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Stock Market Simulation

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Abstract

A fully automated stock market trading simulation was carried out over seven weeks using technical indicators and scripted timing strategies. The effectiveness of the individual strategies, and of this approach to automated trading in general, was assessed. The results were overwhelmingly favorable.

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1 Introduction

1.1 Project goals and scope

The main goal of this project is to learn about the effectiveness of automated trading in the stock market using technical indicator data and scripted timing strategies.

First we will retrieve open, high, low, and close (OHLC) price data from an Internet stock quote server. Next we will calculate the values of several technical indicators for each day of the simulation. We will write timing strategy scripts to generate buy/sell signals by modifying some well-known timing strategies. We would like to test the effectiveness of various combinations of the signals emitted by the various timing strategies so that we may have a greater chance of finding effective strategies. We will accomplish this by generating a set of portfolios which corresponds to the set of all possible unordered pairs of timing strategies. Each portfolio will use as its trade signal the average of the trade signals of its corresponding distinct pair of timing strategies. We will simulate these dual-strategy portfolios for seven weeks, measuring their performance with several statistics such as rate of return, maximum drawdown, etc. Finally we will survey the results and draw conjectures about the effectiveness of the timing strategies we used and of automated trading in general.

The trading simulation will run for seven weeks using a pool of 272 stocks for the portfolios to choose from. For each trading day, analysis will be carried out on the close prices of the previous day and trades will be carried out using the open prices of the next day. Commissions and other fees associated with trading are not part of the scope of this project. The amount of cash allocated to spending on each day will be made to be proportional to the momentum of the S&P500 index, ^GSPC, within a fixed range. A portfolio's worth will be assessed as the sum of its cash assets and the worth of its constituent stocks at the closing price on a given day.

1.2 History of Investment

The earliest forms of the stock market originated over one thousand years ago in the Middle East and Europe when businesses began selling bonds that promised repayment on a certain date plus interest. This proved to be an effective method for raising large amounts of money in short periods of time. That money could then be used to help the business expand or increase profits. This practice later evolved into companies selling “stock” or ownership in their company to the public. By buying stock in a company a person purchases a certain percentage of that company and based on the companies performance in the future he can either make or lose money. Although originally stock markets were open to the public, in today's marketplace individuals are only allowed to buy or sell stock through a “stockbroker.” A stockbroker is a person whose job it is to buy and trade stock on a particular market. They make money by taking commission from every stock that they sell. This method leaves open the potential for a broker to make vast amounts of money in little time.

There are many reasons why a company will allow shares of itself to be traded in the open market. First, it is an easy way to generate money quickly. Unlike taking out a loan, companies are not required to take back stock or pay any interest for selling them.

However, the more stocks a company sells to the public the less control it has over decisions. For example, if a company were to sell more than 51% of its shares then technically the public could override any decisions made by the executive branch of the company. Second, by putting themselves in the public market a company can take advantage of speculation on future performance. This can either greatly enhance or tarnish their reputation so there is possibility for fast growth. Third, many newly created businesses have the potential to expand quickly when provided with startup money from selling stocks. This allows investor's who are willing to take a risk on new companies to invest in them with the hope that the stock will soon rapidly increase in value.

In the United States, New York has always been the center for stock market trading. The first market to be set up in America was called the New York Stock Exchange and was founded in 1792. Businessmen across the country believed that this was the best way to transfer and defer the debt created by the war between England and the United States less than two decades earlier.

In today's economy there are many major stock markets in all areas of the world. Without an organized and efficient way to gather and display data it would be impossible to buy and trade stock correctly. Thanks to the invention of computers and the World Wide Web however databases can now be linked together to give brokers and investors endless amounts of data to search. This has revolutionized the pace at which the stock markets operate and increased the influence they have over world economies.

2 Investment Theory

2.1 Efficient Market Hypothesis

The efficient market hypothesis (EMH) asserts that financial markets are "informationally efficient", or that prices on traded assets, e.g., stocks, bonds, or property, already reflect all known information. The efficient-market hypothesis states that it is impossible to consistently outperform the market by using any information that the market already knows, except through luck. Information or news in the EMH is defined as anything that may affect prices that is unknowable in the present and thus appears randomly in the future. The EMH was developed by Professor Eugene Fama at the University Of Chicago Graduate School Of Business as an academic concept of study through his published Ph.D. thesis in the early 1960s at the same school. There are three common forms in which the efficient-market hypothesis is commonly stated: weak-form efficiency, semi-strong-form efficiency and strong-form efficiency, each of which has different implications for how markets work.

