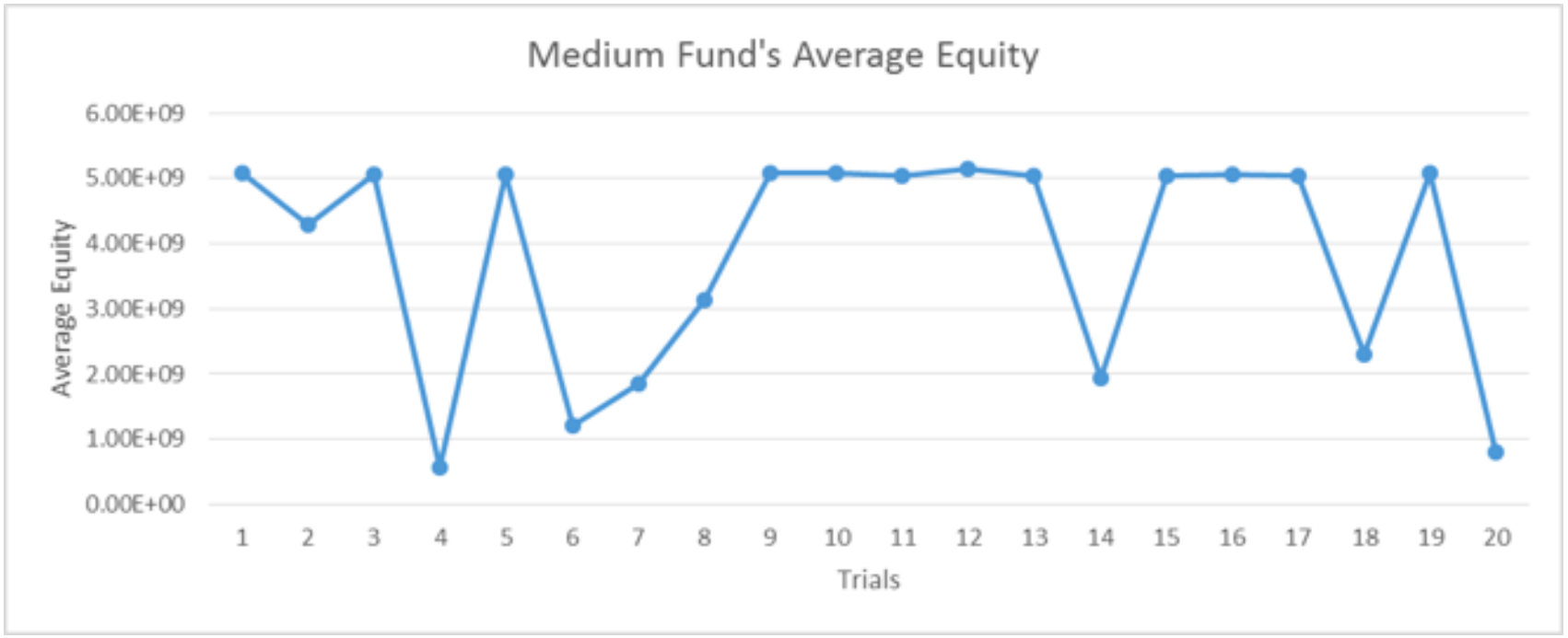
Trial Averages		
1,777,654,797.37	5,752,073,520.26	2,109,058,964.17
176,325,446.74	5,726,695,619.04	10,920,509,749.99
167,134,013.56	5,552,708,824.97	10,798,273,510.15
1,502,602,026.23	1,210,131,504.88	10,841,663,322.72
794,990,508.62	5,586,698,579.55	10,812,490,056.38
1,161,384,357.02	5,827,482,627.08	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

- This table shows the average for each fund in 20 trials
  - Column 1 represents the small hedge fund, column 2 represents the medium size hedge fund, and column 3 represents the large hedge fund

