THE PENNSYLVANIA STATE UNIVERSITY
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# A REPRESENTATION OF INVESTOR LEARNING BEHAVIOR THROUGH CELLULAR GENETIC ALGORITHMS

ALVARO RAMIRO PEREDO CENTELLAS
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Reviewed and approved* by the following:

Jingzhi Huang
Professor of Finance, McKinley Professor of Business and Professor of Mathematics
Thesis Supervisor

Brian Davis
Clinical Associate Professor of Finance
Honors Advisor

* Signatures are on file in the Schreyer Honors College.

## ABSTRACT

This paper implements a Cellular Genetic Algorithm (CGA) to compare key statistics on the earnings of a population of investors with different learning and innovation rates, defined as crossover and mutation rate, respectively. The data used was the adjusted closing price for the S&P Index 500, 'INX', from two low volatility periods-from 2004 to 2007, and from 2014 to 2017- and a relatively high volatility period-from 2008 to 2011-. This study concluded that there exists a significant difference when investors learn from performing peers and that optimal learning rates may vary between high and low volatility periods, being particularly beneficial in the former ones.

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# Chapter 1

## Introduction

This paper establishes a link between the behavior parameters of a population of investors and the mechanisms found in a Cellular Genetic Algorithm (CGA) over two low volatility periods (2004-2007, 2014-2017) and one high volatility period (2008-2011). Genetic Algorithms (GA) are well known for their capacity to imitate the evolutionary processes of natural selection and lead to efficient answers for non-linear or complex problems. They are particularly useful in cases when timing is as important as optimality. It is with no surprise that GAs have been implemented in the world of Finance, particularly in the search for investment strategies and sources of arbitrage. Several models have been designed in search for the most effective implementation of this type of algorithms such as the one designed by Papadamou and Stephanides (2007) and Dempster (2001).

Rather than focusing in the solution and convergence aspect of the GA, this paper will focus in how the crossover rate and mutation rate, two key parameters in the evolutionary nature of the algorithm, can be used as proper representations of the ability of investors to learn and innovate in the markets. By systematically changing these two parameters we hope to gain insight into how learning and innovative behavior in a population of investors may lead to better or worse returns in different market conditions.

To improve the representative capacity of our GA several choices regarding form and data input were made. In the interest to capture the financial markets, the model uses adjusted closing prices from the S&P Index 500 (quote: INX). In addition, rather than using a general

form GA, a Cellular Genetic Algorithm (CGA) was implemented. The main difference between a traditional GA and a CGA is that the latter one sets the population into a grid- much like cells in an organism- and individuals are only able to breed and cross "genes" with members in nearby cells. This study found that there exists significant difference in earnings of a population of investors when changing the learning rate, primarily in high volatility periods. The study also found that optimal learning behavior is harder to achieve in low volatility periods and also is less effective in recent times compared to the past.

The rest of this thesis will provide detail to the characteristics of the model along with the results. Chapter 2 is a literature review of previous work related to the use of GAs in Finance. Chapter 3 will hold a brief description of some properties of GAs along with specifics about the model created for this paper. Chapter 4 will set the methodology, particularly with the operations of the CGA. Chapter 5 will present the results extracted from the data collected from the algorithm. Finally, Chapter 6 will provide a conclusion along with insight for future improvements and areas of research.

# Chapter 2

## Literature Review

Genetic Algorithms were originally created to solve optimization problems in the world of physics and engineering, outside the scope of finance. Due to their capacity to achieve acceptable answers with speed, they were particularly useful in non-linear and time sensitive problems. One of the firs published papers linking genetic algorithms to finance was Bauer and Leipins in 1994 with their book "Genetic Algorithms and Investment Strategies" in which they provided practical guidance about how genetic algorithms could develop profitable trading strategies based on fundamental analysis. It is after them that researchers in the financial markets discovered the applicability of genetic algorithms, specifically as a valid approach towards developing and choosing technical trading strategies.

One of the most cited papers regarding the use of GAs in developing trading strategies is Michael Dempster's "A Real-Time Adaptive Trading System Using Genetic Programming" published in 2001. As a professor in the University of Cambridge with a specialty in Mathematical and Computational Finance and Economics with non-linear analysis, he has published several papers in search of creating efficient trading strategies based on technical indicators. His paper on genetic algorithms concluded that a majority of indicator-based rules generate losses when used individually or collectively. However, his research also shows that it is possible to profit from entry signals resulting from combining indicators, similar to the way a technical trader would behave in the markets. Even thought, Dempster's research led up to losses

when applying the algorithm, he acknowledged the possibility of creating a GA that could be profitable in the future.

Dempster opened the door for researchers to elaborate variations of his algorithm focused in technical trading. Most studies coming after Dempster focused in optimizing his model either by changing its underlying methodologies and programming tools, or by increasing the type and quantity of inputs. One such case is "Adaptive Systems for Foreign Exchange Trading" published in 2004 by Mark Austin. According to this paper, making sensible indicators is relatively straightforward, but the real challenge relies in identifying genuinely useful combinations of such indicators. With his research, Austin was able to prove that foreign exchange markets had become more efficient over the last years by comparing the profitability thresholds of his GA over two different periods (1994-1998 vs 1999-2002). This hypothesis was also confirmed by Allen and Karjalainen (1999), where they showed that it is not possible to make money after transaction costs for highly traded stocks. An extension to Dempster's model was Austin's incorporation of indicators based on market orders and price limit orders into the algorithm, tested on the USD/JPY, EUR/USD, GBP/USD, and EUR/GBP between 2002 and 2003. However, this data is only available to market makers and it can't be attributed to information an average investor would possess. Austin concluded that incorporating flow and order data was indeed useful to generate better returns in the GA.

New and more complex tools where incorporated in Hryshko and Downs's paper "System of Foreign Exchange Trading Using Genetic Algorithms and Reinforcement Learning", published in 2004. In their research, the authors implemented previous studies on Reinforcement Learning – namely RL and Q-Learning- and decided to create a hybrid approach in which reinforcement learning mechanisms grant positive or negative feedback to the genetic algorithm.

The feedback directly affected the algorithm by changing the probability of crossing or extending certain "genes" to next generations. Results revealed that the hybrid led to improved profitability with a cyclical behavior. Due to the ever-changing nature of the markets, indicators selected loosed their applicability through time and the learning mechanism lagged to push the algorithm into a new optimum. Hryshko and Down's research led to further questions about optimality in the markets, and the use of reinforcement learning pushed the boundaries for computer programs to be able to model investor behavior and their capacity of learning from environmental cues.

Dempster's algorithm was further improved by Zhang and Ren's model, which implemented about nine different indicators. In their paper "High Frequency Foreign Exchange Trading Strategies Based on Genetic Algorithms" published in 2010, the authors included a significant upgrade by creating a neutral position in the algorithm, rather than forcing the members of the population to buy or sell. This change leads to substantial improvements in profitability of 3.7% in the span of the research, compared to Dempster's model which generated losses.

Rather than focusing on the algorithm itself, Papadamou and Stephanides in "Improving Technical Trading Systems by using a new MATLAB-Based Genetic Algorithm Procedure" (2015), focused on the effect of using different programs for the genetic algorithm, as well as proving the declared optimal parameters of population size, crossing and mutation rate. The authors point the optimal parameters from the book "Genetic Algorithms in Search, Optimization, and Machine Learning" by Goldberg. Per the authors' research, average solutions improved with population size, however the marginal benefits of increasing population size decreased drastically after size 30. Further analysis on computation costs and returns determined

that the best value was 20. Analysis on crossover rates revealed that a change in this parameter did not critically affect the algorithm if the population size was appropriate.

Nowadays, there is still strong interest in the applicability of Genetic Algorithm in the world of financial markets. In 2014 a patent was filled for "Distributed Evolutionary Algorithm for Asset Management and Trading" by Hodjat, Shahrzad, Blondeau, Cheyer and Harrigan. The authors devised a variation of a GA which implements separate processing units that handle multiple tasks. An innovation within this system was that indicators and specific "genes" where periodically analyzed for fitness. If a strategy was set as dominant, then it would be constantly tested for a threshold, which if trespassed, would direct the algorithm to drop the strategy and proceed with one that was performing. Parallel processing units would exchange strings of chromosomes between each other to increase the subspace of optimization.

From the papers reviewed and mentioned earlier in this chapter, most, if not all, of the experiments conducted focused in developing a profit generating GA by managing the inputs and processing style of the algorithm. A dialogue was initiated by Dempster and followed several other analysts that resulted in the development of better and accurate ways of incorporating market data and mirror the decision-making process of a rational investor. From all this papers, the model seems to improve as their actions start matching more closely to the behavior of an investor. It is particularly interesting the capacity that GAs have to learn from the markets, a quality that leads the algorithm to mimic investor's behavior. Based on this, it is possible for a genetic algorithm to model investors of different learning behaviors toward incorporating successful strategies from their peers. Certainly, in the markets, not all individuals are willing to accept other's strategies just because they have been successful in recent times. Thus, we can use genetic algorithms to represent the willingness to learn of an investor and analyze which degree

of flexibility is most profitability given certain market conditions. The model used in this paper, based greatly on the simple model introduced by Dempster, systematically changes the crossover rate and mutation rate to portray such willingness to learn.

# Chapter 3

# About Genetic Algorithms

## What is a Genetic Algorithm?

Goldberg, a professor from the University of Alabama who dedicated several of his papers toward Genetic Algorithms, defined them as “search algorithms based on the mechanics of natural selection and natural genetics” (Goldberg, 1989). The main theme within Genetic Algorithms (GAs) is the idea of robustness, the balance between efficacy and efficiency and their capacity of finding solutions in complex spaces.

Unlike other optimizations and search procedures GAs differ in four main aspects. First, GAs work with a coding of the parameter set, not the parameter itself. In other words, rather than tweaking with the parameter in small steps until a local optimal is reached, the algorithm requires to code the parameter set as a finite length string. Second, GAs search from a population of points rather than a single point. Third, GA’s use the payoff from the objective function for information, not relying on derivatives or other knowledge. Finally, GA’s are probabilistic in nature, without deterministic behavior.

**Gene transfer, fitness and convergence**

As mentioned in the previous section, GAs search for solutions by replicating the process of evolution and natural selection. Organisms that are better adapted to an environment have better chances of producing offspring and thus, passing on their genes to the next generation. The algorithm behaves similarly: instances which perform better at the objective function relative to other instances will have a higher chance of passing their "genes" to the next population. In nature if the environment changes drastically then it may happen that other organisms who were not adapted to the previous environment are now better adapted and can pass their genes to the next generation. In the algorithm, when the objective function changes there is a change in the performance of the instances and the "genes" passed over to the next population may differ.

The performance of an instance in a GA is defined as its fitness. Because the characteristics of an objective function can be varied in a GA, the way fitness is calculated is specific to the problem. In our case, fitness is calculated as the return of an investor, and the greater the return, the higher the fitness value of that instance.

In problems where the objective function does not change, or changes slightly, the GA is expected to reach convergence. Convergence can be defined in several ways:

$$|F_{n+1} - F_n| < \varepsilon$$

Where:

$-\mathrm{F_n}$ is the fitness or performance of generation n

$-\varepsilon$ is a small enough threshold

Note that in this case $F_n$ can be the maximum fitness of the population, or the average fitness of the population.

$$F_n > \alpha$$

Where:

$-\alpha$ is a minimum desired level of fitness

For problems with changing objective function, or where neither of the previous criteria is reached. It is typical to establish a stopping criterion:

$$n \geq K$$

Where:

$-$n is the number of generations

$-$K is the maximum number of generations permitted by the algorithm

**Main steps of a traditional Genetic Algorithm**

Since a GA is based on the mechanics found in nature, it is no surprise that the steps of such GA also share similar logic to those processes in nature related to breeding and evolution.

First step in a GA involves creating a population. The parameters found in the objective function are programmed in a set of binary strings – which are the genes- and combined into a larger string -identified as the chromosomes. The chromosome is generated randomly, making sure that the population has a proper genetic diversity, fundamental for the success of the algorithm. The solution for the algorithm is present in the initial population as a combination of their chromosomes plus some mutations.

After creating a population, the algorithm translates the gene into parameters which are evaluated in the objective function. The objective function will produce a value which then may be manipulated (comparatively with the values produced by others in the population) to provide

a fitness value. The algorithm then selects the subset of the population with highest fitness values. With that subset, the algorithm will perform one of the following operations:

- Delete all members of the population which are not in the subset and fill the empty places with the offspring of members of the subset.
- Preserve the subset, and create a roulette, in which the genes of a member are present more often the higher the fitness value. Note that in this case, instances with low fitness values still have a chance of passing their genes onward.
- Preserve the subset and cross the genes of each member not in the subset with one randomly selected member from the subset.

Producing offspring involves the concepts of crossing and mutation. The probability that a pair of instances produce offspring is defined as the crossover rate. Similarly, the probability that an offspring has a gene (bit) changed to another value different from the parent is defined as the mutation rate. Once a pair has been chosen to breed, the chromosomes are combined into a child chromosome. This new chromosome can be created in different manners. The typical method is a single point crossover (explained in further detail in the Methodology), however other frequent methods involve k-point crossover and uniform crossover.

Once the algorithm finishes creating the new population, the program evaluates the new fitness of each instance and repeats the process of selecting those with the highest fitness, breeding and mutating. This loop runs until one of the stopping criteria is reached, and the solution is provided as the genetic code of the instance with the highest fitness value.

**Model adaptations for this paper**

The goal of this paper is to use the mechanisms of GAs to grasp an understanding of how the learning behavior of a population of investors influence in their capacity to generate returns. Instead of looking for the "optimal" solution as a combination of trading strategies, we seek to compare how the population behaves under different crossover and mutation rates. We draw a relationship between the crossover rate and the willingness to learn from a population of investors. Similarly, we draw a relationship between the mutation rate and the capacity of innovation of a population.

Some changes were made to the algorithm to facilitate our analysis and help us portray the reality of financial markets. The population is set into a square grid shaped in the form of a torus to allow information to be transmitted with equal chance to all individuals. The mechanism that selects the pairs of instances that will breed has also been changed so to represent the way information spreads faster between members close to each other. All significant changes are detailed in the following chapter.

# Chapter 4

# Methodology

## Language, environment and data Sourcing

The Genetic Algorithm was implemented in Python 3.5.2 with Spyder 3.0.0 as an environment. Python and particularly Spyder, were selected, because of the pre-installed packets, which permitted easy access and manipulation of data. The coding for the algorithm was based in the structure provided by David Adler (2016) for a genetic algorithm which looked for a list of integers and operators that when evaluated approached a target value.

The data used for this research was the Adjusted Closing price of the S&P 500 Index 'INX' extracted from Yahoo! Finance through **pandas** library. Pandas allows direct access to financial data coming from Yahoo, Google or other sources, which is incorporated into Python and can be easily manipulated as a time series.

Information about 'INX' will be extracted from three different time periods:

1. Jan 1, 2004 – Jan 1,2007: Low volatility period with a Volatility S&P 500 (VIX) average value of 13.7
2. Jan 1, 2008 – Jan 1,2011: High Volatility period, with a VIX average value of 28.91
3. Jan 1, 2014 – Jan 1, 2017: Low volatility period, post Great Recession, with a VIX average value of 15.56.

**The "Investor" Class**

To create a population capable of representing the quantitative and qualitative characteristics of an investor, it is useful to create a data structure within the program which stores such values and is readily able to be updated with each iteration of the genetic algorithm. A ***class*** in python is a good structure to perform this functions. The class "Investor" holds the following attributes:

- **Chromosome:** A finite binary list which codes for the strategies that will be considered for an investor and the AND/OR operands.
- **Position:** A binary digit {0,1} which results from translating an investor's chromosome into a buy {1} or neutral {0} position.
- **Earnings:** Holds the earnings (or losses) generated by an investor in a time interval.
- **Total Profits:** A value indicating the difference between current capital and initial capital ,allocated at the beginning of the algorithm.
- **Location:** A set of coordinates {x,y} which save the location of the investor in the grid.
- **Capital:** Starts with current capital and is updated with each period's earnings. Shows the total capital available to an investor.
- **List of Returns:** List which holds the k most recent returns of an investor. If the position by an investor is 1 then the rate of return for that period is the same as the one of the stock or asset, else it is 0.
- **Return to Date:** Stores the total return on investment of an investor through the following formula:

$$Return\ To\ Date = \ln\left(\frac{Capital_T}{Capital_0}\right)$$

- **Return Memory:** Stores the average of the elements found in ***List of Returns*** for an investor

**The "DataCollector" Class**

This data structure will hold the population statistics for each period. Allowing us to retrieve this data and use it during our final analysis. The class "DataCollector" holds the following elements:

- **Period:** A list of integers [0, T] to reiterate the period in which data is collected.
- **Maximum Capital:** A list of elements which will store the capital of the investor in the population with the highest capital for that period.
- **Minimum Capital:** A list of elements which will store the capital of the investor in the population with the lowest capital for that period.
- **Average Capital:** A list of values which will store the average capital of the entire population of investors for that period.
- **Investors in the money:** Counts the number of individuals from the population that have generated a positive return from the initial capital
- **Investors off the money:** Counts the number of individuals from the population that have generated losses compared to the initial capital
- **Neutral Investors:** Counts the number of individuals from the population that have not generated losses or gains compared to the initial capital

**Creating a population of investors and a genetic pool**

In accordance to the CGA, a population of $n^2$investors is created and each instance is allocated into an $n \times n$ grid. During breeding period, instances will only be able to cross with investors located within a radius, representing how in the markets information may spread unevenly. Furthermore, to prevent isolation of investors located in the corners or sides of the population, the grid will represent relative locations of each instance in a torus. Whitley in his book "A genetic algorithm tutorial" (1994), observes that with this cellular structure, we expect small local pockets of similar string to form, which then compete with other pockets, resulting in fewer and larger "neighborhoods".