Weak-Form Efficiency

Excess returns cannot be earned by using investment strategies based on historical share prices. Technical analysis techniques will not be able to consistently produce excess returns, though some forms of fundamental analysis may still provide excess returns. Share prices exhibit no serial dependencies. This implies that future price movements are determined entirely by unexpected information and therefore are random.

Semi-Strong-form Efficiency

Share prices adjust to publicly available new information very rapidly and in an unbiased fashion, such that no excess returns can be earned by trading on that information. Semi-strong-form efficiency implies that neither fundamental analysis nor technical analysis techniques will be able to reliably produce excess returns. To test for semi-strong-form efficiency, the adjustments to previously unknown news must be of a reasonable size and must be instantaneous. To test for this, consistent upward or downward adjustments after the initial change must be looked for. If there are any such adjustments it would suggest that investors had interpreted the information in a biased fashion and hence in an inefficient manner.

Strong-Form Efficiency

Share prices reflect all information, public and private, and no one can earn excess returns. If there are legal barriers to private information becoming public, as with insider trading laws, strong-form efficiency is impossible, except in the case where the laws are universally ignored. To test for strong-form efficiency, a market needs to exist where investors cannot consistently earn excess returns over a long period of time. Even if some money managers are consistently observed to beat the market, no refutation even of strong-form efficiency follows: with hundreds of thousands of fund managers worldwide, even a normal distribution of returns (as efficiency predicts) should produce a few outliers.

2.2 Fundamental and Technical Analysis

Analysis of financial markets is often arbitrarily divided into two broad disciplines, known as fundamental analysis and technical analysis. Both forms of analysis are different approaches to the decision making process in the context of trading or investing in financial markets. In general terms, this process is about selecting markets and instruments in which to trade or invest and timing when to open and close trades or investments so as to maximize returns.

2.2.1 Fundamental Analysis

Fundamental analysis approaches the decision-making process by attempting to determine the intrinsic value of a financial instrument. Conventional wisdom indicates that the price of an instrument that is trading for less than its intrinsic value should rise and the price of an instrument that is trading for more than its intrinsic value should fall. Intrinsic value is estimated by examining the factors that affect supply and demand for whatever is underlying the financial instrument. For example: A company, a commodity, a currency, an interest rate or a market index. The fundamental analyst thus studies the causes of prices, or changes in prices, of financial instruments. Fundamental analysis tells us what ought to be the direction in which prices will move. A problem with fundamental analysis is that it assumes that information is disseminated perfectly and that it is acted on rationally. Practical observation of markets suggests that these assumptions do not necessarily hold in the real world, particularly in the short term. However, it is generally accepted that prices will move as indicated by intrinsic value over the longer term.

2.2.2 Technical Analysis

Technical analysis approaches the decision-making process by examining the market for the financial instrument itself. The data from the market are primarily the price, volume and, in futures markets, the open interest. Technical analysis is not concerned with the value of whatever underlies the financial instrument, but with how the forces of supply and demand impact its price. While they interact with each other, conceptually there are two separate markets associated with traded financial instruments. There is the market for the physical asset that underlies the financial instrument. There is also the market in the financial instrument itself. While prices in the market for the physical asset impact upon prices of the financial instruments, there can be significant differences — especially in equity markets where control of companies is not an active market compared to trading in shares in the company.

Fundamental analysis tends to the view that prices for a financial instrument are directly related to the intrinsic value of the asset underlying it. Technical analysis, on the other hand, recognizes that there are other forces at play that shape supply and demand for a financial instrument and cause its price to deviate significantly from a consistent relationship with the intrinsic value of the underlying asset. The technical analyst therefore studies changes in the level of supply and demand for the traded instrument directly, rather than indirectly via the factors affecting supply and demand for the underlying asset.