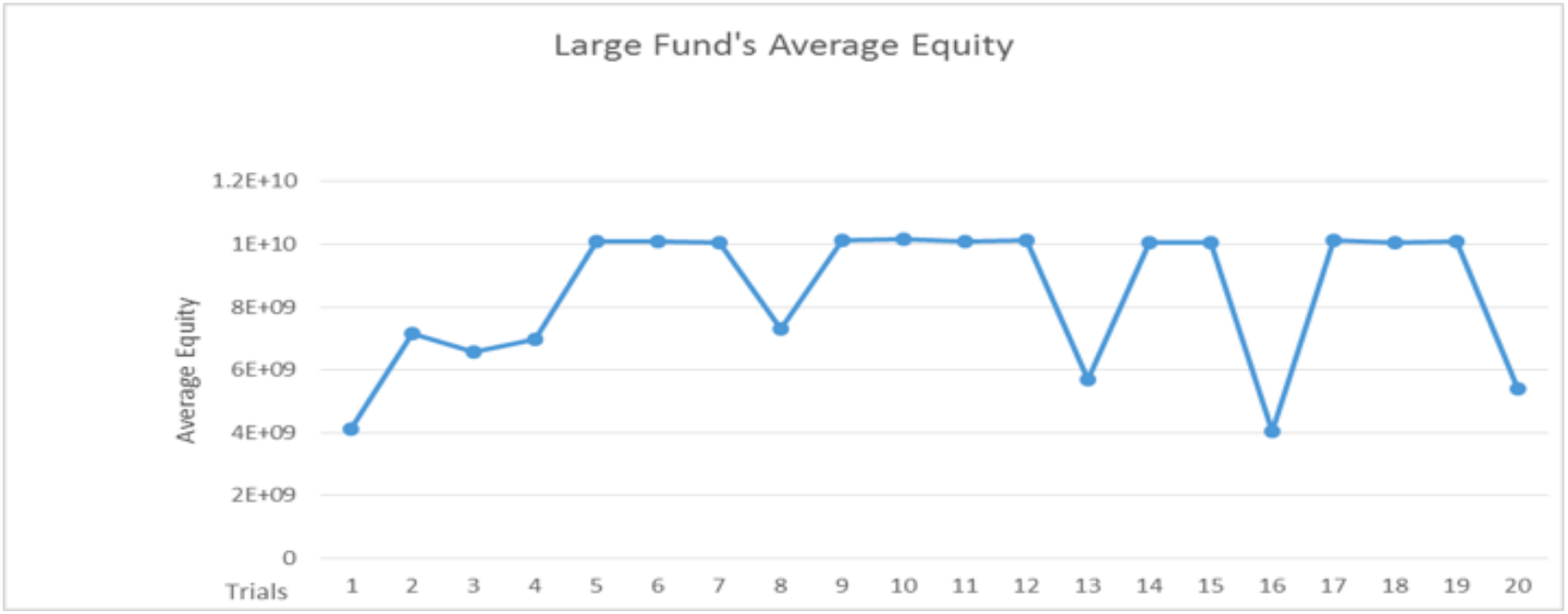
Run Results


Small Fund's Average Equity
Average Equity
1.4E+09
1.2E+09
1E+09
800000000
600000000
400000000
200000000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Trials