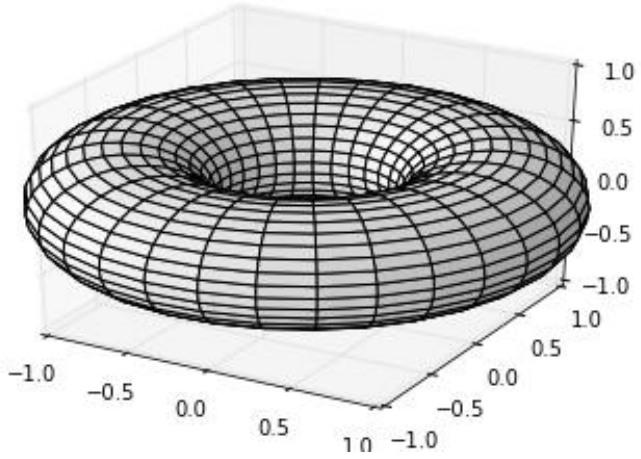



**Figure 1: A Torus Generated in Python**

Keeping in mind the goal of this paper, it is only necessary to select a few trading strategies that can be easily implemented in our algorithm and have low cost in terms of time and processing power. The trading strategies included into the genetic algorithm are the following:

- Simple moving average for 50 days, 100 days and 200 days
- Comparison of moving average 50vs100 days, 50vs200 days, 100vs200 days
- Momentum Oscillator (10 days)
- Slow Stochastic

Further detail about these strategies can be found in Hryshko and Downs (2004). A total of 8 strategies will make up the genetic pool, along with AND/OR links that will assure a proper diversity in the genetic makeup the population. The operands AND/OR will be represented as 1 and 0 respectively in the binary string.

**Generating the chromosomes**

For each instance of our "Investor" class the algorithm will randomly generate a binary string of length $2n-1$,where $n$ corresponds to the number of trading strategies in the genetic pool. In the case of our algorithm, with 8 strategies the program will generate a string of 15 elements.

| Location | 0 | 1 | 2 | 3 | 4 | 5 | | 2n-2 |
|---|---|---|---|---|---|---|---|---|
| Binary Code | 1 | 0 | 1 | 1 | 0 | 1 | … | 1 |

**Table 1 Chromosome of length 2n-1**

In the figure above the top row represents the location of each character in the binary string (note that gene location is set in basis 0, thus the last location is 2n-1). Strategies are set to

even locations including zeros, whereas AND/OR operands are allocated to odd locations. The binary string will determine whether a strategy is active {1} or inactive {0} and whether an AND {1} or OR {0} operand will be used between such strategies.

Only with 15 elements the number of different chromosomes is large. Since each location is binary, the total number of possibilities is $2^{15}$ =32768. In general, given $n$ strategies, the number of possible different chromosomes is $2^{2n-1}$

**Translating an investor's chromosome**

The genes found within a chromosome of an investor are read from left to right and operators are compared with the next immediate active strategy. The algorithm breaks down each chromosome into two lists: one holding the outcomes of the active strategies, and another one holding the list of operators.

Consider the following interpretation:

| Location | 0 | 1 | 2 | 3 | 4 | 5 | 6 | … | 2n-4 | 2n-3 | 2n-2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Binary Code | 1 | 0 | 1 | 1 | 0 | 1 | 1 | … | 1 | 1 | 0 |
| Translation | Active | OR | Active | AND | Inactive | AND | Active | … | Active | AND | Inactive |

**Table 2: Example of chromosome translation**

This list will be split into two, and only the operators found to the immediate right of an Active gene is included in the operator list. Furthermore, if the last gene of the chromosome is inactive, then the operator to the right of the last active strategy is ignored.

The active strategy list will hold the expressed genes which will be evaluated for a Buy {1} or Hold {0}.

| Strategy List | | | | | |
|---|---|---|---|---|---|
| Active Strategies | Strategy 0 | Strategy 2 | Strategy 6 | … | Strategy 2n-4 |
| Evaluation | 1<br>Buy | 0<br>Hold | 1<br>Buy | … | 1<br>Buy |

**Table 3: List of strategies along with their output**

The operator list will hold the operators to the immediate right of an active strategy. Where operand $k \leq 2n - 5$, in this case.

| Operand List | | | | | |
|---|---|---|---|---|---|
| Active Operands | Operand 1 | Operand 3 | Operand 7 | … | Operand k |
| Interpretation | OR | AND | … | … | … |

**Table 4: List of operators along their translated gene**

Finally, lists are evaluated by grabbing the first two elements of the strategy list, and using the first operand to determine if the resulting value is a 1 or 0. The algorithm grabs the following strategy and uses the operand and the previous result to obtain a new result {0.1}. This result is further compared with the following strategy and operand and so on, until the end of both lists is reached and a position is set {0,1}.

| Strategy 0 | Strategy 2 | Strategy 6 | … | Strategy 2n-4 |
|---|---|---|---|---|
| 1<br>Buy | 0<br>Hold | 1<br>Buy | … | 1<br>Buy |

| Operand 1 | Operand 3 | Operand 7 | … | Operand k |
|---|---|---|---|---|
| OR | AND | … | … | … |

**Table 5: Strategy and operator list from the original chromosome**

Example two iterations of the evaluation process:

| | | | | | |
|---|---|---|---|---|---|
| First Iteration | Strategy 0 | Operand 1 | Strategy 2 | = | Result |
| | 1 | OR | 0 | = | 1 |
| Second Iteration | Result | Operand 3 | Strategy 6 | = | Result |
| | 1 | AND | 1 | = | 1 |

**Table 6: Two iterations of the translating mechanism**

**Calculating fitness and subset of elite investors**

After evaluating the chromosome, the investor will take a position $S_t$, such that:

$$S_t = \begin{cases} 1 \text{ if position is a buy} \\ 0 \text{ if no position is taken} \end{cases}$$

Starting from t, the algorithm will proceed to the next period, $t + \delta$, and calculates the returns corresponding to owning the asset for such period. Thus, the return for an investor is the following:

$$R_{i,t+\delta} = \begin{cases} \ln \frac{P_{t+\delta}}{P_t}, & S_{t,i} = 1 \\ 0, & S_{t,i} = 0 \end{cases}$$

Where:

$-R_{i,t+\delta}$ is the return for an investor i at time $t + \delta$

$-P_t$ is the price of the asset at time t

$-S_{t,i}$ is the position taken by an investor i at time t

This return will be appended to an **Investor.ListofReturns** structure, so to be used later as a fitness indicator. Returns are independent from each other thus a new return is calculated at every new $\delta$ step. The GA developed does not provide any penalties or rewards when a significant group of investors enter or exit the market, thus we assume that investors have marginally no effect on the price of assets.

Once returns are extracted the current capital is calculated as follows:

$$C_{i,t+\delta} = C_{i,t} \times (1 + R_{i,t+\delta}) \times I$$

Where:

$-C_{i,t+\delta}$ is the total capital of investor i at time $t + \delta$

$-I$ is the investment rate, which remains constant $0 < I \leq 1$

Capital is dependent on previous levels of capital for an investor, thus good and bad "decisions" compound through time. In mathematical terms, for a time $T \geq t + 3\delta$

$$C_T = C_t \times (1 + R_{i,t+\delta}) \times (1 + R_{i,t+2\delta}) \ldots \times (1 + R_{i,t+n\delta})$$

Earnings for a period can be easily calculated through the following formula:

$$E_{t+\delta} = C_{t+\delta} - C_t$$

The algorithm can implement different types of fitness measures. The most direct method involves sorting the population and selecting those investors with highest capital or which generated the highest amount of earnings during the period. Under this fitness measure, we can draw the scenario where investors tend to learn from those with highest reputation, which can generate higher earnings per period due to substantial levels of capital.

A second method utilizes the list of last k returns and calculates either a simple or a weighted average of such returns. For example, the simple average can be calculated as follows:

$$\bar{R_i} = \frac{R_1 + R_2 + \cdots + R_k}{k}$$

Under this fitness measure, we can draw the scenario where investors tend to learn from those who report recent higher returns, independently of their level of success prior to the past k periods.

**Population breeding and mutation**

Once the initial population has been generated with their respective chromosomes, the genetic algorithm will run through an "accommodation" period where no crossover happens. During this time, defined to be a year before the actual analysis period, investors in the population will take a position and generate profits or losses. Differences between members of the population will increase during that year, which will allow to create an elite list of individuals that are significantly better than other members.

When the actual testing period starts, the algorithm selects a top percentage of the population – say 15% - from which nearby investors can "learn". This "elite members" will have an area of influence which is embedded on the torus shape of the grid.

For a pair of investors in the grid, one being an elite and the other an instance found within its radius of influence, the probability of them breeding is set as the crossover rate, which as a probability is bounded by 0 and 1. If the algorithm determines that the pair is breeding then a single-point crossover is set between the chromosomes and one of the resulting children is assigned to the non-elite parent.

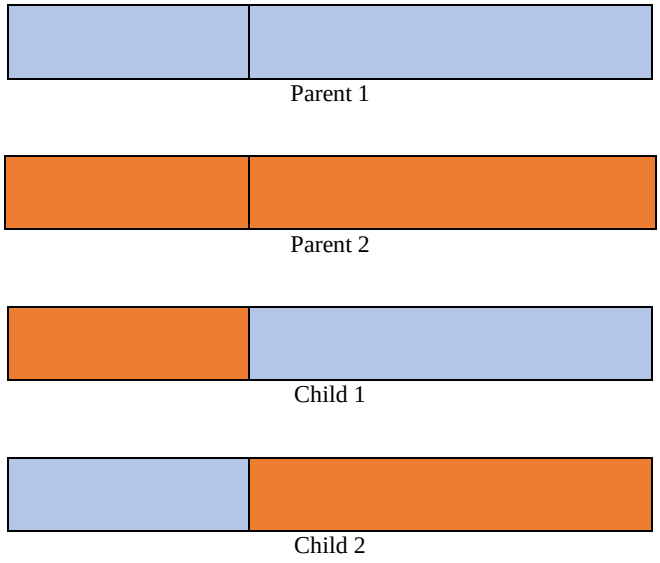



**Figure 2: Color coded example of single-point crossover**

The algorithm created selects a crossover point as a random uniform variable, thus the probability for any gene to be selected as the crossover point is $1/n$ ,where n is the number of genes in a chromosome. Furthermore, each child has a ½ probability of being assigned to the non-elite parent.

Before the selected child is assigned as the parent's new chromosome one of the child's gene may face mutation. The probability of mutation, or mutation rate ($M_r$), is usually lower than the crossover rate, and we can understand it as the rate of innovation within the markets. The algorithm randomly generates a value x such that $0 \leq x \leq 1$ and randomly selects a gene from the chromosome ($G_i$) and performs the following operation:

$$if\ x \leq M_r\ \text{then} \begin{cases} \text{if } G_i = 0, & \text{set } G_i = 1 \\ \text{if } G_i = 1, & \text{set } G_i = 0 \end{cases}$$

**A new population and moving onward**

Once the algorithm has run through its first breeding cycle, the new population will consist of three groups:

- The elite members from the original population $In_0$
- The non-elite members from the original population $In_0$ which did not breed with elite members
- The members with new chromosomes resulting from crossing and mutation between elite members and non-elite members

All these groups now form part of a new generation $In_1$, which may have a different behavior depending on their genetic makeup and the current state of the markets. The chromosome of each investor instance is translated, market information is processed and positions are determined. The algorithm moves to the following period, calculates returns and capital and uses the data to determine a new elite for $In_1$. Finally, the elite crosses with non-elite members from its radius of influence, and a new population is created ($In_2$).

The cycle repeats over and over from $In_0 In_1 In_2 \ldots In_k$ until the algorithm reaches the end of the timeline provided. For each population, the class "DataCollector", gathers relevant statistics which will be used to write our results.

**Summary diagram of the main steps**

Generate Initial Population $In_0$

↓

Chromosomes are translated into positions at time t

↓

Proceed to time $t + \delta$

↓

Calculate Returns and Capital

↓

Use Returns or Capital to select elite members

↓

Store statistics of population $In_0$

↓

Breed elite members with $non - elite$ members found in their radius

↓

Population $In_1$

↓

Repeat process with new population at time $t + \delta$

**Figure 3:Steps of the Cellular Genetic Algorithm**

# Chapter 5

# Results

## General parameters in the algorithm

The Algorithm ran with a population of 100 investors on the INX with a mutation rate of 5%, investment rate of 25%, diameter of influence of 5 cells, and an elite list consisting of 15% of our population size. The accommodation period starts a year before the beginning date of each period and ends when the beginning date is reached. (i.e. January 1, 2003- January 1, 2004). The time interval between breeding of investors,$\delta$, has been set to 30 days (1 month). Elite members were selected by comparing their average of the last 10 period returns. The crossover rate was changed systematically to analyze the impact of learning rate on the main statistics of the population. For each crossover rate the algorithm was implemented 30 times so to obtain a proper sample size. Student's t-test for paired means was utilized to compare the crossover rates.

## Results for January 1, 2004 - January 1, 2007

As it can be observed in the Appendix D.1 the t-test results for this period show that, for population average capital, there is a significant difference between the base case of crossover rate 0 and the higher crossover rates. Particularly, there was a positive significant difference for the rates of 0.4 and 0.6. The other rates revealed a negative impact. It is also interesting to note that the variance of population average capital was higher for all crossover rates compared to the base case, with exception of crossover rate 0.6.

Appendix D.2 shows the t-tests for the minimum capital found in the population. For all higher crossover rates, a positive significant difference was evidenced along with lower variance compared to the base case.

Appendix D.3 shows the t-tests for the maximum capital found in the population. For all higher crossover rates, with exception of the 100% case, there was a positive significant difference compared to the base case. Furthermore, all higher crossover rates showed lower variance compared to the base case.

Appendices D.4, D.5 and D.6 show the average count of positive, negative and neutral return investors, relative to the initial period, of the sample. Both the positive and negative counts show a significant positive difference (there are more of both in the population) and higher variance compared to the base case. On the other hand, the count of instances with no loss or return has a significant negative difference and higher variance for all higher crossover rates compared to the base case.

| | Statistical Significance | | | | | Variance | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Crossover Rates | 20% | 40% | 60% | 80% | 100% | 20% | 40% | 60% | 80% | 100% |
| Average | Negative | Positive | Positive | Negative | Negative | Higher | Higher | Lower | Higher | Higher |
| Minimum | Positive | Positive | Positive | Positive | Positive | Lower | Lower | Lower | Lower | Lower |
| Maximum | Positive | Positive | Positive | Positive | Negative | Lower | Lower | Lower | Lower | Lower |
| Positive Count | Positive | Positive | Positive | Positive | Positive | Higher | Higher | Higher | Higher | Higher |
| Negative Count | Positive | Positive | Positive | Positive | Positive | Higher | Higher | Higher | Higher | Higher |
| Neutral Count | Negative | Negative | Negative | Negative | Negative | Higher | Higher | Higher | Higher | Higher |

**Table 7: 2004 to 2007 statistical analysis versus the base case**

**Results for January 1, 2008 - January 1, 2011**

As evidenced in Appendix E.1 the t-test results show that, for the population average capital, there exists a significant difference between the base case and the populations with higher crossover rate. The crossover rate has a positive impact for all higher values with exception of the population with 80% crossover rate, which shows a negative impact. Variance in average capital was lower for all cases compared to the base case, with exception of the 80% case.

Appendix E.2 shows the t-tests for the minimum capital found in the population. For all higher crossover rates, a positive significant difference was evidenced along with lower variance compared to the base case.

Appendix E.3 shows the t-tests for the maximum capital found in the population. For all higher crossover rates, a positive significant difference was evidenced along with lower variance compared to the base case.