2.3 Modern Portfolio Theory

Modern portfolio theory (MPT) proposes how rational investors will use diversification to optimize their portfolios, and how a risky asset should be priced. The basic concepts of the theory are Markowitz diversification, the efficient frontier, capital asset pricing model, the alpha and beta coefficients, the Capital Market Line and the Securities Market Line. MPT models an asset's return as a random variable, and models a portfolio as a weighted combination of assets so that the return of a portfolio is the weighted combination of the assets' returns. Moreover, a portfolio's return is a random variable, and consequently has an expected value and a variance. Risk, in this model, is the standard deviation of return. The model assumes that investors are risk averse, meaning that given two assets that offer the same expected return, investors will prefer the less risky one. Thus, an investor will take on increased risk only if compensated by higher expected returns. Conversely, an investor who wants higher returns must accept more risk. The exact trade-off will differ by investor based on individual risk aversion characteristics. The implication is that a rational investor will not invest in a portfolio if a second portfolio exists with a more favorable risk-return profile – e.g., if for that level of risk an alternative portfolio exists which has better expected returns.

2.4 Capital Asset Pricing Model

Capital Asset Pricing Model (CAPM) is used in finance to determine a theoretically appropriate required rate of return of an asset, if that asset is to be added to an already well-diversified portfolio, given that asset's market risk (also known as systemic risk). The model takes into account the asset's sensitivity to market risk, often represented by the quantity beta in the financial industry, as well as the expected return of the market and the expected return of a theoretical risk-free asset. The model was introduced by Jack Treynor, William Sharpe, John Lintner and Jan Mossin independently, building on the earlier work of Harry Markowitz on diversification and modern portfolio theory. Sharpe received the Nobel Memorial Prize in Economics (jointly with Markowitz and Merton Miller) for this contribution to the field of financial economics. Once the expected return is calculated using CAPM, the future cash flows of the asset can be discounted to their present value using this rate to establish the correct price for the asset. In theory an asset is correctly priced when its observed price is the same as its value calculated using the CAPM derived discount rate. If the observed price is higher than the valuation, then the asset is overvalued (and undervalued when the observed price is below the CAPM valuation). Alternatively, one can "solve for the discount rate" for the observed price given a particular valuation model and compare that discount rate with the CAPM rate. If the discount rate in the model is lower than the CAPM rate then the asset is overvalued (and undervalued for a too high discount rate).

2.5 Arbitrage Pricing Theory

Arbitrage pricing theory (APT) is a general theory of asset pricing that has become influential in the pricing of shares. The theory was initiated by the economist Stephen

Ross in 1976. APT holds that the expected return of a financial asset can be modeled as a linear function of various macro-economic factors or theoretical market indices, where sensitivity to changes in each factor is represented by a factor-specific beta coefficient. The model-derived rate of return will then be used to price the asset correctly - the asset price should equal the expected end of period price discounted at the rate implied by model. If the price diverges, arbitrage should bring it back into line.

2.6 CAPM vs APT

The APT along with the CAPM is one of two influential theories on asset pricing. The APT differs from the CAPM in that it is less restrictive in its assumptions. It allows for an explanatory (as opposed to statistical) model of asset returns. It assumes that each investor will hold a unique portfolio with its own particular array of betas, as opposed to the identical "market portfolio". In some ways, the CAPM can be considered a "special case" of the APT in that the securities market line represents a single-factor model of the asset price, where beta is exposed to changes in value of the Market. Additionally, the APT can be seen as a "supply side" model, since its beta coefficients reflect the sensitivity of the underlying asset to economic factors. Thus, factor shocks would cause structural changes in the asset's expected return, or in the case of stocks, in the firm's profitability. On the other side, the capital asset pricing model is considered a "demand side" model. Its results, although similar to those in the APT, arise from a maximization problem of each investor's utility function, and from the resulting market equilibrium (investors are considered to be the "consumers" of the assets).

2.7 Dow Theory

Dow Theory is a heterodox theory on stock price movements that is used as the basis for technical analysis. The theory was derived from 255 Wall Street Journal editorials written by Charles H. Dow, journalist, founder and first editor of the Wall Street Journal and co-founder of Dow Jones and Company. Following Dow's death, William P. Hamilton, Robert Rhea and E. George Schaefer organized and collectively represented "Dow Theory," based on Dow's editorials. Dow himself never used the term "Dow Theory," nor presented it as a trading system. There are six tenets of Dow Theory: the market has three movements, trends have three phases, the stock market discounts all news, stock market averages must confirm each other, trends are confirmed by volume, and trends exist until definitive signals prove that they have ended. Even though this theory is well documented, there is little academic support for the profitability of the Dow Theory.