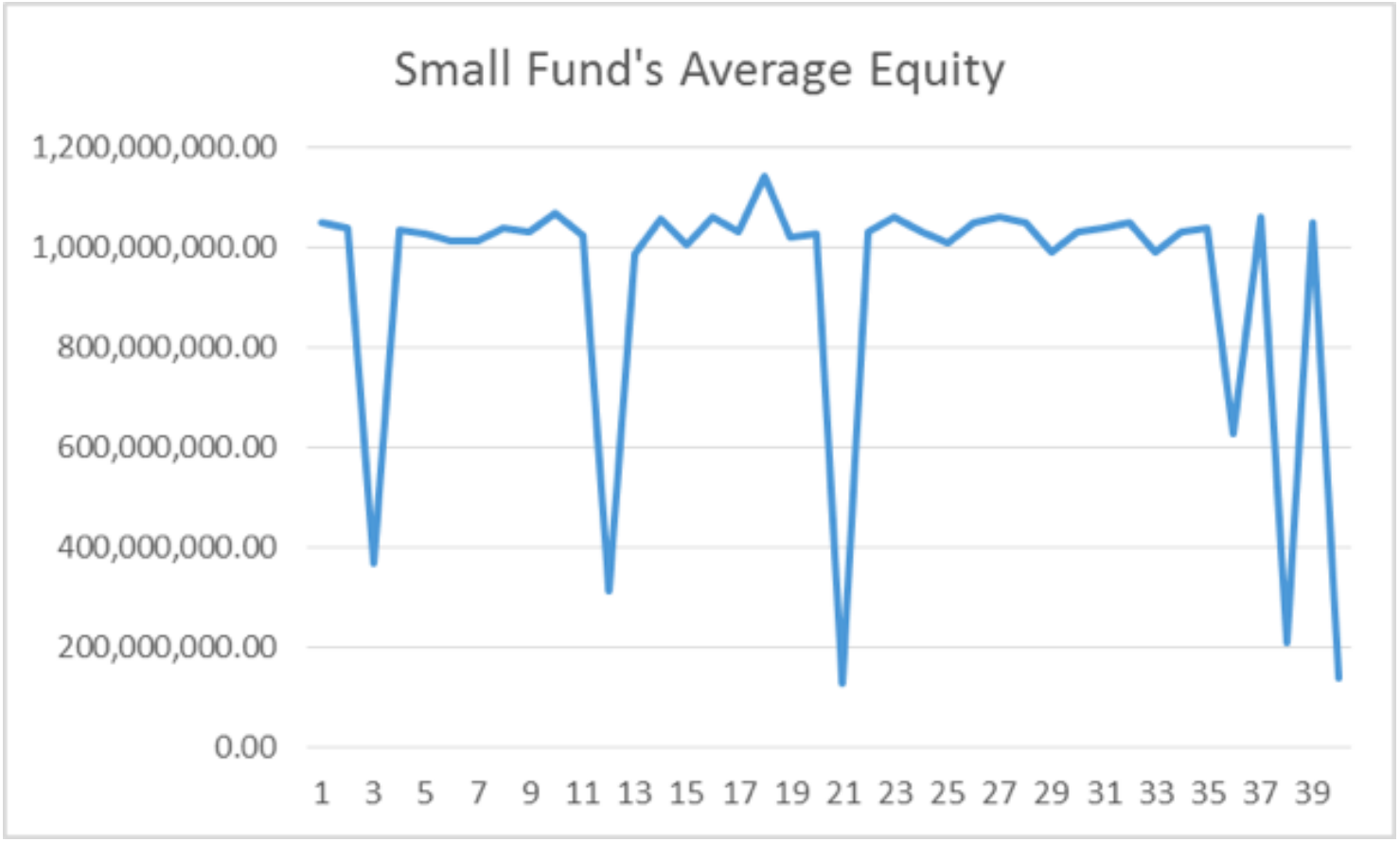
Run Results


Medium Fund's Average Equity
Average Equity
6.00E+09
5.00E+09
4.00E+09
3.00E+09
2.00E+09
1.00E+09
0.00E+00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Trials

Run Results


Large Fund's Average Equity
Average Equity
1.2E+10
1E+10
8E+09
6E+09
4E+09
2E+09
0
Trials
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Run Results