Appendices E.4, E.5 and E.6 show the average count of positive, negative and neutral return investors, relative to the initial period, of the sample. Both the positive and negative counts show a significant positive difference (there are more of both in the population). In terms of variance, the base case displayed lower variance for number of investors with overall negative return, while showing higher variance for the number of investors with overall positive return, compared to the higher crossover rates. The count of instances with no return or loss has a significant negative difference and higher variance for all higher crossover rates compared to the base case.

| | Statistical Significance | | | | | Variance | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Crossover Rates | 20% | 40% | 60% | 80% | 100% | 20% | 40% | 60% | 80% | 100% |
| Average | Positive | Positive | Positive | Negative | Positive | Lower | Lower | Lower | Higher | Lower |
| Minimum | Positive | Positive | Positive | Positive | Positive | Lower | Lower | Lower | Lower | Lower |
| Maximum | Positive | Positive | Positive | Positive | Positive | Lower | Lower | Lower | Lower | Lower |
| Positive Count | Positive | Positive | Positive | Positive | Positive | Lower | Lower | Lower | Lower | Lower |
| Negative Count | Positive | Positive | Positive | Positive | Positive | Higher | Higher | Higher | Higher | Higher |
| Neutral Count | Negative | Negative | Negative | Negative | Negative | Higher | Higher | Higher | Higher | Higher |

**Table 8: 2008 to 20011 statistical analysis versus the base case**

**Results for January 1, 2014 - January 1, 2017**

Appendix F.1 shows the t-tests for the population average capital in relation to the crossover rate of the population. Statistical analysis shows that there is no significant difference from the base case (0% crossover rate) for populations with the crossover rates of 20% and 60%. Analysis shows that a crossover rates of 40% and 100% has a significant negative impact on the average capital of the population compared to the base case. On the other hand, a crossover rate of 80% had a significant positive impact on the average capital of the population compared to the base case. Variance was higher for crossover rates of 60% and 80% and lower for crossover rates of 20%, 40% and 100% relative to the base case.

The t-tests in Appendix F.2 present the statistical analysis on the minimum capital of the population at different crossover rates. According to the t-test, all crossover rates above 0% show a significant decrease in the minimum capital of the population. Investor populations with crossover rates above 0% also showed lower variance compared to the base case.

Statistical analysis on the maximum capital of the population at different crossover rates, as seen in the Appendix F.3, shows that all crossover rates above 0% show a significant increase compared to the base case. The variance of the base case is of larger magnitude than for the other cases with exception of the case with 100% crossover rate.

Appendices F.4, F.5 and F.6 show the average count of positive, negative and neutral return investors, relative to the initial period, of the sample. Both the positive and negative counts show a significant positive difference (there are more of both in the population). In terms of variance, the base case displayed lower variance for number of investors with overall negative return. For the number of investors with overall positive return, the base case shows a higher variance to all cases, with exception to the population with crossover rate of 20%. The count of instances with no return or loss has a significant negative difference and higher variance for all crossover rates higher to the base case.

| | Statistical Significance | | | | | Variance | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Crossover Rates | 20% | 40% | 60% | 80% | 100% | 20% | 40% | 60% | 80% | 100% |
| Average | Unsignificant | Negative | Unsignificant | Positive | Negative | Lower | Lower | Higher | Higher | Lower |
| Minimum | Negative | Negative | Negative | Negative | Negative | Lower | Lower | Lower | Lower | Lower |
| Maximum | Positive | Positive | Positive | Positive | Positive | Lower | Lower | Lower | Lower | Higher |
| Positive Count | Positive | Positive | Positive | Positive | Positive | Higher | Lower | Lower | Lower | Lower |
| Negative Count | Positive | Positive | Positive | Positive | Positive | Higher | Higher | Higher | Higher | Higher |
| Neutral Count | Negative | Negative | Negative | Negative | Negative | Higher | Higher | Higher | Higher | Higher |

**Table 9: 2014 to 2017 statistical analysis versus the base case**

# Chapter 6

## Conclusion

This paper attempts to determine whether the willingness to learn from its peers of a population of investors has significant impact on the population's earnings given high or low volatility market conditions. This analysis was achieved by creating a genetic algorithm which utilized different levels of crossover rates that represented the learning behavior of an investor. The algorithm was run a total of 30 times per crossover rate in {0,0.2,0,4,0.6,0.8,1} and for each high/low volatility period as stated in the methodology (2004-2007, 2008-2011,2014-2017). The samples were then compiled into averages and then used to check for statistical significance by using Student's t-test for paired means.

The model can still be improved and adapted to be a more accurate portrayal of the behavior of investors in the market. A significant addition to the algorithm would be to allow investors to not only take a buy {1} and hold {0} position, but also be capable of shorting {-1} the asset. Better results might be available by including more strategies (as genes) to the chromosomes, especially those that include information about volatility. The market environment can also be represented more accurately by introducing a penalty when a significant proportion of the population enter the markets, since in practice this would reduce the profitability of a strategy. Our analysis was realized with data from the INX on a few number of periods and more insights may be available by using the algorithm with stocks, foreign exchange or other types of assets or by using periods outside the scope of this paper. In terms of the coding itself, Reeves in "Genetic Algorithms-Principles and Perspectives: A guide to GA Theory"

(2003) mentions that real-value parameters might be better represented through a Gray Code representation, rather than the binary representation.

The analysis performed in the study reveals that there is usually a significant difference in earnings between populations of investors having different crossover rates. As observed in the results, a crossover rate above 0% will usually generate better returns and lower variance for the population if going through a period of high volatility. Further t-tests between positive cases for the period of 2008 to 2011 showed that the optimal crossover rate is around 20% and 40%. For the low volatility period, difference is significant however it is mostly negative with exceptions of some crossover rates. For the pre-financial crisis low volatility period, only crossover rates of 40% and 60% revealed a positive impact. A t-test between these two populations also revealed that 60% crossover rate is significantly better for the average return of the population. The post-financial crisis low volatility period has only an 80% crossover rate having a significantly positive impact to the average profitability of the population. Unlike the other periods, the post-recession period also holds cases where learning behavior has no significant impact in the population.

The results suggest to investors that their learning behavior should be different between periods of high and low volatility. More specifically, investors should be more open to learn during period of high volatility, around 20% to 40% of the times, and adopt currently successful strategies. It is difficult to point to an optimal willingness to learn for periods of low volatility, particularly post-recession, as an 80% crossover rate may generate profits but also makes the probable minimum lower and maximum higher. For an individual investor, this may mean there is a tradeoff of risk and return in terms of learning behavior.

It is interesting to note that the optimal learning behavior also changes between periods with similar levels of volatility. Pre-and post-recession time intervals show that nowadays, it is harder to generate positive returns by learning from other successful investors and that it conveys higher risks compared to previous eras.

# Appendix A

## Average data obtained from the GA for the period 2004-2007

### A.1 Average population capital for 30 iterations

| Average Population Capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 968.8612 | 968.3994 | 968.295 | 969.3686 | 967.1837 | 968.7995 |
| 1 | 956.2619 | 958.6435 | 956.7122 | 957.7099 | 954.191 | 957.1305 |
| 2 | 960.7931 | 961.7516 | 960.8068 | 961.8554 | 959.6833 | 961.5186 |
| 3 | 971.8284 | 975.3178 | 977.9526 | 973.9696 | 972.4289 | 973.7622 |
| 4 | 969.3983 | 972.505 | 975.2424 | 971.0828 | 970.2606 | 970.7969 |
| 5 | 948.008 | 947.3443 | 955.138 | 953.0834 | 947.8754 | 946.1694 |
| 6 | 945.1819 | 944.9428 | 953.1215 | 951.0517 | 944.6519 | 943.0664 |
| 7 | 945.1819 | 944.9428 | 953.1215 | 951.0517 | 944.6519 | 943.0664 |
| 8 | 945.1819 | 944.9428 | 953.1215 | 951.0517 | 944.6519 | 943.0664 |
| 9 | 945.1819 | 944.9428 | 953.1215 | 951.0517 | 944.6519 | 943.0664 |
| 10 | 945.1819 | 944.9428 | 953.1215 | 951.0517 | 944.6519 | 943.0664 |
| 11 | 941.717 | 941.4538 | 950.9389 | 948.7514 | 941.2298 | 940.9025 |
| 12 | 941.717 | 941.4538 | 950.9389 | 948.7514 | 941.2298 | 940.9025 |
| 13 | 941.717 | 941.4538 | 950.9389 | 948.7514 | 941.2298 | 940.9025 |
| 14 | 956.7839 | 957.4952 | 965.3226 | 966.0378 | 957.0275 | 958.8741 |
| 15 | 913.2676 | 903.3395 | 915.8716 | 917.0162 | 904.0998 | 902.9386 |
| 16 | 906.6401 | 894.7816 | 908.3201 | 911.6919 | 895.4345 | 895.6901 |
| 17 | 906.6401 | 894.7816 | 908.3201 | 911.6919 | 895.4345 | 895.6901 |
| 18 | 896.7177 | 884.0476 | 895.3456 | 903.0873 | 883.9179 | 881.3596 |
| 19 | 896.7177 | 884.0476 | 895.3456 | 903.0873 | 883.9179 | 881.3596 |
| 20 | 896.7177 | 884.0476 | 895.3456 | 903.0873 | 883.9179 | 881.3596 |
| 21 | 896.7177 | 884.0476 | 895.3456 | 903.0873 | 883.9179 | 881.3596 |
| 22 | 893.6194 | 880.9502 | 893.1015 | 899.3234 | 880.9006 | 877.4144 |
| 23 | 893.6194 | 880.9502 | 893.1015 | 899.3234 | 880.9006 | 877.4144 |
| 24 | 888.3035 | 876.7904 | 887.8347 | 893.9705 | 875.5131 | 870.2213 |
| 25 | 888.3035 | 876.7904 | 887.8347 | 893.9705 | 875.5131 | 870.2213 |
| 26 | 888.3035 | 876.7904 | 887.8347 | 893.9705 | 875.5131 | 870.2213 |
| 27 | 888.3035 | 876.7904 | 887.8347 | 893.9705 | 875.5131 | 870.2213 |
| 28 | 888.3035 | 876.7904 | 887.8347 | 893.9705 | 875.5131 | 870.2213 |
| 29 | 896.1715 | 886.4561 | 895.3539 | 903.5346 | 885.3981 | 879.6664 |
| 30 | 914.5505 | 917.7623 | 920.773 | 928.0514 | 914.9514 | 896.4573 |
| 31 | 887.9838 | 870.9601 | 883.1035 | 897.3498 | 880.067 | 871.8984 |
| 32 | 882.8026 | 865.3994 | 877.7421 | 891.7803 | 874.446 | 866.3404 |
| 33 | 910.7722 | 890.9472 | 906.6715 | 923.4204 | 905.7725 | 897.1971 |
| 34 | 892.7251 | 869.7205 | 883.6271 | 899.9801 | 883.6779 | 876.7611 |
| 35 | 882.9309 | 859.4976 | 873.6383 | 889.9079 | 873.5746 | 867.0879 |
| 36 | 874.8847 | 851.7239 | 866.0125 | 881.6783 | 865.4198 | 857.7719 |

## A.2 Minimum capital in the population for 30 iterations

| Minimum capital in the population | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 828.4624 | 828.8211 | 829.6698 | 828.4624 | 828.4624 | 829.6698 |
| 1 | 785.7972 | 800.7505 | 800.431 | 803.4106 | 798.669 | 806.2278 |
| 2 | 794.3108 | 804.8372 | 801.6686 | 805.2752 | 800.5423 | 807.1644 |
| 3 | 798.3489 | 810.7695 | 806.778 | 805.5333 | 809.722 | 809.2454 |
| 4 | 789.376 | 806.7679 | 804.4542 | 801.2717 | 806.782 | 804.5018 |
| 5 | 745.34 | 779.941 | 777.8438 | 780.9821 | 778.8482 | 778.3929 |
| 6 | 745.34 | 774.8268 | 777.1782 | 776.6375 | 775.639 | 774.6191 |
| 7 | 745.34 | 774.8268 | 777.1782 | 776.6375 | 775.639 | 774.6191 |
| 8 | 745.34 | 774.8268 | 777.1782 | 776.6375 | 775.639 | 774.6191 |
| 9 | 745.34 | 774.8268 | 777.1782 | 776.6375 | 775.639 | 774.6191 |
| 10 | 745.34 | 774.8268 | 777.1782 | 776.6375 | 775.639 | 774.6191 |
| 11 | 744.2594 | 767.0474 | 777.1289 | 774.7112 | 769.5897 | 770.6668 |
| 12 | 744.2594 | 767.0474 | 777.1289 | 774.7112 | 769.5897 | 770.6668 |
| 13 | 744.2594 | 767.0474 | 777.1289 | 774.7112 | 769.5897 | 770.6668 |
| 14 | 776.6787 | 768.0591 | 784.5695 | 778.1692 | 777.0293 | 774.7648 |
| 15 | 720.3849 | 695.1798 | 708.887 | 714.2879 | 703.1929 | 712.4068 |
| 16 | 693.6425 | 686.4256 | 698.7285 | 707.4566 | 692.5724 | 704.0131 |
| 17 | 693.6425 | 686.4256 | 698.7285 | 707.4566 | 692.5724 | 704.0131 |
| 18 | 662.5812 | 673.9556 | 681.1784 | 700.5001 | 684.3118 | 688.9587 |
| 19 | 662.5812 | 673.9556 | 681.1784 | 700.5001 | 684.3118 | 688.9587 |
| 20 | 662.5812 | 673.9556 | 681.1784 | 700.5001 | 684.3118 | 688.9587 |
| 21 | 662.5812 | 673.9556 | 681.1784 | 700.5001 | 684.3118 | 688.9587 |
| 22 | 651.5903 | 672.1364 | 679.6758 | 696.2825 | 680.4192 | 684.0265 |
| 23 | 651.5903 | 672.1364 | 679.6758 | 696.2825 | 680.4192 | 684.0265 |
| 24 | 610.306 | 662.0211 | 670.95 | 684.0025 | 670.2493 | 668.4572 |
| 25 | 610.306 | 662.0211 | 670.95 | 684.0025 | 670.2493 | 668.4572 |
| 26 | 610.306 | 662.0211 | 670.95 | 684.0025 | 670.2493 | 668.4572 |
| 27 | 610.306 | 662.0211 | 670.95 | 684.0025 | 670.2493 | 668.4572 |
| 28 | 610.306 | 662.0211 | 670.95 | 684.0025 | 670.2493 | 668.4572 |
| 29 | 637.6975 | 669.1337 | 677.628 | 690.4986 | 677.6593 | 673.7403 |
| 30 | 683.561 | 680.4848 | 693.2002 | 700.7906 | 692.728 | 680.3704 |
| 31 | 630.5586 | 634.7072 | 654.6761 | 664.3875 | 660.5623 | 646.1231 |
| 32 | 623.2252 | 629.7868 | 650.709 | 661.4544 | 655.9847 | 642.1227 |
| 33 | 666.7577 | 644.1553 | 668.4219 | 681.0973 | 673.4719 | 655.6775 |
| 34 | 641.0624 | 626.0726 | 651.8085 | 661.2306 | 654.9933 | 637.9754 |
| 35 | 627.1175 | 618.2932 | 642.9365 | 654.0531 | 648.4556 | 629.908 |
| 36 | 613.3593 | 613.2361 | 636.1457 | 646.793 | 642.9971 | 621.266 |

## A.3 Maximum capital in the population for 30 iterations

| Maximum capital in the population | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 1076.195 | 1086.241 | 1086.749 | 1093.125 | 1089.382 | 1086.749 |
| 1 | 1063.779 | 1081.21 | 1083.56 | 1086.749 | 1085.686 | 1083.052 |
| 2 | 1067.63 | 1084.951 | 1090.477 | 1098.783 | 1097.532 | 1091.982 |
| 3 | 1120.746 | 1125.954 | 1133.536 | 1135.711 | 1135.184 | 1132.193 |
| 4 | 1114.28 | 1124.055 | 1130.477 | 1132.844 | 1133.313 | 1128.933 |
| 5 | 1058.647 | 1110.478 | 1121.004 | 1114.561 | 1112.103 | 1103.896 |
| 6 | 1038.643 | 1108.965 | 1119.231 | 1114.281 | 1109.152 | 1102.491 |
| 7 | 1038.643 | 1108.965 | 1119.231 | 1114.281 | 1109.152 | 1102.491 |
| 8 | 1038.643 | 1108.965 | 1119.231 | 1114.281 | 1109.152 | 1102.491 |
| 9 | 1038.643 | 1108.965 | 1119.231 | 1114.281 | 1109.152 | 1102.491 |
| 10 | 1038.643 | 1108.965 | 1119.231 | 1114.281 | 1109.152 | 1102.491 |
| 11 | 1034.673 | 1108.965 | 1118.722 | 1114.281 | 1108.686 | 1101.429 |
| 12 | 1034.673 | 1108.965 | 1118.722 | 1114.281 | 1108.686 | 1101.429 |
| 13 | 1034.673 | 1108.965 | 1118.722 | 1114.281 | 1108.686 | 1101.429 |
| 14 | 1086.732 | 1162.968 | 1164.857 | 1159.135 | 1136.576 | 1141.965 |
| 15 | 1034.682 | 1120.703 | 1138.306 | 1139.039 | 1119.91 | 1113.75 |
| 16 | 1027.225 | 1111.893 | 1135.149 | 1137.535 | 1112.827 | 1109.417 |
| 17 | 1027.225 | 1111.893 | 1135.149 | 1137.535 | 1112.827 | 1109.417 |
| 18 | 1006.435 | 1103.336 | 1126.854 | 1134.294 | 1103.645 | 1098.388 |
| 19 | 1006.435 | 1103.336 | 1126.854 | 1134.294 | 1103.645 | 1098.388 |
| 20 | 1006.435 | 1103.336 | 1126.854 | 1134.294 | 1103.645 | 1098.388 |
| 21 | 1006.435 | 1103.336 | 1126.854 | 1134.294 | 1103.645 | 1098.388 |
| 22 | 1006.435 | 1099.867 | 1125.494 | 1129.841 | 1098.111 | 1092.319 |
| 23 | 1006.435 | 1099.867 | 1125.494 | 1129.841 | 1098.111 | 1092.319 |
| 24 | 1006.435 | 1099.867 | 1120.385 | 1128.949 | 1096.584 | 1089.376 |
| 25 | 1006.435 | 1099.867 | 1120.385 | 1128.949 | 1096.584 | 1089.376 |
| 26 | 1006.435 | 1099.867 | 1120.385 | 1128.949 | 1096.584 | 1089.376 |
| 27 | 1006.435 | 1099.867 | 1120.385 | 1128.949 | 1096.584 | 1089.376 |
| 28 | 1006.435 | 1099.867 | 1120.385 | 1128.949 | 1096.584 | 1089.376 |
| 29 | 1006.435 | 1117.356 | 1133.344 | 1145.224 | 1115.759 | 1106.669 |
| 30 | 1018.777 | 1179.967 | 1184.184 | 1198.046 | 1165.857 | 1147.834 |
| 31 | 1006.435 | 1134.968 | 1153.872 | 1171.981 | 1131.582 | 1126.605 |
| 32 | 1001.708 | 1127.758 | 1147.305 | 1162.662 | 1124.988 | 1120.43 |
| 33 | 1066.272 | 1183.7 | 1192.396 | 1217.994 | 1182.517 | 1170.718 |
| 34 | 1025.18 | 1154.107 | 1168.507 | 1188.371 | 1167.134 | 1146.723 |
| 35 | 1004.999 | 1141.176 | 1159.316 | 1176.474 | 1156.458 | 1134.055 |
| 36 | 1000 | 1136.253 | 1152.328 | 1165.974 | 1145.375 | 1125.881 |