3 Investment Types

3.1 Types of Stockbrokers

There are three main types of stockbrokers that an individual may use. The first, called a discretionary dealer, is best for individuals who either have little knowledge of the stock market, or do not have the time needed to properly invest their money themselves. This type of broker takes money from an individual and decides which stocks to buy and which to sell when he sees fit. At the end of the day he can report back to the individual with either a loss or a gain. The second type of broker is called an advisory dealer. This type of broker will recommend decisions to his / her clients based on what he thinks will benefit them the most, however, he does not directly buy or sell without his / her client's consent. Finally, execution dealers are brokers whose only job is to buy and sell stock when told to do so. They generally do not advise their clients and only act when told to.

3.2 Types of Stock

In today's economy there are many different types of stocks that can be traded. The first and most widely traded by individuals are “common” stock. These stocks are often the riskiest to buy but have potential to pay more than most other sectors of the market. If the company does well, the stock will become more valuable. However, if the company goes bankrupt, the stock will be worthless. Another type of stock is called “preferred” stock. These shareholders generally are not able to make decisions for the company, but collect payments based on the companies’ performance. In exchange, if the company goes bankrupt, preferred stockholders are paid back before common stockholders.

Furthermore, companies are allowed to customize stocks to include different levels of voting powers. It is through this method that companies can distribute more stocks of itself while at the same time keeping voting powers to a smaller, more centralized group of people.

Mutual funds are one way of investing in the stock market. This method is often best for people who do not want to take much risk with their money and do not mind seeing only mild return rates. Their money is pooled with other investors' money and spread through diverse sectors of the market. Mutual funds have vast amounts of stocks that are invested and traded and so investors try to make small gains across the market. This method is not very risky because there are so many stocks in the portfolio that for the most part the losses and gains balance out at the end of the day and the investor is left with either a little profit or a little loss. However, this portion of the market is one of the biggest, worth over $25 trillion dollars. There are many different types of mutual funds in today's world. These include, among others, equity funds, bond funds, money market funds, and hedge funds.

Another investment option is bonds. Bonds are certificates that promise to pay a person a certain amount of debt with an additional interest added onto it. This is a classic and easy way for governments to finance huge operations while deferring debt payments until a later date. Bonds can be issued by companies as well as governments. While some bond trading is risky, generally any bond issued by a major government is almost guaranteed to make the investor some money as interest is paid every six or twelve months. Although there are too many bond types to list the major ones include treasury bonds, municipal bonds, war bonds, lottery bonds, and fixed rate bonds. Another type called high yield bonds is one of the riskier types of bonds because they are more often defaulted on. However it is also one that can make investors more money if paid off.

Another generally low risk way of investing is investment in certificates of deposit. Using this method, an individual will deposit a certain amount of money into a bank with the agreement that this individual will not withdraw the money before a certain amount of time has passed. Because the individual is willing to leave the money deposited for an extended period of time, he / she earns a higher interest rate than on a normal deposit. In the meantime the bank has a greater amount of spending money to invest with and make money on.

3.3 Other Investment Markets

Besides the stock market there are many other types of markets open to investors. These include money markets and derivatives markets. Derivatives markets are markets that buy and sell derivatives. One market in this category is the futures market. In this market investors try to predict if a company will grow or shrink in the future and buy contracts that promise the stock will be sold on a later date for a specific amount of money. Using this method companies can defer their debt by putting it on investors, and can use available funds to make more money off these investments before repurchasing the stock for the set price. Another type of contract in the derivatives market is called the options contract. These contracts give the buyer the right to sell his / her shares back at a future date but do not force him / her to do so. Other derivatives markets include over-the-counter derivatives, and exchange traded derivatives.

Whereas the derivatives market is focused more on long term investments, others focus rather on short term buying and selling by brokers. The money market is another type of market that offers relatively low risk investment options with small return rates. In money markets short term contracts are traded between people who wish to borrow money and those who wish to lend it out. Commercial paper, bankers' acceptances, treasury bills, and other contracts are included in the trading. Because of the large amount of cash flow in these markets, they are comprised largely of banks and other institutions who lend money. Because they are trading with other banks and large corporations, this market is relatively safe. The return rate on money markets, however, is generally only around 1.5%.