Small Fund's Average Equity
1,200,000,000.00
1,000,000,000.00
800,000,000.00
600,000,000.00
400,000,000.00
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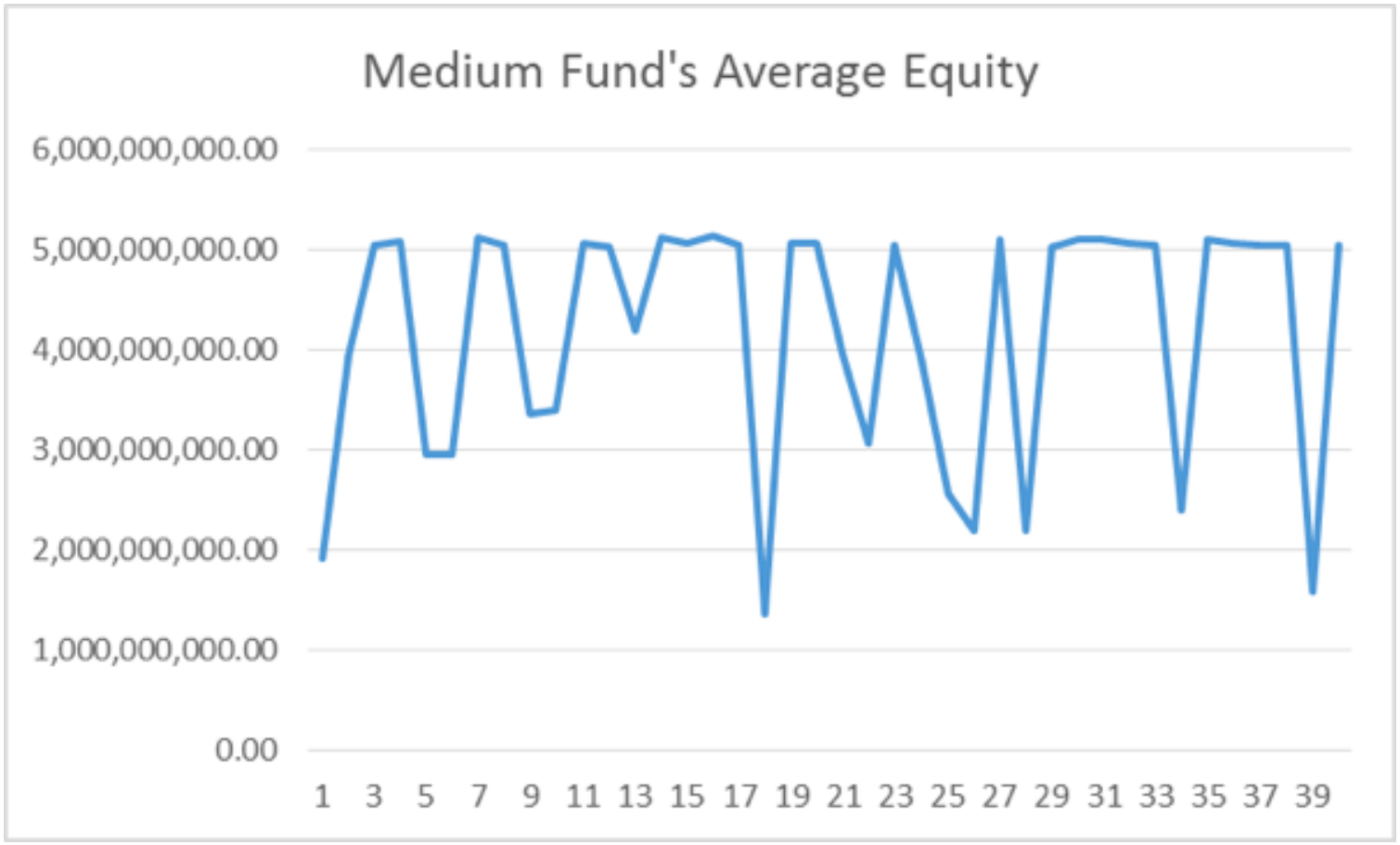
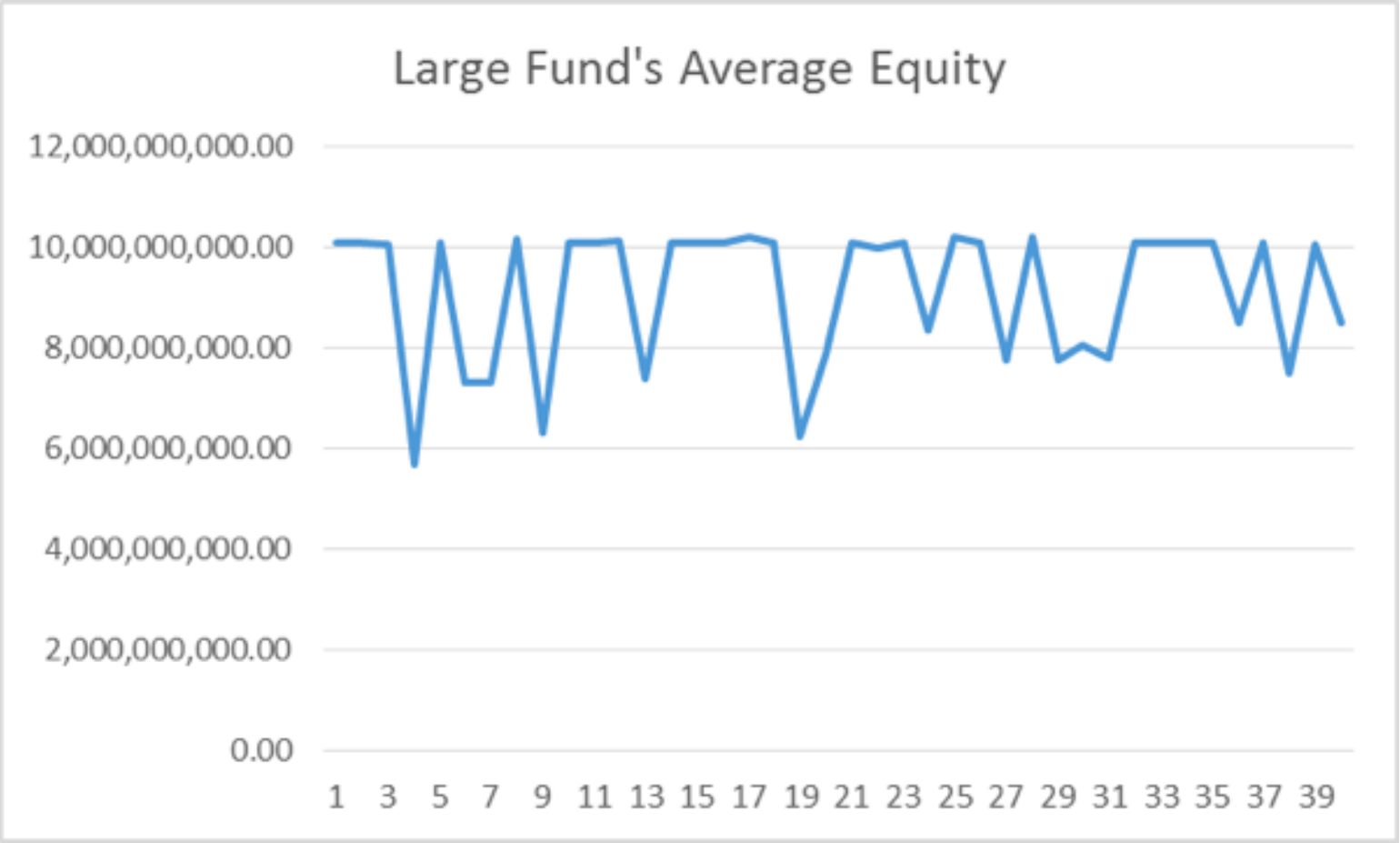
0.00
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39