## A.4 Count of investors with overall negative return

| Number of investors with negative return from initial capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 42.63333 | 42.7 | 43.16667 | 42.53333 | 45 | 42.83333 |
| 1 | 48.1 | 52.03333 | 55.5 | 54.4 | 58.56667 | 55.16667 |
| 2 | 47.56667 | 51.6 | 54.76667 | 53.6 | 57.36667 | 54.26667 |
| 3 | 40.1 | 47.46667 | 49.13333 | 49.13333 | 53 | 50.4 |
| 4 | 41.63333 | 55.2 | 54.73333 | 57 | 58.36667 | 57.53333 |
| 5 | 51.43333 | 70.7 | 67.63333 | 67.16667 | 72.16667 | 72.33333 |
| 6 | 51.73333 | 71.83333 | 69.06667 | 68.66667 | 73.96667 | 74.26667 |
| 7 | 51.73333 | 71.83333 | 69.06667 | 68.66667 | 73.96667 | 74.26667 |
| 8 | 51.73333 | 71.83333 | 69.06667 | 68.66667 | 73.96667 | 74.26667 |
| 9 | 51.73333 | 71.83333 | 69.06667 | 68.66667 | 73.96667 | 74.26667 |
| 10 | 51.73333 | 71.83333 | 69.06667 | 68.66667 | 73.96667 | 74.26667 |
| 11 | 52.5 | 73.5 | 69.93333 | 69.73333 | 75.66667 | 74.73333 |
| 12 | 52.5 | 73.5 | 69.93333 | 69.73333 | 75.66667 | 74.73333 |
| 13 | 52.5 | 73.5 | 69.93333 | 69.73333 | 75.66667 | 74.73333 |
| 14 | 49.23333 | 65.73333 | 63.43333 | 61.53333 | 68.03333 | 64.76667 |
| 15 | 60.76667 | 82.56667 | 79.16667 | 77.76667 | 83.73333 | 82.96667 |
| 16 | 61.06667 | 85.1 | 81.7 | 79.56667 | 86.06667 | 85.43333 |
| 17 | 61.06667 | 85.1 | 81.7 | 79.56667 | 86.06667 | 85.43333 |
| 18 | 61.53333 | 87.7 | 85.2 | 82.36667 | 88.5 | 88.7 |
| 19 | 61.53333 | 87.7 | 85.2 | 82.36667 | 88.5 | 88.7 |
| 20 | 61.53333 | 87.7 | 85.2 | 82.36667 | 88.5 | 88.7 |
| 21 | 61.53333 | 87.7 | 85.2 | 82.36667 | 88.5 | 88.7 |
| 22 | 61.53333 | 88.3 | 85.6 | 83.26667 | 88.9 | 89.46667 |
| 23 | 61.53333 | 88.3 | 85.6 | 83.26667 | 88.9 | 89.46667 |
| 24 | 61.53333 | 88.86667 | 86.43333 | 84.26667 | 89.43333 | 90.2 |
| 25 | 61.53333 | 88.86667 | 86.43333 | 84.26667 | 89.43333 | 90.2 |
| 26 | 61.53333 | 88.86667 | 86.43333 | 84.26667 | 89.43333 | 90.2 |
| 27 | 61.53333 | 88.86667 | 86.43333 | 84.26667 | 89.43333 | 90.2 |
| 28 | 61.53333 | 88.86667 | 86.43333 | 84.26667 | 89.43333 | 90.2 |
| 29 | 61.53333 | 86.76667 | 84.53333 | 81.33333 | 87.43333 | 88.23333 |
| 30 | 60.1 | 77.4 | 76.1 | 73.6 | 78.43333 | 83.16667 |
| 31 | 61.53333 | 88.2 | 85.5 | 81.53333 | 85.5 | 87.13333 |
| 32 | 67.76667 | 89.26667 | 87.2 | 82.9 | 86.36667 | 88.43333 |
| 33 | 62.46667 | 83.1 | 79.23333 | 73.86667 | 78.33333 | 80.16667 |
| 34 | 63.06667 | 87.5 | 84.7 | 80.13333 | 83.23333 | 84.83333 |
| 35 | 67.76667 | 89.26667 | 87 | 82.76667 | 85.13333 | 86.4 |
| 36 | 68.26667 | 90.46667 | 88.3 | 84.76667 | 86.96667 | 87.96667 |

## A.5 Count of investors with no earnings or losses from initial capital

| Number of investors with no earnings or losses from initial capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 51.36667 | 52 | 51.33333 | 50.73333 | 48.73333 | 51.3 |
| 1 | 47.16667 | 43.06667 | 39.63333 | 39.3 | 35.63333 | 39.56667 |
| 2 | 47.16667 | 39.73333 | 35.16667 | 35.03333 | 29.73333 | 34.46667 |
| 3 | 47.16667 | 33.7 | 27.9 | 29.86667 | 24.96667 | 29.16667 |
| 4 | 47.16667 | 26.06667 | 22.43333 | 22.33333 | 19.96667 | 22.23333 |
| 5 | 44.5 | 14.53333 | 13.3 | 15.1 | 11.26667 | 12 |
| 6 | 44.5 | 13.8 | 12.23333 | 14.1 | 10 | 10.83333 |
| 7 | 44.5 | 13.8 | 12.23333 | 14.1 | 10 | 10.83333 |
| 8 | 44.5 | 13.8 | 12.23333 | 14.1 | 10 | 10.83333 |
| 9 | 44.5 | 13.8 | 12.23333 | 14.1 | 10 | 10.83333 |
| 10 | 44.5 | 13.8 | 12.23333 | 14.1 | 10 | 10.83333 |
| 11 | 44.5 | 12.56667 | 11.83333 | 13.3 | 9.2 | 10.56667 |
| 12 | 44.5 | 12.56667 | 11.83333 | 13.3 | 9.2 | 10.56667 |
| 13 | 44.5 | 12.56667 | 11.83333 | 13.3 | 9.2 | 10.56667 |
| 14 | 44.5 | 9.966667 | 9.166667 | 10.23333 | 6.866667 | 8.666667 |
| 15 | 37.96667 | 5.2 | 4.8 | 5.566667 | 3.6 | 4.033333 |
| 16 | 37.96667 | 3.966667 | 3.866667 | 4.533333 | 2.733333 | 2.9 |
| 17 | 37.96667 | 3.966667 | 3.866667 | 4.533333 | 2.733333 | 2.9 |
| 18 | 37.96667 | 2.9 | 3.066667 | 3.233333 | 1.966667 | 1.933333 |
| 19 | 37.96667 | 2.9 | 3.066667 | 3.233333 | 1.966667 | 1.933333 |
| 20 | 37.96667 | 2.9 | 3.066667 | 3.233333 | 1.966667 | 1.933333 |
| 21 | 37.96667 | 2.9 | 3.066667 | 3.233333 | 1.966667 | 1.933333 |
| 22 | 37.96667 | 2.666667 | 2.933333 | 3.033333 | 1.933333 | 1.866667 |
| 23 | 37.96667 | 2.666667 | 2.933333 | 3.033333 | 1.933333 | 1.866667 |
| 24 | 37.96667 | 2.533333 | 2.733333 | 2.833333 | 1.933333 | 1.7 |
| 25 | 37.96667 | 2.533333 | 2.733333 | 2.833333 | 1.933333 | 1.7 |
| 26 | 37.96667 | 2.533333 | 2.733333 | 2.833333 | 1.933333 | 1.7 |
| 27 | 37.96667 | 2.533333 | 2.733333 | 2.833333 | 1.933333 | 1.7 |
| 28 | 37.96667 | 2.533333 | 2.733333 | 2.833333 | 1.933333 | 1.7 |
| 29 | 37.96667 | 1.966667 | 2.4 | 2.266667 | 1.633333 | 1.366667 |
| 30 | 37.96667 | 1.333333 | 1.466667 | 1.366667 | 0.666667 | 0.9 |
| 31 | 37.96667 | 0.6 | 0.6 | 0.8 | 0.333333 | 0.466667 |
| 32 | 31.73333 | 0.3 | 0.3 | 0.566667 | 0.133333 | 0.133333 |
| 33 | 31.73333 | 0.233333 | 0.133333 | 0.166667 | 0.033333 | 0.066667 |
| 34 | 31.73333 | 0.066667 | 0.066667 | 0.066667 | 0.033333 | 0 |
| 35 | 31.73333 | 0.066667 | 0.033333 | 0 | 0 | 0 |
| 36 | 31.73333 | 0.066667 | 0 | 0 | 0 | 0 |

## A.6 Count of investors with overall positive return

| Number of investors with positive return from initial capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 6 | 5.3 | 5.5 | 6.733333 | 6.266667 | 5.866667 |
| 1 | 4.733333 | 4.9 | 4.866667 | 6.3 | 5.8 | 5.266667 |
| 2 | 5.266667 | 8.666667 | 10.06667 | 11.36667 | 12.9 | 11.26667 |
| 3 | 12.73333 | 18.83333 | 22.96667 | 21 | 22.03333 | 20.43333 |
| 4 | 11.2 | 18.73333 | 22.83333 | 20.66667 | 21.66667 | 20.23333 |
| 5 | 4.066667 | 14.76667 | 19.06667 | 17.73333 | 16.56667 | 15.66667 |
| 6 | 3.766667 | 14.36667 | 18.7 | 17.23333 | 16.03333 | 14.9 |
| 7 | 3.766667 | 14.36667 | 18.7 | 17.23333 | 16.03333 | 14.9 |
| 8 | 3.766667 | 14.36667 | 18.7 | 17.23333 | 16.03333 | 14.9 |
| 9 | 3.766667 | 14.36667 | 18.7 | 17.23333 | 16.03333 | 14.9 |
| 10 | 3.766667 | 14.36667 | 18.7 | 17.23333 | 16.03333 | 14.9 |
| 11 | 3 | 13.93333 | 18.23333 | 16.96667 | 15.13333 | 14.7 |
| 12 | 3 | 13.93333 | 18.23333 | 16.96667 | 15.13333 | 14.7 |
| 13 | 3 | 13.93333 | 18.23333 | 16.96667 | 15.13333 | 14.7 |
| 14 | 6.266667 | 24.3 | 27.4 | 28.23333 | 25.1 | 26.56667 |
| 15 | 1.266667 | 12.23333 | 16.03333 | 16.66667 | 12.66667 | 13 |
| 16 | 0.966667 | 10.93333 | 14.43333 | 15.9 | 11.2 | 11.66667 |
| 17 | 0.966667 | 10.93333 | 14.43333 | 15.9 | 11.2 | 11.66667 |
| 18 | 0.5 | 9.4 | 11.73333 | 14.4 | 9.533333 | 9.366667 |
| 19 | 0.5 | 9.4 | 11.73333 | 14.4 | 9.533333 | 9.366667 |
| 20 | 0.5 | 9.4 | 11.73333 | 14.4 | 9.533333 | 9.366667 |
| 21 | 0.5 | 9.4 | 11.73333 | 14.4 | 9.533333 | 9.366667 |
| 22 | 0.5 | 9.033333 | 11.46667 | 13.7 | 9.166667 | 8.666667 |
| 23 | 0.5 | 9.033333 | 11.46667 | 13.7 | 9.166667 | 8.666667 |
| 24 | 0.5 | 8.6 | 10.83333 | 12.9 | 8.633333 | 8.1 |
| 25 | 0.5 | 8.6 | 10.83333 | 12.9 | 8.633333 | 8.1 |
| 26 | 0.5 | 8.6 | 10.83333 | 12.9 | 8.633333 | 8.1 |
| 27 | 0.5 | 8.6 | 10.83333 | 12.9 | 8.633333 | 8.1 |
| 28 | 0.5 | 8.6 | 10.83333 | 12.9 | 8.633333 | 8.1 |
| 29 | 0.5 | 11.26667 | 13.06667 | 16.4 | 10.93333 | 10.4 |
| 30 | 1.933333 | 21.26667 | 22.43333 | 25.03333 | 20.9 | 15.93333 |
| 31 | 0.5 | 11.2 | 13.9 | 17.66667 | 14.16667 | 12.4 |
| 32 | 0.5 | 10.43333 | 12.5 | 16.53333 | 13.5 | 11.43333 |
| 33 | 5.8 | 16.66667 | 20.63333 | 25.96667 | 21.63333 | 19.76667 |
| 34 | 5.2 | 12.43333 | 15.23333 | 19.8 | 16.73333 | 15.16667 |
| 35 | 0.5 | 10.66667 | 12.96667 | 17.23333 | 14.86667 | 13.6 |
| 36 | 0 | 9.466667 | 11.7 | 15.23333 | 13.03333 | 12.03333 |

# Appendix B

## Average data obtained from the GA for the period 2008-2011

### B.1 Average population capital for 30 iterations

| Average Population Capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 1106.619 | 1107.645 | 1108.418 | 1102.031 | 1107.645 | 1104.821 |
| 1 | 1081.541 | 1076.979 | 1076.626 | 1075.914 | 1079.846 | 1081.553 |
| 2 | 1099.972 | 1095.632 | 1092.913 | 1092.4 | 1095.669 | 1096.903 |
| 3 | 1116.969 | 1114.184 | 1108.06 | 1107.352 | 1109.16 | 1112.541 |
| 4 | 1028.158 | 1013.512 | 1022.088 | 1031.145 | 1020.103 | 1019.676 |
| 5 | 997.5056 | 993.848 | 1000.522 | 1007.565 | 990.0682 | 999.6026 |
| 6 | 966.8465 | 976.7917 | 978.3907 | 977.7774 | 964.1162 | 972.9707 |
| 7 | 959.0343 | 972.7972 | 971.0991 | 969.9599 | 954.0031 | 966.5093 |
| 8 | 959.0343 | 972.7972 | 971.0991 | 969.9599 | 954.0031 | 966.5093 |
| 9 | 959.0343 | 972.7972 | 971.0991 | 969.9599 | 954.0031 | 966.5093 |
| 10 | 950.4338 | 962.3992 | 961.9669 | 958.1879 | 939.5529 | 953.4841 |
| 11 | 950.4338 | 962.3992 | 961.9669 | 958.1879 | 939.5529 | 953.4841 |
| 12 | 950.4338 | 962.3992 | 961.9669 | 958.1879 | 939.5529 | 953.4841 |
| 13 | 950.4338 | 962.3992 | 961.9669 | 958.1879 | 939.5529 | 953.4841 |
| 14 | 951.3264 | 964.2629 | 963.4945 | 960.0728 | 940.2827 | 955.1072 |
| 15 | 950.4144 | 960.6169 | 961.4182 | 957.8429 | 939.0143 | 953.1242 |
| 16 | 952.1874 | 962.468 | 963.559 | 960.2912 | 940.8268 | 955.906 |
| 17 | 952.1874 | 962.468 | 963.559 | 960.2912 | 940.8268 | 955.906 |
| 18 | 948.3915 | 956.3899 | 956.8224 | 956.2813 | 936.2739 | 952.6992 |
| 19 | 948.3915 | 956.3899 | 956.8224 | 956.2813 | 936.2739 | 952.6992 |
| 20 | 948.3915 | 956.3899 | 956.8224 | 956.2813 | 936.2739 | 952.6992 |
| 21 | 933.8013 | 941.4078 | 942.1702 | 941.6797 | 923.0731 | 939.0662 |
| 22 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 23 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 24 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 25 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 26 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 27 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 28 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 29 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 30 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 31 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 32 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 33 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 34 | 930.3423 | 938.4164 | 937.5637 | 934.5843 | 916.5671 | 934.4587 |
| 35 | 918.3606 | 924.6647 | 923.3314 | 920.6061 | 900.0229 | 923.0634 |
| 36 | 918.3606 | 924.6647 | 923.3314 | 920.6061 | 900.0229 | 923.0634 |