4 Stock selection

4.1 Stock selection strategy

In today's market there are many methods that an investor can use to create a list of stocks that he or she believes will be profitable. The efficient market hypothesis (EMH) states that because the day-to-day fluctuations of a market are random, there is no method for choosing stocks that can guarantee future profit. However, there are many methods for categorizing stocks based on various values that an investor believes is important. By performing fundamental analysis techniques using variables important to an investor it is possible to determine a stock's intrinsic value. Intrinsic value is how much an investor believes a certain stock is worth. It can be calculated using quantitative characteristics of a stock such as the company's cash flow statistics, qualitative characteristics of the company, or some combination thereof.

4.1.2 Quantitative fundamental analysis

Choosing stocks is made simpler with quantitative fundamental analysis because an investor can compare the intrinsic value with the market value and decide whether or not a stock is worth purchasing. If the intrinsic value is significantly higher than the market value of a stock then it is a good idea to purchase the stock and hope that the value will rise. Although different methods of fundamental analysis prioritize cash flow variables differently, they all rely on a company's cash flow analysis. The basic equation used in quantitative fundamental analysis of stocks is the discounted cash flow equation:

$$DCF = \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_n}{(1+r)^n}$$

r: discount rate
CF: cash flow

Figure 1: Discounted Cash Flow equation

The equation above essentially states that a company's future worth can be determined by how much money the company will make through various cash influxes, called the discounted cash flows versus future time value of money and inflation. Some important variables that are taken into account when performing fundamental analysis on a stock are: the prior year's cash flow, which shows how much money the company returned to investor's in the previous year; cash flow, which is the amount of profit made by the company that could in theory be completely returned to stockholders; growth rate, which is a one to five year prediction on how much a company will expand and if their sector of the market is expected to grow or shrink; discount factor and discount per year, five year value and five year cash return, which are also predictions on how the company will perform in five years; as well as many others. Because there is more than one method for performing fundamental analysis, it is up to the investor to determine which variables are most important and which are not.

4.1.3 Qualitative fundamental analysis

Although many investors use different numbers and variables to determine a certain company's worth there are always other non-mathematical, human factors that affect how a stock performs. These factors must be taken into account when deciding upon whether or not to invest in a stock. Both speculation about future events and the publics perception of a company can enhance that company's reputation which will increase its market value. If a company has been in the public eye for a long time and is a household name then even during tough times it will receive support from the public and can keep a high market value because investors know that the company is relatively stable and that based on past stability will rise again at some point in the future.

However, at the same time these two factors can tarnish a company’s reputation and cause stock prices to drop. If there is speculation of management problems, upcoming layoffs, or other bad signs and investors begin selling shares, stock prices will drop and even slow trends can pick up speed rapidly causing devastating monetary losses.

Another factor that can greatly affect a company's market value is the strength of the management team in charge. The more involved an investor is with a company the better information he / she receives about its well being and can make better guesses about future performance. By knowing who manages the company an investor can better understand how decisions will be made and which way management will fall on certain issues. By examining personal histories of important company workers such as the chief financial officer (CFO), chief information officer (CIO), chief operating officer (COO), and chief executive officer (CEO), an investor can better understand what the company's future will hold.

If management has a strong background and is filled with dedicated people then there is a better chance they will make decisions that will help drive their market price up. The addition of a strong-minded and previously successful CEO can cause a company's market share to increase just based on the fact that the CEO performed well in previous years. However, if management is weak and filled with people that do not work well together then important issues will not be taken care of quickly and opportunities for growth can slip by. Also, the mere fact that management is weak will look bad in the public view and regardless of whether or not the company could be successful there will not be much public interest to start this upward trend.

Finally, another major factor that can affect a company is previous momentum. A couple of examples of this are the housing market industry and the computer boom age of the 1990's. Both sectors of the market saw tremendous increases in value and profits that steadily climbed for years straight. However, the reason market value for shares in the tech industry and housing industry were increasing was not that company's were making vast amounts of money, but rather the fact that in previous years the market was rising and so speculators believed this period of growth would continue for years on end. Driven by this speculation prices kept increasing and investors thought these two sectors of the market were guaranteed to bring profit if invested in. They became backbone investments for millions of people and growth was exponential. However, once the public began to realize that prices were being driven by speculation and profits were not nearly as high as expected, prices rapidly dropped and within a short period of time many large companies had lost everything. These are two examples of how speculation can drive whole sectors of the market for years on end and then quickly burst the bubble, causing investors to lose everything.

4.2 Stock categorization

It is important that a portfolio is diversified so that it experiences minimal unsystematic risk. In order to diversify, however, it is necessary to identify how to partition a market into categories. We will use two categorizations: market sector and market capitalization (market cap). By selecting stocks with diverse market cap in diverse sectors of the market during the screening process, we will create a pool of stocks that has strong diversity.