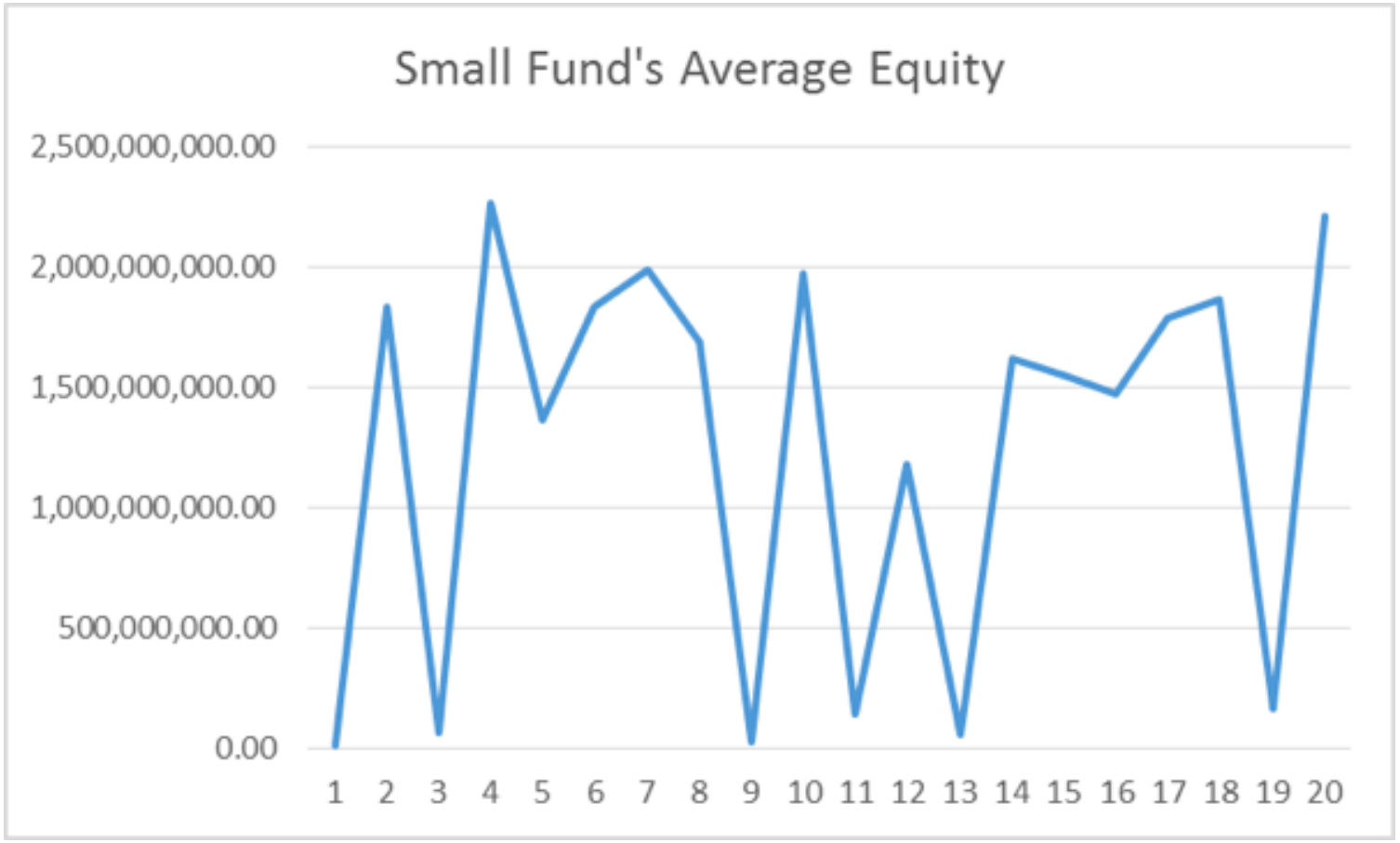
Run Results


Medium Fund's Average Equity
6,000,000,000.00
5,000,000,000.00
4,000,000,000.00
3,000,000,000.00
2,000,000,000.00
1,000,000,000.00
0.00
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39