## B.2 Minimum capital in the population for 30 iterations

| Minimum capital in the population | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| 1 | 992.6172 | 962.1923 | 962.1923 | 962.1923 | 962.1923 | 962.1923 |
| 2 | 1000 | 962.1923 | 962.1923 | 962.1923 | 962.1923 | 963.1185 |
| 3 | 1000 | 963.8527 | 963.8527 | 966.3433 | 963.0225 | 970.0943 |
| 4 | 909.5884 | 838.2211 | 836.7796 | 841.8249 | 837.5837 | 844.9006 |
| 5 | 909.5884 | 776.9737 | 780.9426 | 785.3603 | 779.6923 | 792.8168 |
| 6 | 803.8929 | 723.0486 | 729.2751 | 731.4851 | 714.4392 | 739.4772 |
| 7 | 754.6298 | 708.6455 | 716.8283 | 718.1645 | 700.545 | 723.0241 |
| 8 | 754.6298 | 708.6455 | 716.8283 | 718.1645 | 700.545 | 723.0241 |
| 9 | 754.6298 | 708.6455 | 716.8283 | 718.1645 | 700.545 | 723.0241 |
| 10 | 632.5803 | 675.283 | 680.0708 | 675.0457 | 664.1218 | 684.5328 |
| 11 | 632.5803 | 675.283 | 680.0708 | 675.0457 | 664.1218 | 684.5328 |
| 12 | 632.5803 | 675.283 | 680.0708 | 675.0457 | 664.1218 | 684.5328 |
| 13 | 632.5803 | 675.283 | 680.0708 | 675.0457 | 664.1218 | 684.5328 |
| 14 | 645.2463 | 676.6055 | 680.9134 | 676.5258 | 664.1218 | 685.2022 |
| 15 | 632.3048 | 673.9723 | 677.5762 | 675.0348 | 663.6047 | 682.8755 |
| 16 | 634.1133 | 674.4772 | 678.4955 | 677.5088 | 664.5872 | 684.5856 |
| 17 | 634.1133 | 674.4772 | 678.4955 | 677.5088 | 664.5872 | 684.5856 |
| 18 | 623.318 | 668.1618 | 672.2033 | 672.2975 | 660.5502 | 682.059 |
| 19 | 623.318 | 668.1618 | 672.2033 | 672.2975 | 660.5502 | 682.059 |
| 20 | 623.318 | 668.1618 | 672.2033 | 672.2975 | 660.5502 | 682.059 |
| 21 | 594.9069 | 655.4823 | 660.2149 | 658.9427 | 646.152 | 669.6373 |
| 22 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 23 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 24 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 25 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 26 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 27 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 28 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 29 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 30 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 31 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 32 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 33 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 34 | 544.1569 | 653.6097 | 652.1706 | 653.9286 | 635.9231 | 667.5762 |
| 35 | 529.8054 | 636.8625 | 634.9505 | 639.7702 | 625.7421 | 654.415 |
| 36 | 529.8054 | 636.8625 | 634.9505 | 639.7702 | 625.7421 | 654.415 |

## B.3 Maximum capital in the population for 30 iterations

| Maximum capital in the population | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 1270.088 | 1270.088 | 1270.088 | 1270.088 | 1270.088 | 1270.088 |
| 1 | 1222.068 | 1270.088 | 1266.257 | 1270.088 | 1265.771 | 1267.372 |
| 2 | 1257.36 | 1300.878 | 1296.861 | 1300.803 | 1296.437 | 1301.601 |
| 3 | 1289.906 | 1331.092 | 1325.905 | 1326.582 | 1314.928 | 1324.05 |
| 4 | 1119.847 | 1304.431 | 1297.865 | 1304.711 | 1287.067 | 1299.811 |
| 5 | 1057.637 | 1303.3 | 1290.232 | 1294.519 | 1277.055 | 1292.601 |
| 6 | 1057.637 | 1303.25 | 1275.393 | 1281.176 | 1274.132 | 1282.188 |
| 7 | 1057.637 | 1300.433 | 1269.055 | 1280.113 | 1267.743 | 1278.152 |
| 8 | 1057.637 | 1300.433 | 1269.055 | 1280.113 | 1267.743 | 1278.152 |
| 9 | 1057.637 | 1300.433 | 1269.055 | 1280.113 | 1267.743 | 1278.152 |
| 10 | 1057.637 | 1300.433 | 1269.055 | 1280.035 | 1267.575 | 1266.908 |
| 11 | 1057.637 | 1300.433 | 1269.055 | 1280.035 | 1267.575 | 1266.908 |
| 12 | 1057.637 | 1300.433 | 1269.055 | 1280.035 | 1267.575 | 1266.908 |
| 13 | 1057.637 | 1300.433 | 1269.055 | 1280.035 | 1267.575 | 1266.908 |
| 14 | 1057.637 | 1303.505 | 1273.697 | 1283.709 | 1269.36 | 1271.596 |
| 15 | 1057.637 | 1299.863 | 1269.746 | 1282.432 | 1269.319 | 1269.811 |
| 16 | 1057.637 | 1302.38 | 1275.654 | 1290.45 | 1272.944 | 1275.289 |
| 17 | 1057.637 | 1302.38 | 1275.654 | 1290.45 | 1272.944 | 1275.289 |
| 18 | 1057.637 | 1298.822 | 1269.503 | 1287.462 | 1270.889 | 1270.994 |
| 19 | 1057.637 | 1298.822 | 1269.503 | 1287.462 | 1270.889 | 1270.994 |
| 20 | 1057.637 | 1298.822 | 1269.503 | 1287.462 | 1270.889 | 1270.994 |
| 21 | 1057.637 | 1282.731 | 1258.278 | 1271.765 | 1261.844 | 1261.796 |
| 22 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 23 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 24 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 25 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 26 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 27 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 28 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 29 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 30 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 31 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 32 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 33 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 34 | 1057.637 | 1280.438 | 1258.278 | 1268.427 | 1254.975 | 1261.796 |
| 35 | 1057.637 | 1270.803 | 1251.895 | 1257.675 | 1243.742 | 1255.627 |
| 36 | 1057.637 | 1270.803 | 1251.895 | 1257.675 | 1243.742 | 1255.627 |

## B.4 Count of investors with overall negative return

| Number of investors with negative return from initial capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 2.866667 | 31.76667 | 33.9 | 31.76667 | 31.63333 | 26.33333 |
| 2 | 0 | 30.33333 | 32.46667 | 30.73333 | 30.6 | 25.53333 |
| 3 | 0 | 16.4 | 22.46667 | 21.73333 | 21.8 | 17.1 |
| 4 | 20 | 48.7 | 46.76667 | 43.7 | 46.26667 | 46 |
| 5 | 24.7 | 53.83333 | 52.13333 | 50.5 | 55.33333 | 52.03333 |
| 6 | 43.56667 | 58.43333 | 58.8 | 57.96667 | 61.93333 | 59.2 |
| 7 | 43.56667 | 59.63333 | 61.03333 | 60.1 | 64.76667 | 60.53333 |
| 8 | 43.56667 | 59.63333 | 61.03333 | 60.1 | 64.76667 | 60.53333 |
| 9 | 43.56667 | 59.63333 | 61.03333 | 60.1 | 64.76667 | 60.53333 |
| 10 | 43.56667 | 62 | 63.13333 | 62.53333 | 66.7 | 62.53333 |
| 11 | 43.56667 | 62 | 63.13333 | 62.53333 | 66.7 | 62.53333 |
| 12 | 43.56667 | 62 | 63.13333 | 62.53333 | 66.7 | 62.53333 |
| 13 | 43.56667 | 62 | 63.13333 | 62.53333 | 66.7 | 62.53333 |
| 14 | 43.56667 | 61.3 | 62.66667 | 61.96667 | 66.6 | 62.2 |
| 15 | 43.56667 | 62.63333 | 63.4 | 62.6 | 67 | 62.43333 |
| 16 | 43.56667 | 61.9 | 62.7 | 61.76667 | 66.56667 | 61.86667 |
| 17 | 43.56667 | 61.9 | 62.7 | 61.76667 | 66.56667 | 61.86667 |
| 18 | 43.56667 | 63.73333 | 64.53333 | 63 | 67.76667 | 63.13333 |
| 19 | 43.56667 | 63.73333 | 64.53333 | 63 | 67.76667 | 63.13333 |
| 20 | 43.56667 | 63.73333 | 64.53333 | 63 | 67.76667 | 63.13333 |
| 21 | 46.36667 | 67.16667 | 68 | 66.9 | 70.9 | 66.86667 |
| 22 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 23 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 24 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 25 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 26 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 27 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 28 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 29 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 30 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 31 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 32 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 33 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 34 | 46.36667 | 67.43333 | 68.93333 | 68.5 | 71.9 | 68.16667 |
| 35 | 50.23333 | 70.93333 | 72.06667 | 71.5 | 74.43333 | 71.2 |
| 36 | 50.23333 | 70.93333 | 72.06667 | 71.5 | 74.43333 | 71.2 |

## B.5 Count of investors with no earnings or losses from initial capital

| Number of investors with no earnings or losses from initial capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 44.33333 | 44.73333 | 43.4 | 46.26667 | 43.96667 | 44.93333 |
| 1 | 44.33333 | 15.1 | 11.73333 | 16.46667 | 14.06667 | 19.86667 |
| 2 | 44.33333 | 7.933333 | 6.2 | 8.3 | 8.166667 | 11.73333 |
| 3 | 44.33333 | 3.766667 | 3.3 | 4.166667 | 3.733333 | 5.8 |
| 4 | 44.33333 | 1.666667 | 1.8 | 2.666667 | 1.8 | 2.533333 |
| 5 | 44.33333 | 1.5 | 1.533333 | 2.033333 | 1.233333 | 1.866667 |
| 6 | 44.33333 | 1.233333 | 1.2 | 1.766667 | 1 | 1.566667 |
| 7 | 44.33333 | 1.1 | 1.1 | 1.6 | 0.766667 | 1.533333 |
| 8 | 44.33333 | 1.1 | 1.1 | 1.6 | 0.766667 | 1.533333 |
| 9 | 44.33333 | 1.1 | 1.1 | 1.6 | 0.766667 | 1.533333 |
| 10 | 44.33333 | 1 | 0.966667 | 1.533333 | 0.766667 | 1.5 |
| 11 | 44.33333 | 1 | 0.966667 | 1.533333 | 0.766667 | 1.5 |
| 12 | 44.33333 | 1 | 0.966667 | 1.533333 | 0.766667 | 1.5 |
| 13 | 44.33333 | 1 | 0.966667 | 1.533333 | 0.766667 | 1.5 |
| 14 | 44.33333 | 0.9 | 0.9 | 1.533333 | 0.766667 | 1.266667 |
| 15 | 44.33333 | 0.766667 | 0.866667 | 1.433333 | 0.666667 | 1.233333 |
| 16 | 44.33333 | 0.733333 | 0.733333 | 1.3 | 0.633333 | 1.2 |
| 17 | 44.33333 | 0.733333 | 0.733333 | 1.3 | 0.633333 | 1.2 |
| 18 | 44.33333 | 0.633333 | 0.633333 | 1.2 | 0.566667 | 0.966667 |
| 19 | 44.33333 | 0.633333 | 0.633333 | 1.2 | 0.566667 | 0.966667 |
| 20 | 44.33333 | 0.633333 | 0.633333 | 1.2 | 0.566667 | 0.966667 |
| 21 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.366667 | 0.6 |
| 22 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 23 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 24 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 25 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 26 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 27 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 28 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 29 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 30 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 31 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 32 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 33 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 34 | 44.33333 | 0.466667 | 0.366667 | 0.8 | 0.333333 | 0.533333 |
| 35 | 43.86667 | 0.433333 | 0.266667 | 0.733333 | 0.333333 | 0.4 |
| 36 | 43.86667 | 0.433333 | 0.266667 | 0.733333 | 0.333333 | 0.4 |

## B.6 Count of investors with overall positive return

| Number of investors with positive return from initial capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 55.66667 | 55.26667 | 56.6 | 53.73333 | 56.03333 | 55.06667 |
| 1 | 52.8 | 53.13333 | 54.36667 | 51.76667 | 54.3 | 53.8 |
| 2 | 55.66667 | 61.73333 | 61.33333 | 60.96667 | 61.23333 | 62.73333 |
| 3 | 55.66667 | 79.83333 | 74.23333 | 74.1 | 74.46667 | 77.1 |
| 4 | 35.66667 | 49.63333 | 51.43333 | 53.63333 | 51.93333 | 51.46667 |
| 5 | 30.96667 | 44.66667 | 46.33333 | 47.46667 | 43.43333 | 46.1 |
| 6 | 12.1 | 40.33333 | 40 | 40.26667 | 37.06667 | 39.23333 |
| 7 | 12.1 | 39.26667 | 37.86667 | 38.3 | 34.46667 | 37.93333 |
| 8 | 12.1 | 39.26667 | 37.86667 | 38.3 | 34.46667 | 37.93333 |
| 9 | 12.1 | 39.26667 | 37.86667 | 38.3 | 34.46667 | 37.93333 |
| 10 | 12.1 | 37 | 35.9 | 35.93333 | 32.53333 | 35.96667 |
| 11 | 12.1 | 37 | 35.9 | 35.93333 | 32.53333 | 35.96667 |
| 12 | 12.1 | 37 | 35.9 | 35.93333 | 32.53333 | 35.96667 |
| 13 | 12.1 | 37 | 35.9 | 35.93333 | 32.53333 | 35.96667 |
| 14 | 12.1 | 37.8 | 36.43333 | 36.5 | 32.63333 | 36.53333 |
| 15 | 12.1 | 36.6 | 35.73333 | 35.96667 | 32.33333 | 36.33333 |
| 16 | 12.1 | 37.36667 | 36.56667 | 36.93333 | 32.8 | 36.93333 |
| 17 | 12.1 | 37.36667 | 36.56667 | 36.93333 | 32.8 | 36.93333 |
| 18 | 12.1 | 35.63333 | 34.83333 | 35.8 | 31.66667 | 35.9 |
| 19 | 12.1 | 35.63333 | 34.83333 | 35.8 | 31.66667 | 35.9 |
| 20 | 12.1 | 35.63333 | 34.83333 | 35.8 | 31.66667 | 35.9 |
| 21 | 9.3 | 32.36667 | 31.63333 | 32.3 | 28.73333 | 32.53333 |
| 22 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 23 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 24 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 25 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 26 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 27 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 28 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 29 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 30 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 31 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 32 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 33 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 34 | 9.3 | 32.1 | 30.7 | 30.7 | 27.76667 | 31.3 |
| 35 | 5.9 | 28.63333 | 27.66667 | 27.76667 | 25.23333 | 28.4 |
| 36 | 5.9 | 28.63333 | 27.66667 | 27.76667 | 25.23333 | 28.4 |