A market sector is a subset of a market which participates in a particular type of industry. For example, the S&P 500 is divided into the following sectors [http://www.sectorspdr.com]: energy, consumer discretionary, consumer staples, financial, health care, industries, materials, technology, and utilities. This categorization is significant because often the general trend of a sector will both reflect and feed back into the performance of its constituent stocks. To avoid losses on a portfolio that has stocks in a poorly performing sector, the portfolio should contain a significant number of stocks outside that sector.

Market capitalization (cap) is a measure of the current worth of a company, obtained by multiplying its share price by its number of shares. The stock of companies with large market cap (large-cap stocks) tends to behave differently from small-cap stocks. Large-cap stocks are well established, and thus are often less volatile and more strongly correlated with the market or market sector. To help avoid high volatility or low returns, a portfolio should contain stocks with various market caps.

5 Trading Strategy

Although random factors such as emotion and intuition can play a large role in investors' trading practices, those factors alone cannot be relied upon to provide consistent results. Many investors therefore incorporate trading strategies with strict rules into their practices. These rules can be based on calculations of expected return, risk, volatility, correlations, and subjective or calculated tolerances for these calculated factors.

It is helpful to express trading strategies in terms of portfolio management. Expressed in this context, a trading strategy attempts to determine the best set of assets for a portfolio at every point in time for a given trading frequency. Trading frequency—the frequency of purchases or sales of assets in a portfolio—can vary from minutes to months or even years. A strategy can specify rules for managing the overall contents of a portfolio, the amount of each asset for a predetermined set of assets, or the trades in an individual asset.

One common rule for constructing a good portfolio is diversification. Since a portfolio is a subset of all of the assets in a market, the efficient market hypothesis states that the best return one can expect from a portfolio in the long term is the overall return of the market. Modern portfolio theory (MPT) and its derivatives describe methods of using diversification to minimize the risk for a desired rate of return and to construct the portfolio that maximizes the ratio of expected return versus risk. This “market portfolio” is, according to MPT, the best portfolio that a rational investor can have.

Another popular class of portfolio management rules is based on technical analysis. The main principle of technical analysis is that future asset prices can be forecast from past prices. Strategies based on technical analysis use past price data to determine when to buy or sell certain assets. The methods can range from intuition-based pattern recognition to statistical or numerical analysis.

5.1 Modern Portfolio Theory

One method of optimizing our portfolio is the Markowitz Model. This model proposes how rational investors will use diversification to optimize their portfolios, and how a risky asset should be priced. The basic concepts of the theory are Markowitz Diversification, the Efficient Frontier, Capital Asset Pricing Model, and the Capital Market Line. We consider an asset's return as a random variable, and model a portfolio as a weighted combination of assets so that the return of a portfolio is the weighted combination of the assets' returns. Moreover, a portfolio's return is a random variable, and consequently has an expected value and a variance. Risk, in this model, is the standard deviation of return.

The model assumes that investors are risk adverse, meaning that given two assets that offer the same expected return, investors will prefer the less risky one. Thus, an investor will take on increased risk only if compensated by higher expected returns. Conversely, an investor who wants higher returns must accept more risk. The exact trade-off will differ by investor based on individual risk aversion characteristics. The implication is that a rational investor will not invest in a portfolio if a second portfolio exists with a more favorable risk-return profile – i.e., if for that level of risk an alternative portfolio exists which has better expected returns. It is further assumed that investor's risk / reward preference can be described via a quadratic utility function. The effect of this assumption is that only the expected return and the volatility (mean return and standard deviation) matter to the investor. The investor is indifferent to other characteristics of the distribution of returns, such as its skew (measures the level of asymmetry in the distribution) or kurtosis (measure of the thickness).

An investor can reduce portfolio risk simply by holding instruments which are not perfectly correlated. In other words, investors can reduce their exposure to individual asset risk by holding a diversified portfolio of assets. Diversification will allow for the same portfolio return with reduced risk. Portfolio volatility is a function of the correlation ρ of the component assets. The change in volatility is non-linear as the weighting of the component assets changes. Volatility is mathematically represented by the square root of the portfolio variance (i.e., the standard deviation).