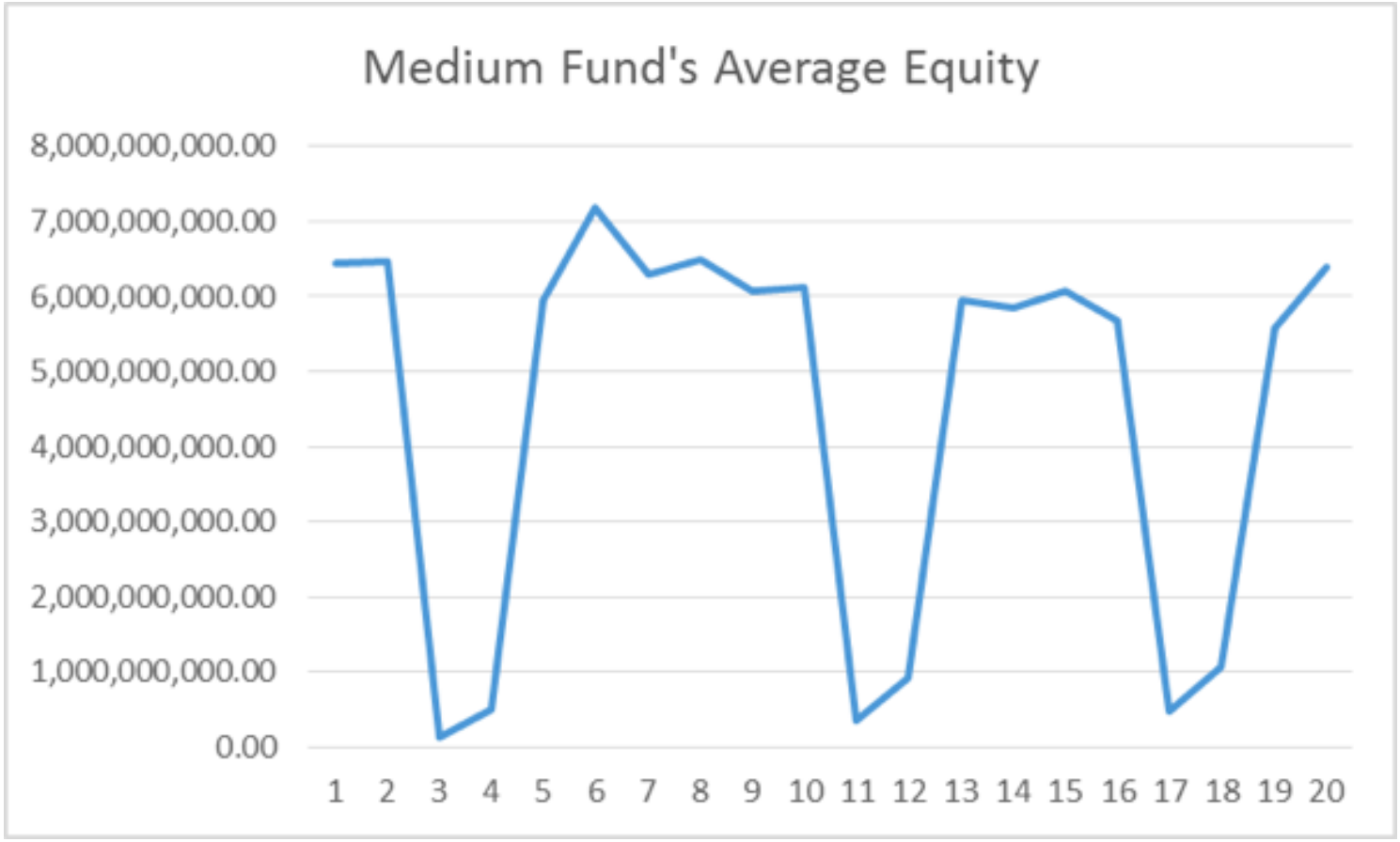
Run Results


Large Fund's Average Equity
12,000,000,000.00
10,000,000,000.00
8,000,000,000.00
6,000,000,000.00
4,000,000,000.00
2,000,000,000.00
0.00
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39