# Appendix C

## Average data obtained from the GA for the period 2014-2017

### C.1 Average population capital for 30 iterations

| Average Population Capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 997.1079 | 997.4735 | 997.4416 | 997.5051 | 997.4094 | 997.6399 |
| 1 | 998.0293 | 998.2461 | 998.0253 | 998.2841 | 998.1104 | 998.2224 |
| 2 | 1004.799 | 1006.859 | 1005.782 | 1007.444 | 1005.161 | 1005.805 |
| 3 | 1004.799 | 1006.859 | 1005.782 | 1007.444 | 1005.161 | 1005.805 |
| 4 | 1004.799 | 1006.859 | 1005.782 | 1007.444 | 1005.161 | 1005.805 |
| 5 | 1004.799 | 1006.859 | 1005.782 | 1007.444 | 1005.161 | 1005.805 |
| 6 | 997.5866 | 998.7981 | 998.5911 | 999.7698 | 998.9355 | 998.1782 |
| 7 | 996.1364 | 997.6611 | 997.4495 | 998.5331 | 997.9205 | 996.7927 |
| 8 | 995.0093 | 996.731 | 996.4865 | 997.2087 | 996.6491 | 995.8215 |
| 9 | 986.0627 | 989.5617 | 987.7909 | 986.5389 | 986.7597 | 980.415 |
| 10 | 986.0627 | 989.5617 | 987.7909 | 986.5389 | 986.7597 | 980.415 |
| 11 | 986.0627 | 989.5617 | 987.7909 | 986.5389 | 986.7597 | 980.415 |
| 12 | 985.0194 | 987.9939 | 986.7631 | 984.6989 | 985.5415 | 979.6857 |
| 13 | 985.0194 | 987.9939 | 986.7631 | 984.6989 | 985.5415 | 979.6857 |
| 14 | 985.0194 | 987.9939 | 986.7631 | 984.6989 | 985.5415 | 979.6857 |
| 15 | 990.9157 | 992.5086 | 991.5992 | 991.0441 | 992.3836 | 986.5805 |
| 16 | 990.9157 | 992.5086 | 991.5992 | 991.0441 | 992.3836 | 986.5805 |
| 17 | 983.8532 | 983.4124 | 982.4329 | 982.5136 | 983.2699 | 978.2632 |
| 18 | 979.3762 | 979.1846 | 978.1846 | 977.7507 | 978.7501 | 974.0406 |
| 19 | 981.2944 | 980.7029 | 979.9747 | 979.9047 | 980.3345 | 976.112 |
| 20 | 998.0914 | 996.0748 | 997.6938 | 1000.099 | 996.9933 | 991.7665 |
| 21 | 984.2052 | 979.3478 | 980.4861 | 984.7014 | 982.2747 | 978.9177 |
| 22 | 988.2953 | 982.9233 | 983.9994 | 988.1965 | 986.4792 | 982.4372 |
| 23 | 998.018 | 992.4776 | 993.4556 | 997.4541 | 997.3697 | 991.6827 |
| 24 | 1000.166 | 994.9279 | 995.8288 | 999.7097 | 999.8502 | 994.0873 |
| 25 | 1000.166 | 994.9279 | 995.8288 | 999.7097 | 999.8502 | 994.0873 |
| 26 | 1000.166 | 994.9279 | 995.8288 | 999.7097 | 999.8502 | 994.0873 |
| 27 | 1025.491 | 1023.126 | 1023.63 | 1025.829 | 1027.359 | 1018.784 |
| 28 | 1032.747 | 1032.603 | 1032.046 | 1034.793 | 1034.991 | 1025.609 |
| 29 | 1019.633 | 1016.47 | 1015.757 | 1019.672 | 1021.032 | 1011.646 |
| 30 | 1012.7 | 1009.743 | 1008.902 | 1012.098 | 1013.808 | 1004.881 |
| 31 | 1012.7 | 1009.743 | 1008.902 | 1012.098 | 1013.808 | 1004.881 |
| 32 | 1017.295 | 1014.586 | 1013.705 | 1016.14 | 1018.883 | 1010.256 |
| 33 | 1032.747 | 1032.217 | 1031.387 | 1031.064 | 1035.952 | 1025.664 |
| 34 | 1043.852 | 1046.507 | 1043.784 | 1044.782 | 1047.563 | 1038.68 |
| 35 | 1023.885 | 1019.713 | 1021.652 | 1022.352 | 1026.867 | 1018.201 |
| 36 | 1026.879 | 1022.843 | 1024.136 | 1025.462 | 1029.117 | 1021.126 |

## C.2 Minimum capital in the population for 30 iterations

| Minimum capital in the population | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 941.0376 | 940.7501 | 941.3252 | 942.0509 | 940.7501 | 940.4724 |
| 1 | 945.2766 | 941.0324 | 941.6075 | 942.192 | 940.8912 | 941.204 |
| 2 | 961.581 | 945.4985 | 945.1777 | 945.6826 | 941.1788 | 945.2799 |
| 3 | 961.581 | 945.4985 | 945.1777 | 945.6826 | 941.1788 | 945.2799 |
| 4 | 961.581 | 945.4985 | 945.1777 | 945.6826 | 941.1788 | 945.2799 |
| 5 | 961.581 | 945.4985 | 945.1777 | 945.6826 | 941.1788 | 945.2799 |
| 6 | 945.5729 | 934.4664 | 935.5125 | 934.7958 | 932.3799 | 934.1824 |
| 7 | 942.1641 | 933.3382 | 934.3659 | 933.6842 | 931.4058 | 932.7376 |
| 8 | 939.4295 | 932.7331 | 932.63 | 932.3351 | 929.533 | 931.9992 |
| 9 | 908.5974 | 906.1392 | 901.726 | 904.3912 | 903.7793 | 900.6223 |
| 10 | 908.5974 | 906.1392 | 901.726 | 904.3912 | 903.7793 | 900.6223 |
| 11 | 908.5974 | 906.1392 | 901.726 | 904.3912 | 903.7793 | 900.6223 |
| 12 | 907.8569 | 903.2 | 899.6659 | 902.5432 | 900.8589 | 898.9727 |
| 13 | 907.8569 | 903.2 | 899.6659 | 902.5432 | 900.8589 | 898.9727 |
| 14 | 907.8569 | 903.2 | 899.6659 | 902.5432 | 900.8589 | 898.9727 |
| 15 | 914.1755 | 903.5983 | 899.7763 | 903.3469 | 903.3597 | 901.7867 |
| 16 | 914.1755 | 903.5983 | 899.7763 | 903.3469 | 903.3597 | 901.7867 |
| 17 | 897.8148 | 893.8667 | 889.1903 | 894.6178 | 891.1084 | 891.7408 |
| 18 | 889.1809 | 889.6857 | 885.6418 | 889.6568 | 887.5277 | 888.0552 |
| 19 | 893.4974 | 890.8393 | 887.0712 | 892.1909 | 888.6443 | 890.1792 |
| 20 | 931.2853 | 895.8314 | 894.0084 | 903.4807 | 898.2941 | 896.4446 |
| 21 | 907.5881 | 878.2023 | 873.0228 | 888.933 | 880.9816 | 880.2167 |
| 22 | 915.437 | 879.7232 | 875.9334 | 891.59 | 883.6335 | 882.804 |
| 23 | 930.2865 | 886.5467 | 882.8045 | 897.0277 | 891.7696 | 888.0743 |
| 24 | 933.9492 | 888.5191 | 885.1315 | 899.1457 | 894.0987 | 890.7777 |
| 25 | 933.9492 | 888.5191 | 885.1315 | 899.1457 | 894.0987 | 890.7777 |
| 26 | 933.9492 | 888.5191 | 885.1315 | 899.1457 | 894.0987 | 890.7777 |
| 27 | 975.1842 | 906.1114 | 902.4286 | 909.6792 | 909.5456 | 903.4734 |
| 28 | 981.678 | 912.2649 | 910.2711 | 917.983 | 915.8013 | 909.2366 |
| 29 | 966.4416 | 898.3379 | 893.4281 | 903.0935 | 901.5659 | 896.0349 |
| 30 | 956.7833 | 890.7124 | 885.8093 | 895.5772 | 893.906 | 889.6927 |
| 31 | 956.7833 | 890.7124 | 885.8093 | 895.5772 | 893.906 | 889.6927 |
| 32 | 965.0665 | 892.0181 | 891.223 | 898.8516 | 899.5682 | 894.0297 |
| 33 | 983.277 | 901.9298 | 898.0572 | 907.0079 | 910.0307 | 904.3407 |
| 34 | 983.277 | 911.7234 | 909.4305 | 918.0216 | 919.0067 | 913.4747 |
| 35 | 980.1522 | 883.8851 | 890.5185 | 892.5109 | 895.7716 | 889.6719 |
| 36 | 981.9728 | 886.8004 | 892.5081 | 894.638 | 896.9645 | 892.9639 |

## C.3 Maximum capital in the population for 30 iterations

| Maximum capital in the population | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 1033.091 | 1033.091 | 1033.091 | 1033.091 | 1033.091 | 1033.091 |
| 1 | 1036.193 | 1035.728 | 1035.107 | 1035.262 | 1035.883 | 1035.658 |
| 2 | 1054.066 | 1051.371 | 1050.103 | 1052.169 | 1049.387 | 1050.818 |
| 3 | 1054.066 | 1051.371 | 1050.103 | 1052.169 | 1049.387 | 1050.818 |
| 4 | 1054.066 | 1051.371 | 1050.103 | 1052.169 | 1049.387 | 1050.818 |
| 5 | 1054.066 | 1051.371 | 1050.103 | 1052.169 | 1049.387 | 1050.818 |
| 6 | 1035.885 | 1049.212 | 1047.323 | 1049.698 | 1046.995 | 1046.916 |
| 7 | 1031.219 | 1048.621 | 1046.222 | 1048.119 | 1046.521 | 1046.105 |
| 8 | 1026.488 | 1047.667 | 1045.582 | 1047.32 | 1045.724 | 1045.106 |
| 9 | 1019.234 | 1047.664 | 1045.017 | 1046.434 | 1044.435 | 1043.115 |
| 10 | 1019.234 | 1047.664 | 1045.017 | 1046.434 | 1044.435 | 1043.115 |
| 11 | 1019.234 | 1047.664 | 1045.017 | 1046.434 | 1044.435 | 1043.115 |
| 12 | 1019.234 | 1046.622 | 1044.697 | 1044.805 | 1043.594 | 1042.076 |
| 13 | 1019.234 | 1046.622 | 1044.697 | 1044.805 | 1043.594 | 1042.076 |
| 14 | 1019.234 | 1046.622 | 1044.697 | 1044.805 | 1043.594 | 1042.076 |
| 15 | 1056.131 | 1080.807 | 1079.646 | 1077.193 | 1077.544 | 1073.971 |
| 16 | 1056.131 | 1080.807 | 1079.646 | 1077.193 | 1077.544 | 1073.971 |
| 17 | 1036.92 | 1071.842 | 1070.671 | 1070.456 | 1069.566 | 1067.922 |
| 18 | 1026.948 | 1068.714 | 1066.646 | 1066.743 | 1064.621 | 1064.222 |
| 19 | 1031.934 | 1070.288 | 1067.875 | 1068.625 | 1066.65 | 1067.363 |
| 20 | 1073.249 | 1100.975 | 1096.968 | 1098.775 | 1098.717 | 1093.659 |
| 21 | 1045.94 | 1084.265 | 1083.475 | 1086.056 | 1083.886 | 1084.175 |
| 22 | 1054.852 | 1088.678 | 1086.516 | 1090.647 | 1088.868 | 1090.031 |
| 23 | 1076.659 | 1102.453 | 1100.102 | 1106.133 | 1102.844 | 1103.305 |
| 24 | 1080.898 | 1105.174 | 1102.998 | 1108.589 | 1105.474 | 1105.967 |
| 25 | 1080.898 | 1105.174 | 1102.998 | 1108.589 | 1105.474 | 1105.967 |
| 26 | 1080.898 | 1105.174 | 1102.998 | 1108.589 | 1105.474 | 1105.967 |
| 27 | 1130.869 | 1146.761 | 1145.267 | 1148.992 | 1147.009 | 1143.575 |
| 28 | 1145.187 | 1157.989 | 1155.502 | 1158.341 | 1157.719 | 1151.766 |
| 29 | 1119.31 | 1141.377 | 1141.339 | 1144.242 | 1145.962 | 1137.831 |
| 30 | 1103.76 | 1134.566 | 1134.895 | 1137.972 | 1139.571 | 1130.118 |
| 31 | 1103.76 | 1134.566 | 1134.895 | 1137.972 | 1139.571 | 1130.118 |
| 32 | 1114.357 | 1140.752 | 1141.778 | 1144.1 | 1146.472 | 1138.177 |
| 33 | 1161.552 | 1176.831 | 1179.044 | 1172.476 | 1171.905 | 1162.612 |
| 34 | 1183.778 | 1198.122 | 1194.019 | 1186.794 | 1188 | 1178.003 |
| 35 | 1143.815 | 1176.519 | 1175.408 | 1171.321 | 1173.996 | 1163.118 |
| 36 | 1150.624 | 1180.017 | 1177.784 | 1175.058 | 1177.131 | 1166.802 |

## C.4 Count of investors with overall negative return

| Number of investors with negative return from initial capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 29.6 | 29 | 28.76667 | 29 | 28 | 28.65517 |
| 1 | 29.6 | 29 | 28.76667 | 29 | 28 | 28.65517 |
| 2 | 17.26667 | 19.5 | 21.23333 | 19.46667 | 21.1 | 20.68966 |
| 3 | 17.26667 | 19.5 | 21.23333 | 19.46667 | 21.1 | 20.68966 |
| 4 | 17.26667 | 19.5 | 21.23333 | 19.46667 | 21.1 | 20.68966 |
| 5 | 17.26667 | 19.5 | 21.23333 | 19.46667 | 21.1 | 20.68966 |
| 6 | 36.66667 | 49.53333 | 47.9 | 47.66667 | 43.83333 | 49.31034 |
| 7 | 38.1 | 53.9 | 52.43333 | 52.8 | 49.43333 | 54.55172 |
| 8 | 39.1 | 56.46667 | 56.16667 | 57.4 | 54.83333 | 57.72414 |
| 9 | 49.66667 | 61.83333 | 62.5 | 64.7 | 61.36667 | 67.51724 |
| 10 | 49.66667 | 61.83333 | 62.5 | 64.7 | 61.36667 | 67.51724 |
| 11 | 49.66667 | 61.83333 | 62.5 | 64.7 | 61.36667 | 67.51724 |
| 12 | 51.16667 | 64.06667 | 63.96667 | 66.86667 | 62.76667 | 68.13793 |
| 13 | 51.16667 | 64.06667 | 63.96667 | 66.86667 | 62.76667 | 68.13793 |
| 14 | 51.16667 | 64.06667 | 63.96667 | 66.86667 | 62.76667 | 68.13793 |
| 15 | 44.26667 | 60.2 | 60.06667 | 61.33333 | 57.4 | 62.72414 |
| 16 | 44.26667 | 60.2 | 60.06667 | 61.33333 | 57.4 | 62.72414 |
| 17 | 52.1 | 73.43333 | 74.03333 | 73.1 | 70.9 | 72.58621 |
| 18 | 54.76667 | 76.93333 | 77.7 | 77.66667 | 75.16667 | 76 |
| 19 | 54.53333 | 74.8 | 75.2 | 75.03333 | 72.96667 | 73.82759 |
| 20 | 33.7 | 55.5 | 52.36667 | 50.26667 | 52.5 | 57.7931 |
| 21 | 51.23333 | 70.33333 | 68.33333 | 64.23333 | 65.56667 | 67.17241 |
| 22 | 48.9 | 67 | 65.56667 | 61.3 | 62.3 | 64.55172 |
| 23 | 34.93333 | 58.13333 | 56.36667 | 52.96667 | 52.36667 | 57.68966 |
| 24 | 34.73333 | 55.73333 | 53.53333 | 50.96667 | 50.2 | 55.82759 |
| 25 | 34.73333 | 55.73333 | 53.53333 | 50.96667 | 50.2 | 55.82759 |
| 26 | 34.73333 | 55.73333 | 53.53333 | 50.96667 | 50.2 | 55.82759 |
| 27 | 9.333333 | 30.73333 | 32.13333 | 31.1 | 31.13333 | 36.48276 |
| 28 | 7.9 | 25.66667 | 27 | 26.3 | 26.96667 | 32.58621 |
| 29 | 10.2 | 36.4 | 38.83333 | 36.06667 | 35.5 | 42 |
| 30 | 15.23333 | 41.73333 | 43.56667 | 42.1 | 40.36667 | 47.27586 |
| 31 | 15.23333 | 41.73333 | 43.56667 | 42.1 | 40.36667 | 47.27586 |
| 32 | 12.03333 | 38.16667 | 40.66667 | 38.8 | 36.73333 | 43.2069 |
| 33 | 6.833333 | 28.1 | 30.23333 | 29.66667 | 27.96667 | 34.82759 |
| 34 | 5.533333 | 20.7 | 24.6 | 22.7 | 22.66667 | 27.89655 |
| 35 | 16.3 | 37.43333 | 37 | 36.7 | 33.83333 | 39.31034 |
| 36 | 14.36667 | 35.06667 | 35.56667 | 34.56667 | 32.76667 | 37.44828 |

## C.5 Count of investors with no earnings or losses from initial capital

| Count of investors with no earnings or losses from initial capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 58.83333 | 58.66667 | 58.46667 | 57.86667 | 59.6 | 58.24138 |
| 1 | 56.86667 | 49.93333 | 50.86667 | 47.3 | 50.63333 | 50.68966 |
| 2 | 49.36667 | 26.36667 | 28.16667 | 22.3 | 30.16667 | 29.27586 |
| 3 | 49.36667 | 26.36667 | 28.16667 | 22.3 | 30.16667 | 29.27586 |
| 4 | 49.36667 | 26.36667 | 28.16667 | 22.3 | 30.16667 | 29.27586 |
| 5 | 49.36667 | 26.36667 | 28.16667 | 22.3 | 30.16667 | 29.27586 |
| 6 | 43.2 | 14.36667 | 17.23333 | 12.73333 | 19.4 | 15.06897 |
| 7 | 43.2 | 11.43333 | 13.6 | 9.5 | 15.43333 | 10.58621 |
| 8 | 43.2 | 9.7 | 10.96667 | 6.233333 | 11.26667 | 8.586207 |
| 9 | 43.2 | 8.8 | 9.033333 | 4.9 | 9.433333 | 6.655172 |
| 10 | 43.2 | 8.8 | 9.033333 | 4.9 | 9.433333 | 6.655172 |
| 11 | 43.2 | 8.8 | 9.033333 | 4.9 | 9.433333 | 6.655172 |
| 12 | 43.2 | 7.866667 | 8.7 | 4.3 | 8.466667 | 6.448276 |
| 13 | 43.2 | 7.866667 | 8.7 | 4.3 | 8.466667 | 6.448276 |
| 14 | 43.2 | 7.866667 | 8.7 | 4.3 | 8.466667 | 6.448276 |
| 15 | 43.2 | 7.3 | 7.966667 | 4.033333 | 7.9 | 5.689655 |
| 16 | 43.2 | 7.3 | 7.966667 | 4.033333 | 7.9 | 5.689655 |
| 17 | 43.2 | 3.6 | 3.366667 | 1.666667 | 4.533333 | 3.206897 |
| 18 | 41.56667 | 2.233333 | 1.966667 | 0.366667 | 2.6 | 1.758621 |
| 19 | 41.56667 | 1.633333 | 1.266667 | 0.266667 | 1.766667 | 0.793103 |
| 20 | 40.9 | 1.033333 | 0.866667 | 0.1 | 0.966667 | 0.344828 |
| 21 | 39.76667 | 0.333333 | 0.3 | 0.1 | 0.633333 | 0.103448 |
| 22 | 39.76667 | 0.2 | 0.133333 | 0.066667 | 0.333333 | 0.068966 |
| 23 | 39.76667 | 0.2 | 0.066667 | 0.033333 | 0.066667 | 0.034483 |
| 24 | 39.76667 | 0.066667 | 0.033333 | 0.033333 | 0 | 0 |
| 25 | 39.76667 | 0.066667 | 0.033333 | 0.033333 | 0 | 0 |
| 26 | 39.76667 | 0.066667 | 0.033333 | 0.033333 | 0 | 0 |
| 27 | 39.76667 | 0.066667 | 0.033333 | 0.033333 | 0 | 0 |
| 28 | 39.76667 | 0 | 0 | 0 | 0 | 0 |
| 29 | 39.76667 | 0 | 0 | 0 | 0 | 0 |
| 30 | 39.76667 | 0 | 0 | 0 | 0 | 0 |
| 31 | 39.76667 | 0 | 0 | 0 | 0 | 0 |
| 32 | 39.76667 | 0 | 0 | 0 | 0 | 0 |
| 33 | 39.76667 | 0 | 0 | 0 | 0 | 0 |
| 34 | 39.76667 | 0 | 0 | 0 | 0 | 0 |
| 35 | 39.76667 | 0 | 0 | 0 | 0 | 0 |
| 36 | 39.76667 | 0 | 0 | 0 | 0 | 0 |