Every possible asset combination can be plotted in risk-return space, and the collection of all such possible portfolios defines a region in this space. The line along the upper edge of this region is known as the efficient frontier. Combinations along this line represent portfolios (explicitly excluding the risk-free alternative) for which there is lowest risk for a given level of return. Conversely, for a given amount of risk, the portfolio lying on the efficient frontier represents the combination offering the best possible return.

Mathematically the Efficient Frontier is the intersection of the Set of Portfolios with Minimum Variance and the Set of Portfolios with Maximum Return. The efficient frontier will be convex – this is because the risk-return characteristics of a portfolio change in a non-linear fashion as its component weightings are changed (i.e., the quadratic utility function is positive definite). The efficient frontier is a parabola (hyperbola) when expected return is plotted against variance (standard deviation). The region above the frontier is unachievable by holding risky assets alone. No portfolios can be constructed corresponding to the points in this region. Points below the frontier are suboptimal. A rational investor will hold a portfolio only on the frontier.

The Capital Allocation Line (CAL) is the line of expected return plotted against risk (standard deviation) that connects all portfolios that can be formed using a risky asset and a riskless asset. It has been shown that there is only one point of tangency lying on both the efficient frontier and CAL, and will be our optimal portfolio choice. A quantity known as the Sharpe ratio represents a measure of the amount of additional return (above the risk-free rate) a portfolio provides compared to the risk it carries. The portfolio on the efficient frontier with the highest Sharpe Ratio is known as the market portfolio, or sometimes the super-efficient portfolio, which is our optimal portfolio. This portfolio has the property that any combination of it and the risk-free asset will produce a return that is above the efficient frontier—offering a larger return for a given amount of risk than a portfolio of risky assets on the frontier would.

When the market portfolio is combined with the risk-free asset, the result is the Capital Market Line. All points along the CML have superior risk-return profiles to any portfolio on the efficient frontier. Just the special case of the market portfolio with zero cash weighting is on the efficient frontier. Additions of cash or leverage with the risk-free asset in combination with the market portfolio are on the Capital Market Line. All of these portfolios represent the highest possible Sharpe ratio, but only one sufficiently minimizes the risky assets.

5.2 Technical Analysis

Technical analysis is a class of financial analysis techniques that seeks to forecast future asset prices from past prices. Classical technical analysts study price charts and attempt to recognize patterns in the charts which signal a time to buy or sell a certain asset. More recently this has been augmented with mathematical techniques involving moving averages, regressions, and correlations with other assets. A popular way to define technical analysis strategies is to define an indicator whose value determines whether to buy, sell, or keep an asset, given the asset's past price data. We will focus on these strategies since they are easily quantifiable.

5.2.1 Momentum

Momentum, as it applies to us, is the rate of acceleration of a stock's price or volume [1]. Once a momentum trader sees an acceleration in a stock's price, earnings, or revenues, the trader will often take a long or short position in the stock with the hope that its momentum will continue in either an upwards or downwards direction. Momentum traders may hold their positions for a few minutes, a couple of hours or even the entire length of the trading day, depending on how quickly the stock moves and when it changes direction. The timing strategies for momentum investing are to buy when a stock is “hot”, which we define as being above 0 for at least 3 days, and selling “cold” stocks, which are below zero.

Example timing strategies:

Buy:

- Momentum crosses up through zero and remains above for 3 days

Sell:

- Momentum crosses down through zero

5.2.2 Linear regression angle

The linear regression angle approximates the direction and magnitude of a stock’s current price movement. It is directly proportional to the slope of a linear regression model of the price data, which fits a linear equation to the price’s movement [2]. The direction is determined by the sign of the tangent of this angle, negative implying a decrease, 0 being stable and positive implying an increase. The angle can be used to predict a future price movement based on a significant change in direction in its recent movement.

Example timing strategies:

Buy:

- Angle crosses up through -10°, 0°, or 10°

Sell:

- Angle crosses down through -10°, 0°, or 10°

5.2.3 Directional Indicators

The Directional Indicator is a momentum indicator which attempts to quantify the trending or directional behavior of a market. It helps identify trends which help to determine whether or not price is moving strongly enough to be worth a long or short play. It can help traders take a profit out of the middle of significant trends. A Directional Indicator is defined as the largest part of the current period price range which lies outside the previous period price range. If the larger excess is above the previous period high, it is considered a Positive Directional Indicator, or +DI [3]. If the larger part of the current range is below the previous period low, it is considered a Negative Directional Indicator, or -DI [4].