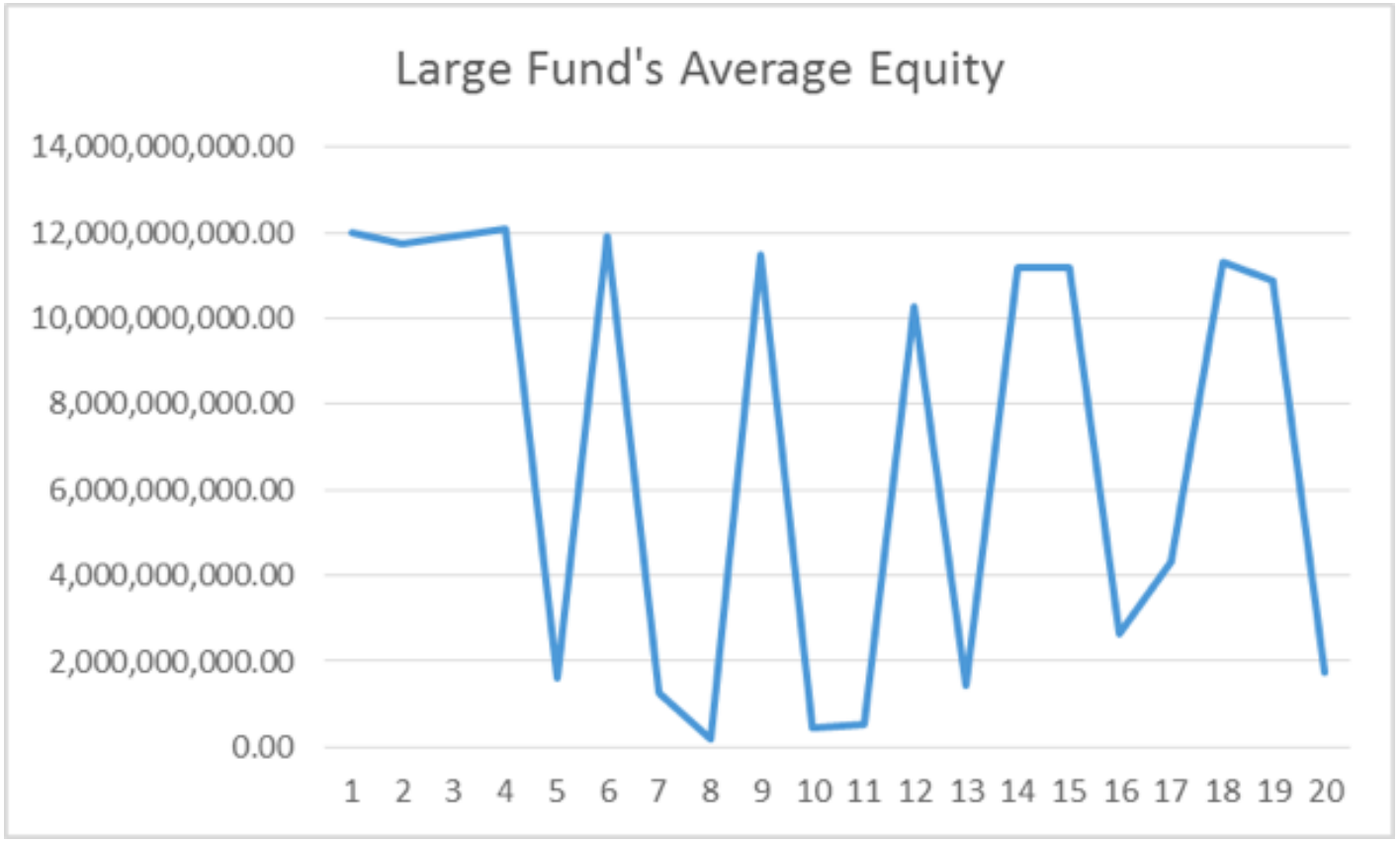
Sensitivity Run 1 Results



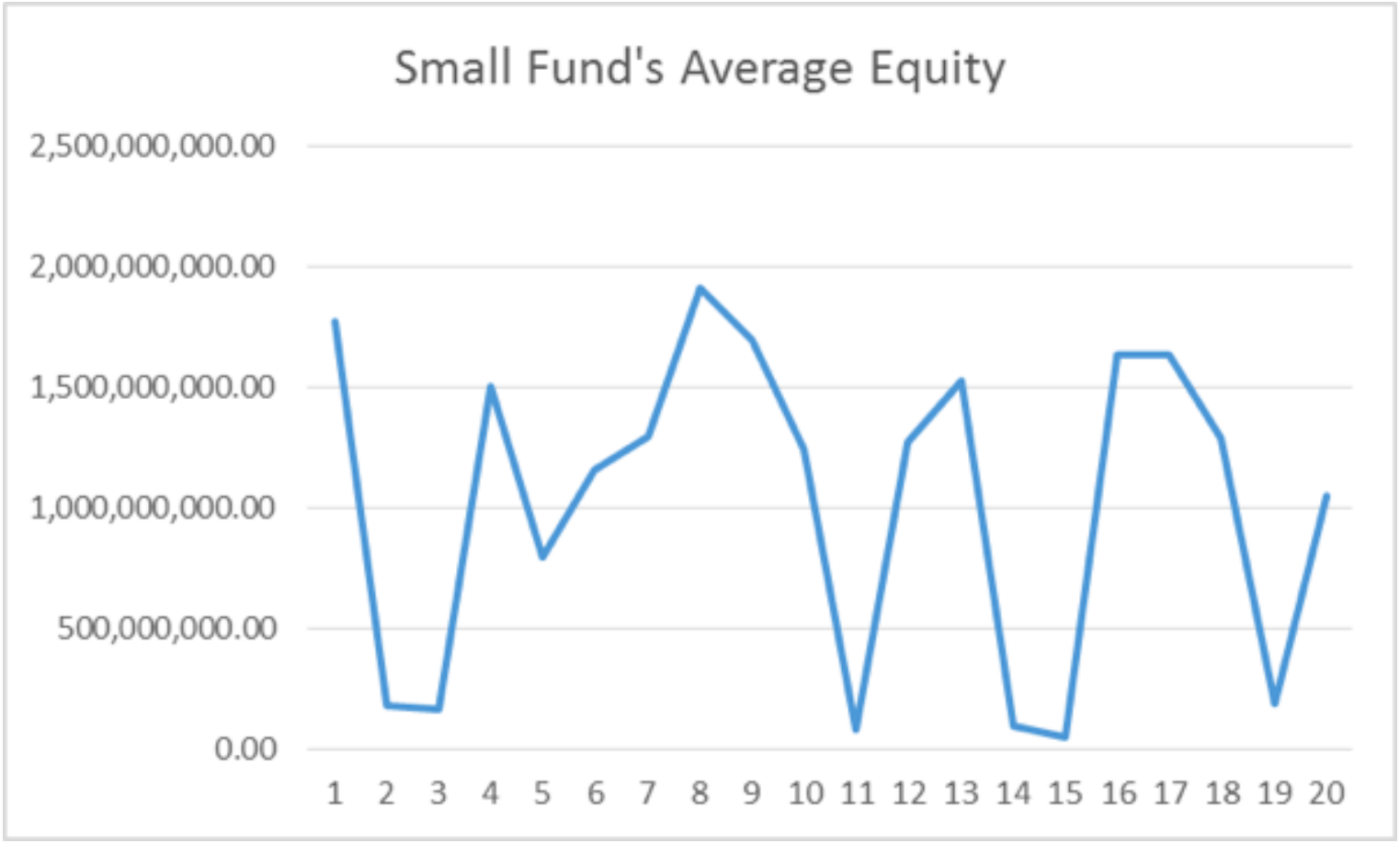
Sensitivity Run 1 Results