## C.6 Count of investors with overall positive return

| Number of investors with positive return from initial capital | | | | | | |
|---|---|---|---|---|---|---|
| | Crossover Rate | | | | | |
| Period | 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
| 0 | 11.56667 | 12.33333 | 12.76667 | 13.13333 | 12.4 | 13.10345 |
| 1 | 13.53333 | 21.06667 | 20.36667 | 23.7 | 21.36667 | 20.65517 |
| 2 | 33.36667 | 54.13333 | 50.6 | 58.23333 | 48.73333 | 50.03448 |
| 3 | 33.36667 | 54.13333 | 50.6 | 58.23333 | 48.73333 | 50.03448 |
| 4 | 33.36667 | 54.13333 | 50.6 | 58.23333 | 48.73333 | 50.03448 |
| 5 | 33.36667 | 54.13333 | 50.6 | 58.23333 | 48.73333 | 50.03448 |
| 6 | 20.13333 | 36.1 | 34.86667 | 39.6 | 36.76667 | 35.62069 |
| 7 | 18.7 | 34.66667 | 33.96667 | 37.7 | 35.13333 | 34.86207 |
| 8 | 17.7 | 33.83333 | 32.86667 | 36.36667 | 33.9 | 33.68966 |
| 9 | 7.133333 | 29.36667 | 28.46667 | 30.4 | 29.2 | 25.82759 |
| 10 | 7.133333 | 29.36667 | 28.46667 | 30.4 | 29.2 | 25.82759 |
| 11 | 7.133333 | 29.36667 | 28.46667 | 30.4 | 29.2 | 25.82759 |
| 12 | 5.633333 | 28.06667 | 27.33333 | 28.83333 | 28.76667 | 25.41379 |
| 13 | 5.633333 | 28.06667 | 27.33333 | 28.83333 | 28.76667 | 25.41379 |
| 14 | 5.633333 | 28.06667 | 27.33333 | 28.83333 | 28.76667 | 25.41379 |
| 15 | 12.53333 | 32.5 | 31.96667 | 34.63333 | 34.7 | 31.58621 |
| 16 | 12.53333 | 32.5 | 31.96667 | 34.63333 | 34.7 | 31.58621 |
| 17 | 4.7 | 22.96667 | 22.6 | 25.23333 | 24.56667 | 24.2069 |
| 18 | 3.666667 | 20.83333 | 20.33333 | 21.96667 | 22.23333 | 22.24138 |
| 19 | 3.9 | 23.56667 | 23.53333 | 24.7 | 25.26667 | 25.37931 |
| 20 | 25.4 | 43.46667 | 46.76667 | 49.63333 | 46.53333 | 41.86207 |
| 21 | 9 | 29.33333 | 31.36667 | 35.66667 | 33.8 | 32.72414 |
| 22 | 11.33333 | 32.8 | 34.3 | 38.63333 | 37.36667 | 35.37931 |
| 23 | 25.3 | 41.66667 | 43.56667 | 47 | 47.56667 | 42.27586 |
| 24 | 25.5 | 44.2 | 46.43333 | 49 | 49.8 | 44.17241 |
| 25 | 25.5 | 44.2 | 46.43333 | 49 | 49.8 | 44.17241 |
| 26 | 25.5 | 44.2 | 46.43333 | 49 | 49.8 | 44.17241 |
| 27 | 50.9 | 69.2 | 67.83333 | 68.86667 | 68.86667 | 63.51724 |
| 28 | 52.33333 | 74.33333 | 73 | 73.7 | 73.03333 | 67.41379 |
| 29 | 50.03333 | 63.6 | 61.16667 | 63.93333 | 64.5 | 58 |
| 30 | 45 | 58.26667 | 56.43333 | 57.9 | 59.63333 | 52.72414 |
| 31 | 45 | 58.26667 | 56.43333 | 57.9 | 59.63333 | 52.72414 |
| 32 | 48.2 | 61.83333 | 59.33333 | 61.2 | 63.26667 | 56.7931 |
| 33 | 53.4 | 71.9 | 69.76667 | 70.33333 | 72.03333 | 65.17241 |
| 34 | 54.7 | 79.3 | 75.4 | 77.3 | 77.33333 | 72.10345 |
| 35 | 43.93333 | 62.56667 | 63 | 63.3 | 66.16667 | 60.68966 |
| 36 | 45.86667 | 64.93333 | 64.43333 | 65.43333 | 67.23333 | 62.55172 |

# Appendix D

## Student's t-test for paired means for the data from 2004-2007

### D.1 T-test for population average capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.2* |
| Mean | 918.0538 | 910.2147 |
| Variance | 925.1722 | 1439.27 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.994814 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 5.759854 | |
| P(T<=t) one-tail | 7.28E-07 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.46E-06 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *1* |
| Mean | 918.0538 | 908.4855 |
| Variance | 925.1722 | 1447.606 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.998585 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 7.421345 | |
| P(T<=t) one-tail | 4.63E-09 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 9.27E-09 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.4* |
| Mean | 918.0538 | 919.5699 |
| Variance | 925.1722 | 1195.987 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.994305 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -1.70249 | |
| P(T<=t) one-tail | 0.048642 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.097284 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.8* |
| Mean | 918.0538 | 911.5923 |
| Variance | 925.1722 | 1259.368 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.997351 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 7.010531 | |
| P(T<=t) one-tail | 1.59E-08 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.18E-08 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.6* |
| Mean | 918.0538 | 924.0965 |
| Variance | 925.1722 | 860.9198 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.996644 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -13.7494 | |
| P(T<=t) one-tail | 3.37E-16 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 6.75E-16 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0.4* | *0.6* |
| Mean | 919.5699 | 924.0965 |
| Variance | 1195.987 | 860.9198 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.994017 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -4.37455 | |
| P(T<=t) one-tail | 4.98E-05 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 9.97E-05 | |
| t Critical two-tail | 2.028094 | |

## D.2 T-test for population minimum capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.2* |
| Mean | 694.9686 | 711.0628 |
| Variance | 4356.871 | 4293.487 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.949517 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -4.68351 | |
| P(T<=t) one-tail | 1.97E-05 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.94E-05 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.6* |
| Mean | 694.9686 | 727.4192 |
| Variance | 4356.871 | 2830.743 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.959738 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -9.33956 | |
| P(T<=t) one-tail | 1.87E-11 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.73E-11 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.4* |
| Mean | 694.9686 | 720.0913 |
| Variance | 4356.871 | 3546.758 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.962581 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -8.33907 | |
| P(T<=t) one-tail | 3.14E-10 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 6.27E-10 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.8* |
| Mean | 694.9686 | 719.7714 |
| Variance | 4356.871 | 3321.867 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.963373 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -8.07867 | |
| P(T<=t) one-tail | 6.67E-10 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.33E-09 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *1* |
| Mean | 694.9686 | 718.0771 |
| Variance | 4356.871 | 3758.706 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.958683 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -7.44491 | |
| P(T<=t) one-tail | 4.32E-09 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 8.64E-09 | |
| t Critical two-tail | 2.028094 | |

## D.3 T-test for population maximum capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.2* |
| Mean | 1031.756 | 1115.669 |
| Variance | 984.4397 | 556.7421 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.127359 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -13.8786 | |
| P(T<=t) one-tail | 2.54E-16 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 5.07E-16 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.6* |
| Mean | 1031.756 | 1135.611 |
| Variance | 984.4397 | 797.6349 |
| Observations | 37 | 37 |
| Pearson Correlation | -0.19668 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -13.6858 | |
| P(T<=t) one-tail | 3.88E-16 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 7.77E-16 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.4* |
| Mean | 1031.756 | 1130.356 |
| Variance | 984.4397 | 529.7139 |
| Observations | 37 | 37 |
| Pearson Correlation | -0.11662 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -14.6214 | |
| P(T<=t) one-tail | 5.12E-17 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.02E-16 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.8* |
| Mean | 1031.756 | 1115.961 |
| Variance | 984.4397 | 527.4681 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.167327 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -14.3684 | |
| P(T<=t) one-tail | 8.77E-17 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.75E-16 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *1* |
| Mean | 1031.756 | 1108.705 |
| Variance | 984.4397 | 415.0271 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.283304 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -14.5329 | |
| P(T<=t) one-tail | 6.17E-17 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.23E-16 | |
| t Critical two-tail | 2.028094 | |

## D.4 T-test for number of investors with overall negative return

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.2* |
| Mean | 57.0036 | 77.88018 |
| Variance | 53.79437 | 181.4168 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.943643 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -18.184 | |
| P(T<=t) one-tail | 4.99E-20 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 9.97E-20 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.6* |
| Mean | 57.0036 | 73.86577 |
| Variance | 53.79437 | 126.9818 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.932795 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -19.8923 | |
| P(T<=t) one-tail | 2.62E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 5.23E-21 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.4* |
| Mean | 57.0036 | 75.75135 |
| Variance | 53.79437 | 152.4649 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.957814 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -19.92 | |
| P(T<=t) one-tail | 2.5E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 5E-21 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.8* |
| Mean | 57.0036 | 78.7991 |
| Variance | 53.79437 | 138.3254 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.910841 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -22.4167 | |
| P(T<=t) one-tail | 4.85E-23 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 9.7E-23 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *1* |
| Mean | 57.0036 | 78.85766 |
| Variance | 53.79437 | 164.6935 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.919506 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -19.7311 | |
| P(T<=t) one-tail | 3.42E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 6.85E-21 | |
| t Critical two-tail | 2.028094 | |

## D.5 T-test for count of investors with no losses or earnings from initial capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.2* |
| Mean | 40.24685 | 10.08468 |
| Variance | 26.30182 | 168.6345 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.838439 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 20.1071 | |
| P(T<=t) one-tail | 1.83E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.67E-21 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.6* |
| Mean | 40.24685 | 9.892793 |
| Variance | 26.30182 | 143.1472 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.856114 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 23.0101 | |
| P(T<=t) one-tail | 2.01E-23 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.02E-23 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.4* |
| Mean | 40.24685 | 9.322523 |
| Variance | 26.30182 | 141.4279 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.832372 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 23.11976 | |
| P(T<=t) one-tail | 1.71E-23 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.43E-23 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.8* |
| Mean | 40.24685 | 7.785586 |
| Variance | 26.30182 | 119.688 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.809539 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 26.58898 | |
| P(T<=t) one-tail | 1.47E-25 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 2.93E-25 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *1* |
| Mean | 40.24685 | 8.540541 |
| Variance | 26.30182 | 145.684 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.814758 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 22.86969 | |
| P(T<=t) one-tail | 2.47E-23 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.94E-23 | |
| t Critical two-tail | 2.028094 | |

## D.6 T-test for number of investors with overall positive return

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.2* |
| Mean | 2.74955 | 12.03514 |
| Variance | 8.87189 | 17.24993 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.548726 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -15.9466 | |
| P(T<=t) one-tail | 3.38E-18 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 6.76E-18 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.6* |
| Mean | 2.74955 | 16.24144 |
| Variance | 8.87189 | 18.86552 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.355225 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -19.0567 | |
| P(T<=t) one-tail | 1.08E-20 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 2.15E-20 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.4* |
| Mean | 2.74955 | 14.92613 |
| Variance | 8.87189 | 24.48458 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.533327 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -17.6373 | |
| P(T<=t) one-tail | 1.34E-19 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 2.69E-19 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.8* |
| Mean | 2.74955 | 13.41532 |
| Variance | 8.87189 | 22.38744 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.63348 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -17.7206 | |
| P(T<=t) one-tail | 1.15E-19 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 2.31E-19 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *1* |
| Mean | 2.74955 | 12.6018 |
| Variance | 8.87189 | 19.92247 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.631537 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -17.2984 | |
| P(T<=t) one-tail | 2.51E-19 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 5.03E-19 | |
| t Critical two-tail | 2.028094 | |

# Appendix E

## Student's t-test for paired means for the data from 2008-2011

### E.1 T-test for population average capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.2* |
| Mean | 961.9652 | 969.0734 |
| Variance | 2864.102 | 2455.001 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.996129 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -7.17797 | |
| P(T<=t) one-tail | 9.6E-09 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.92E-08 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.6* |
| Mean | 961.9652 | 966.9363 |
| Variance | 2864.102 | 2525.134 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.997479 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -6.14319 | |
| P(T<=t) one-tail | 2.24E-07 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.48E-07 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.4* |
| Mean | 961.9652 | 968.8606 |
| Variance | 2864.102 | 2448.709 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.997387 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -7.64474 | |
| P(T<=t) one-tail | 2.39E-09 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.77E-09 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.8* |
| Mean | 961.9652 | 951.2187 |
| Variance | 2864.102 | 3239.227 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.998736 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 14.90294 | |
| P(T<=t) one-tail | 2.83E-17 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 5.66E-17 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *1* |
| Mean | 961.9652 | 965.2116 |
| Variance | 2864.102 | 2618.371 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.999189 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -6.26045 | |
| P(T<=t) one-tail | 1.56E-07 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.12E-07 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0.2* | *1* |
| Mean | 969.0734 | 965.2116 |
| Variance | 2455.001 | 2618.371 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.997863 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 6.40101 | |
| P(T<=t) one-tail | 1.02E-07 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 2.03E-07 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0.2* | *0.6* |
| Mean | 969.0734 | 966.9363 |
| Variance | 2455.001 | 2525.134 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.995778 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 2.802413 | |
| P(T<=t) one-tail | 0.004058 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.008116 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0.2* | *0.4* |
| Mean | 969.0734 | 968.8606 |
| Variance | 2455.001 | 2448.709 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.998915 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 0.560906 | |
| P(T<=t) one-tail | 0.289168 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.578336 | |
| t Critical two-tail | 2.028094 | |

## E.2 T-test for population minimum capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.2* |
| Mean | 663.6267 | 707.6676 |
| Variance | 23640.79 | 10185.05 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.9386 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -3.90883 | |
| P(T<=t) one-tail | 0.000197 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.000393 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.6* |
| Mean | 663.6267 | 709.9216 |
| Variance | 23640.79 | 10213.38 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.946909 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -4.23251 | |
| P(T<=t) one-tail | 7.61E-05 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.000152 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.4* |
| Mean | 663.6267 | 709.3629 |
| Variance | 23640.79 | 10175.42 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.947351 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -4.17998 | |
| P(T<=t) one-tail | 8.89E-05 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.000178 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.8* |
| Mean | 663.6267 | 696.7685 |
| Variance | 23640.79 | 11222.65 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.947613 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -3.19018 | |
| P(T<=t) one-tail | 0.001472 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.002944 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *1* |
| Mean | 663.6267 | 719.4645 |
| Variance | 23640.79 | 9481.211 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.941192 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -4.83241 | |
| P(T<=t) one-tail | 1.25E-05 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 2.5E-05 | |
| t Critical two-tail | 2.028094 | |

## E.3 T-test for population maximum capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.2* |
| Mean | 1081.18 | 1290.832 |
| Variance | 4149.273 | 185.9801 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.138676 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -19.9367 | |
| P(T<=t) one-tail | 2.43E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.86E-21 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.6* |
| Mean | 1081.18 | 1278.231 |
| Variance | 4149.273 | 186.5825 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.451986 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -20.1442 | |
| P(T<=t) one-tail | 1.73E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.45E-21 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.4* |
| Mean | 1081.18 | 1268.349 |
| Variance | 4149.273 | 212.1921 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.619434 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -20.1293 | |
| P(T<=t) one-tail | 1.77E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.54E-21 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.8* |
| Mean | 1081.18 | 1265.412 |
| Variance | 4149.273 | 187.6168 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.632707 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -19.7475 | |
| P(T<=t) one-tail | 3.33E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 6.66E-21 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *1* |
| Mean | 1081.18 | 1270.842 |
| Variance | 4149.273 | 197.3116 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.600879 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -20.2082 | |
| P(T<=t) one-tail | 1.55E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.11E-21 | |
| t Critical two-tail | 2.028094 | |

## E.4 T-test for number of investors with overall negative return

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.2* |
| Mean | 39.20721 | 59.21532 |
| Variance | 215.485 | 233.5108 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.94702 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -24.7756 | |
| P(T<=t) one-tail | 1.64E-24 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.28E-24 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.6* |
| Mean | 39.20721 | 59.57658 |
| Variance | 215.485 | 233.1213 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.95213 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -26.5338 | |
| P(T<=t) one-tail | 1.57E-25 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.15E-25 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.4* |
| Mean | 39.20721 | 60.41892 |
| Variance | 215.485 | 228.0568 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.945716 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -26.2034 | |
| P(T<=t) one-tail | 2.42E-25 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.83E-25 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.8* |
| Mean | 39.20721 | 63.05856 |
| Variance | 215.485 | 266.1148 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.959868 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -31.0099 | |
| P(T<=t) one-tail | 7.23E-28 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.45E-27 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *1* |
| Mean | 39.20721 | 59.21982 |
| Variance | 215.485 | 256.6155 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.965692 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -28.7481 | |
| P(T<=t) one-tail | 9.97E-27 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.99E-26 | |
| t Critical two-tail | 2.028094 | |

## E.5 T-test for count of investors with no losses or earnings from initial capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.2* |
| Mean | 44.30811 | 2.585586 |
| Variance | 0.011445 | 57.78145 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.068617 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 33.41596 | |
| P(T<=t) one-tail | 5.36E-29 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.07E-28 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.6* |
| Mean | 44.30811 | 3.092793 |
| Variance | 0.011445 | 61.04668 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.073183 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 32.11614 | |
| P(T<=t) one-tail | 2.14E-28 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.28E-28 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.4* |
| Mean | 44.30811 | 2.354955 |
| Variance | 0.011445 | 52.37859 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.069927 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 35.29315 | |
| P(T<=t) one-tail | 7.93E-30 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.59E-29 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.8* |
| Mean | 44.30811 | 2.408108 |
| Variance | 0.011445 | 55.87453 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.067266 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 34.12572 | |
| P(T<=t) one-tail | 2.57E-29 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 5.15E-29 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *1* |
| Mean | 44.30811 | 3.109009 |
| Variance | 0.011445 | 63.02658 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.082695 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 31.59888 | |
| P(T<=t) one-tail | 3.76E-28 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 7.52E-28 | |
| t Critical two-tail | 2.028094 | |

## E.6 T-test for number of investors with overall positive return

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.2* |
| Mean | 16.48468 | 38.1991 |
| Variance | 214.9247 | 103.1212 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.921554 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -19.9906 | |
| P(T<=t) one-tail | 2.22E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.45E-21 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.6* |
| Mean | 16.48468 | 37.33063 |
| Variance | 214.9247 | 99.04311 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.929725 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -19.4107 | |
| P(T<=t) one-tail | 5.88E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.18E-20 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.4* |
| Mean | 16.48468 | 37.22613 |
| Variance | 214.9247 | 103.0335 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.948751 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -21.1481 | |
| P(T<=t) one-tail | 3.42E-22 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 6.84E-22 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.8* |
| Mean | 16.48468 | 34.53333 |
| Variance | 214.9247 | 122.3863 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.95913 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -21.4489 | |
| P(T<=t) one-tail | 2.13E-22 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.27E-22 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *1* |
| Mean | 16.48468 | 37.67117 |
| Variance | 214.9247 | 104.4639 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.939776 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -20.9729 | |
| P(T<=t) one-tail | 4.52E-22 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 9.03E-22 | |
| t Critical two-tail | 2.028094 | |

# Appendix F

## Student's t-test for paired means for the data from 2014-2017

### F.1 T-test for population average capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.2* |
| Mean | 1001.614 | 1001.094 |
| Variance | 275.6251 | 260.375 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.983096 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 1.037417 | |
| P(T<=t) one-tail | 0.15323 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.30646 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.6* |
| Mean | 1001.614 | 1001.917 |
| Variance | 275.6251 | 278.675 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.996648 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -1.34945 | |
| P(T<=t) one-tail | 0.09281 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.185619 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.4* |
| Mean | 1001.614 | 1000.692 |
| Variance | 275.6251 | 258.8175 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.9908 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 2.463946 | |
| P(T<=t) one-tail | 0.009326 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.018652 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.8* |
| Mean | 1001.614 | 1002.317 |
| Variance | 275.6251 | 308.6859 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.99872 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -3.29979 | |
| P(T<=t) one-tail | 0.001094 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 0.002188 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *1* |
| Mean | 1001.614 | 997.258 |
| Variance | 275.6251 | 266.2944 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.982912 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 8.669366 | |
| P(T<=t) one-tail | 1.22E-10 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 2.44E-10 | |
| t Critical two-tail | 2.028094 | |

## F.2 T-test for population minimum capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.2* |
| Mean | 938.7857 | 906.8723 |
| Variance | 825.2589 | 447.9882 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.274885 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 6.335024 | |
| P(T<=t) one-tail | 1.24E-07 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 2.48E-07 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.6* |
| Mean | 938.7857 | 910.3557 |
| Variance | 825.2589 | 354.3844 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.376955 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 6.224274 | |
| P(T<=t) one-tail | 1.74E-07 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.49E-07 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.4* |
| Mean | 938.7857 | 904.6603 |
| Variance | 825.2589 | 499.4661 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.325381 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 6.89277 | |
| P(T<=t) one-tail | 2.27E-08 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.54E-08 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *0.8* |
| Mean | 938.7857 | 908.1252 |
| Variance | 825.2589 | 353.3975 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.428685 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 6.971615 | |
| P(T<=t) one-tail | 1.79E-08 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.58E-08 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| *Crossover Rate* | *0* | *1* |
| Mean | 938.7857 | 906.3928 |
| Variance | 825.2589 | 428.3851 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.345913 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 6.789203 | |
| P(T<=t) one-tail | 3.11E-08 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 6.22E-08 | |
| t Critical two-tail | 2.028094 | |

## F.3 T-test for population maximum capital

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.2* |
| Mean | 1069 | 1090.663 |
| Variance | 2189.501 | 2292.173 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.965484 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -10.5557 | |
| P(T<=t) one-tail | 7.18E-13 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.44E-12 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.6* |
| Mean | 1069 | 1090.29 |
| Variance | 2189.501 | 2242.149 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.963589 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -10.1853 | |
| P(T<=t) one-tail | 1.9E-12 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.8E-12 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.4* |
| Mean | 1069 | 1089.118 |
| Variance | 2189.501 | 2314.042 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.966521 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -9.91119 | |
| P(T<=t) one-tail | 3.94E-12 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 7.88E-12 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.8* |
| Mean | 1069 | 1089.293 |
| Variance | 2189.501 | 2335.603 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.963197 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -9.5004 | |
| P(T<=t) one-tail | 1.2E-11 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 2.4E-11 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *1* |
| Mean | 1069 | 1086.604 |
| Variance | 2189.501 | 2031.435 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.963366 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -8.53288 | |
| P(T<=t) one-tail | 1.8E-10 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.6E-10 | |
| t Critical two-tail | 2.028094 | |

## F.4 T-test for number of investors with overall negative return

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.2* |
| Mean | 31.90541 | 47.92072 |
| Variance | 274.16 | 323.6968 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.901375 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -12.4918 | |
| P(T<=t) one-tail | 5.95E-15 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.19E-14 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.6* |
| Mean | 31.90541 | 47.53153 |
| Variance | 274.16 | 317.1424 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.906659 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -12.6329 | |
| P(T<=t) one-tail | 4.27E-15 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 8.54E-15 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.4* |
| Mean | 31.90541 | 48.15766 |
| Variance | 274.16 | 294.143 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.893483 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -12.6734 | |
| P(T<=t) one-tail | 3.89E-15 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 7.77E-15 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.8* |
| Mean | 31.90541 | 46.11802 |
| Variance | 274.16 | 279.2096 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.91046 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -12.2791 | |
| P(T<=t) one-tail | 9.84E-15 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.97E-14 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *1* |
| Mean | 31.90541 | 50.25629 |
| Variance | 274.16 | 298.365 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.866305 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -12.7218 | |
| P(T<=t) one-tail | 3.47E-15 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 6.94E-15 | |
| t Critical two-tail | 2.028094 | |

## F.5 T-test for count of investors with no losses or earnings from initial capital

t-Test: Paired Two Sample for Means

| *Crossover Rate* | *0* | *0.2* |
|---|---|---|
| Mean | 43.02342 | 8.747748 |
| Variance | 21.70462 | 190.6173 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.991105 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 22.63759 | |
| P(T<=t) one-tail | 3.49E-23 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 6.97E-23 | |
| t Critical two-tail | 2.028094 | |

t-Test: Paired Two Sample for Means

| *Crossover Rate* | *0* | *0.6* |
|---|---|---|
| Mean | 43.02342 | 7.06036 |
| Variance | 21.70462 | 171.8025 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.975679 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 25.37017 | |
| P(T<=t) one-tail | 7.3E-25 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.46E-24 | |
| t Critical two-tail | 2.028094 | |

t-Test: Paired Two Sample for Means

| *Crossover Rate* | *0* | *0.4* |
|---|---|---|
| Mean | 43.02342 | 9.217117 |
| Variance | 21.70462 | 201.5158 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.989037 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 21.39247 | |
| P(T<=t) one-tail | 2.33E-22 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.66E-22 | |
| t Critical two-tail | 2.028094 | |

t-Test: Paired Two Sample for Means

| *Crossover Rate* | *0* | *0.8* |
|---|---|---|
| Mean | 43.02342 | 9.659459 |
| Variance | 21.70462 | 213.4422 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.98684 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 20.21275 | |
| P(T<=t) one-tail | 1.54E-21 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 3.08E-21 | |
| t Critical two-tail | 2.028094 | |

t-Test: Paired Two Sample for Means

| *Crossover Rate* | *0* | *1* |
|---|---|---|
| Mean | 43.02342 | 8.575023 |
| Variance | 21.70462 | 206.07 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.98677 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | 21.40986 | |
| P(T<=t) one-tail | 2.27E-22 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.54E-22 | |
| t Critical two-tail | 2.028094 | |

## F.6 T-test for number of investors with overall positive return

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.2* |
| Mean | 25.07117117 | 43.33153 |
| Variance | 297.8797014 | 307.1993 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.966281491 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -24.54895765 | |
| P(T<=t) one-tail | 2.24057E-24 | |
| t Critical one-tail | 1.688297714 | |
| P(T<=t) two-tail | 4.48114E-24 | |
| t Critical two-tail | 2.028094001 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.6* |
| Mean | 25.07117 | 45.40811 |
| Variance | 297.8797 | 285.4988 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.954003 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -23.825 | |
| P(T<=t) one-tail | 6.19E-24 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 1.24E-23 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.4* |
| Mean | 25.07117117 | 42.62523 |
| Variance | 297.8797014 | 282.9404 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.96242995 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -22.76166317 | |
| P(T<=t) one-tail | 2.90063E-23 | |
| t Critical one-tail | 1.688297714 | |
| P(T<=t) two-tail | 5.80126E-23 | |
| t Critical two-tail | 2.028094001 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *0.8* |
| Mean | 25.07117 | 44.22252 |
| Variance | 297.8797 | 291.6104 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.956567 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -23.008 | |
| P(T<=t) one-tail | 2.02E-23 | |
| t Critical one-tail | 1.688298 | |
| P(T<=t) two-tail | 4.03E-23 | |
| t Critical two-tail | 2.028094 | |

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| *Crossover Rate* | *0* | *1* |
| Mean | 25.07117117 | 41.16869 |
| Variance | 297.8797014 | 240.7426 |
| Observations | 37 | 37 |
| Pearson Correlation | 0.961148175 | |
| Hypothesized Mean Difference | 0 | |
| df | 36 | |
| t Stat | -20.05109846 | |
| P(T<=t) one-tail | 2.01107E-21 | |
| t Critical one-tail | 1.688297714 | |
| P(T<=t) two-tail | 4.02215E-21 | |
| t Critical two-tail | 2.028094001 | |

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# ACADEMIC VITA
## ALVARO RAMIRO PEREDO CENTELLAS

## EDUCATION

**The Pennsylvania State University** **University Park, PA**
*Smeal College of Business/Schreyer Honors College:* Finance May 2017
*Eberly College of Science:* Mathematics | Minor in Statistics

## WORK EXPERIENCE

**Morgan Stanley** **New York City, NY**
*Finance Summer Analyst* *Jun 2016-Aug 2016*

- Controlled the transfer of responsibilities of a weekly report presented to upper management from Corporate Reporting to the Financial Planning & Analysis division by carrying a report parallel to the one created by members of FP&A and cross-check for potential errors
- Reviewed financial statements from the supplementary packet and other documents to be released for the second quarter Press Release
- Cooperated with a team of six interns in order to create a knowledge information repository for the Regulatory Reporting group in order to facilitate communication about upcoming deadlines and instructions regarding appropriate filling of forms
- Presented the content of our knowledge information repository to about one hundred members of the Morgan Stanley community
- Programmed the knowledge information repository through HTML/CSS coding language with emphasis on being user friendly

**Inter-American Development Bank** **Washington, D.C.**
*Office of Outreach and Partnerships (ORP) Intern* *Jun—Aug 2015*

- Created a report on historical and future trends of concessional financing for development, with a focus on the role of development finance institutions and multilateral organizations, to be used as introductory material for new hired analysts in the bank
- Conducted reputational and financial risk analysis on 26 of the bank's potential partners as part of the due diligence process carried by the ORP Office and reported the results to their Sales Force account and to the department's chief
- Continued and interpreted a project left by a previous intern which had the objective to create a standardized grading system for measuring the desirability the bank has of partnering with an organization using the analytical hierarchy process
- Retrieved data from Sales Force and created statistical summaries regarding the whole set of about 400 due diligences created by the ORP office and presented them to the Non-sovereign activities office as an effort to outsource the risk analysis step from ORP

**Banco Mercantil Santa Cruz** **La Paz, Bolivia**
*Intern of Treasury and SAFI Investment Fund* *Jul— Aug 2013*

- Analyzed the compilation of norms for banks and financial institutions in the context of the current Bolivian laws in order to apply them on report generation for banking institutions to be presented to the fund manager
- Evaluated bonds and other investment options proposed by financial entities like Société Générale and Santander Bank along the specifications determined by the institutions regarding their desired levels of risk and return
- Produced and revised the annual financial reports for five investment funds which were presented to the Directive Board of the SAFI
- Developed the proposal for the creation of a new investment fund, revising the draft proposal in regards to the manager's specifications

## ACTIVITIES/LEADERSHIP

**Students Consulting For Non-Profit Organizations (SCNO)** **University Park, PA**
*Consultant/Member/Team Lead/V.P of Project Management* *Feb 2013 — May 2015*

- Directed a team of six consultants towards setting project goals, developing deliverables timeline, and determining responsibilities, to correctly plan, design, and implement the appropriate solution for our client
- Devised a cost data collection and analysis methodology which included relevant statistical information for Mount Nittany Health Medical Center as part of an umbrella project to implement profit analysis on Diagnosis Related Groups (D.R.G) in patient care
- Negotiated with and recruited six non-profits located in the Centre County of Pennsylvania to carry year-long projects with SCNO

**Hedge Fund Club** **University Park, PA**
*Member of Foreign Exchange Group* *Aug 2014 — Dec 2015*

- Collaborated with four other members in formulating strategies to gain profit from changes in the currency market, generating a 20% return in our group from a hypothetical nine million budget in a span of six months
- Researched economic, political and societal news along with economic indicators from developing countries such as Mexico, Russia, Turkey and South Africa in search for profit opportunities in foreign exchange between these countries and the US Dollar
- Learned and developed on concepts such as how economic indicators and monetary policy may affect the value of a country's currency along with a mathematical approach concentrating in using historical data to find statistical arbitrage between pair of currencies

**Alpha Kappa Lambda Fraternity** **University Park, PA**
*Vice President of Finance* *Nov 2013 — Dec 2014*

- Introduced a more intuitive system for recording and analyzing payments and expenses related to the fraternity's operating activities, allowing the executive board and member to have access to relevant information such as collection rate or capital allocation
- Coordinated payment options, billing cycles and schedule of charges between the fraternity members and our financial collaborator
- Served as member of the Fraternity's executive board, fundamental in decision making and planning in the organization
- Allocated a cash flow of approximately $100,000 toward different operational functions and expenses of importance for the fraternity

**Skills:** Fluent in Spanish and English; Familiar with C++, Python, R, @Risk, VBA, HTML/CSS, and SAS