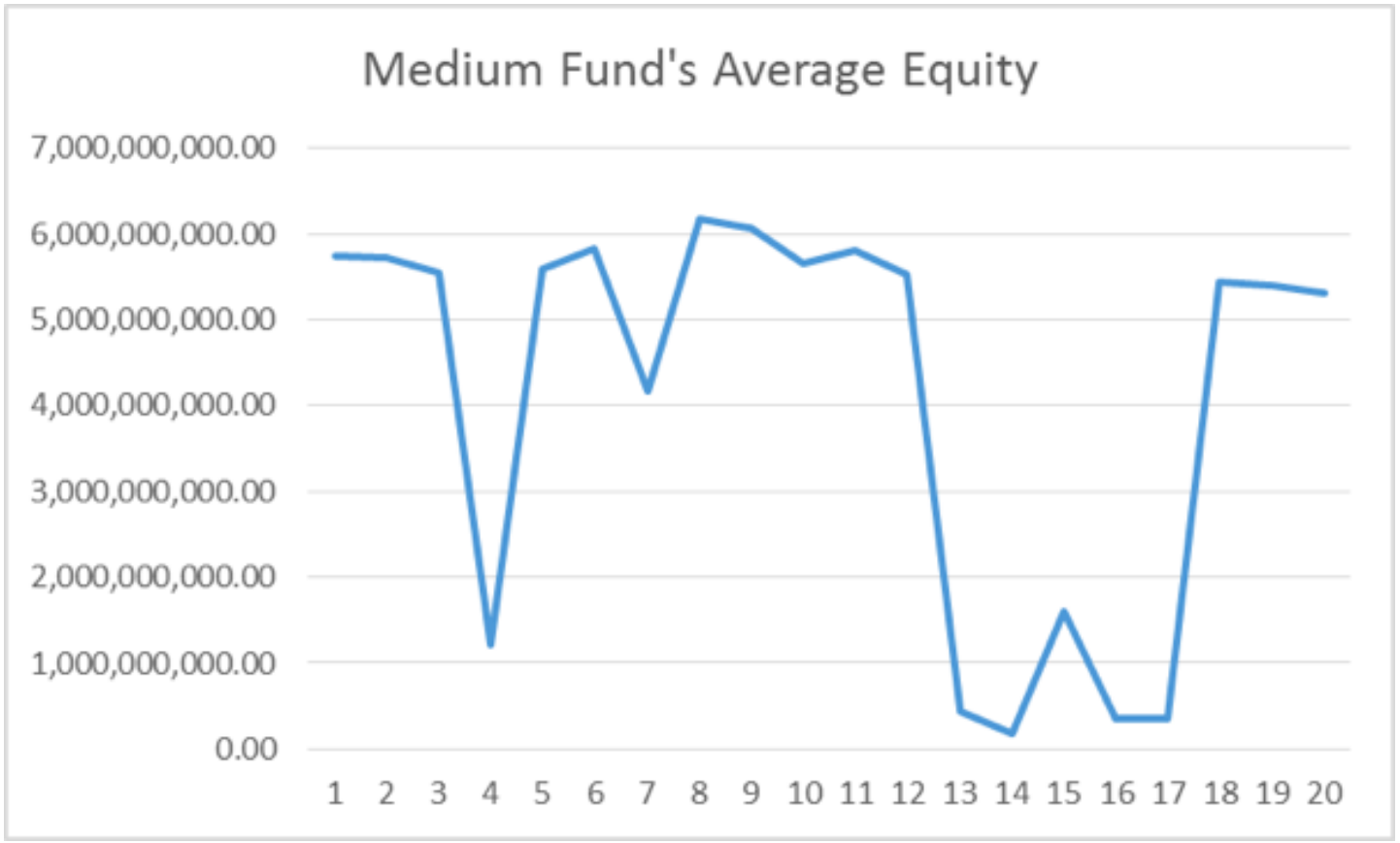
Sensitivity Run 1 Results



Sensitivity Run 2 Results



Sensitivity Run 2 Results



Sensitivity Run 2 Results