Example timing strategies:

Buy:

- +DI crosses up through -DI

Sell:

- -DI crosses up through +DI

5.2.4 Bollinger bands

Bollinger Bands are used to measure the highness or lowness of the price relative to previous trades. Bollinger Bands consist of a middle band being an N-period simple moving average, an upper band at K times an N-period standard deviation above the middle band, and a lower band at K times an N-period standard deviation below the middle band [5]. Typical values for N and K are 20 and 2, respectively. The default choice for the average is a simple moving average, but other types of averages can be employed as needed, such as the exponential moving average.

Example timing strategies:

Buy:

- Price falls to lower band
- Price rises above upper band

Sell:

- Price touches center band
- Price falls below lower band

5.2.5 Keltner Bands

The Keltner Bands indicator is centered on an n-period exponential moving average of the closing price. The channels are created by adding (for the upper channel) and subtracting (for the lower channel) a (n-period simple moving average of an n-period ATR) * (an ATR multiplier) [6]. Keltner Bands define a smoothed range based on volatility (using ATR as the baseline). Keltner Bands are similar to Bollinger Bands except that Keltner uses an ATR volatility method whereas Bollinger Bands use a standard deviation method.

Example timing strategies:

Buy:

- Price falls below lower channel

Sell:

- Price rises above upper channel
- Price rises above center channel

5.2.6 Relative Strength Index

Another class of indicators uses moving averages of the positive price changes (ups) and negative price changes (downs) of an asset to assess the "strength" of the asset. One popular indicator of this type is the ratio of the exponential moving average (EMA) of ups to the sum of the EMAs of ups and downs. When this ratio is multiplied by 100, it is called the Wilder Relative Strength Index (RSI) [7]. A common strategy is to sell if the RSI is above a certain threshold (70-80 is popular) and to buy if it is below a certain threshold (20-30 is popular). The rationale for this is that if the RSI is high, then the asset is likely overbought, and vice versa. Some investors vary their thresholds upward if they perceive a bull market, or downward if they perceive a bear market. A variation called Cutler's RSI takes the ratio of the simple moving average (SMA) of ups to the SMA of downs. Its signals are usually only slightly different from the Wilder RSI, but it is easier to compute.

Example timing strategies:

Buy:

- RSI rises above 30 or 50
- RSI rises above 30 or 50 and the SMA has positive slope
- RSI rises above 30 or 50 and the SMA has negative slope

Sell:

- RSI falls below 70 or 50
- RSI falls below 70 or 50 and the SMA has negative slope
- RSI falls below 70 or 50 and the SMA has positive slope

5.2.7 Moving Average Convergence/Divergence

One of the simplest types of indicators is the moving average indicator, usually using an exponential moving average. A simple moving average indicator may signal "buy" if the asset's price crosses up through the moving average, or "sell" if the price crosses down. Another type of moving average indicator uses the difference between two moving averages taken at different periods. This indicator has a special name, Moving Average Convergence/Divergence (MACD) [8]. It is common to take the difference of 12-day and 26-day moving averages, then take the difference of that value and its 9-day moving average as the indicator. Since MACD is a lagging indicator, in the sense that its trends follow the price trends of the asset, its effectiveness is limited to situations where the momentum of the asset price is a primary factor in its future price. By itself MACD tends to give negative returns in general, but some investors incorporate it into their strategies by using multiple MACD indicators with various timeframes or by filtering the buy/sell commands given by the indicator.

Example timing strategies:

Buy:

- MACD crosses up through zero
- MACD crosses up through zero and remains above for 2 days
- MACD histogram crosses up through zero
- MACD histogram crosses up through zero and remains above for 2 days
- Positive divergence between MACD and price
- Positive divergence between MACD histogram and price

Sell:

- MACD crosses down through zero
- MACD crosses down through zero and remains below for 3 days
- MACD histogram crosses down through zero
- MACD histogram crosses down through zero and remains below for 3 days
- Negative divergence between MACD and price
- Negative divergence between MACD histogram and price

5.2.8 Aroon oscillator

Yet another class of indicators compares the "strength" of uptrends and downtrends. The Aroon(up) indicator starts at a given point in time (time 0) and measures the strength of an asset's uptrend at time X as (100 * [1 - (time elapsed since highest price up to time X) / X]). The Aroon(down) indicator similarly measures the strength of the asset's downtrend. The Aroon oscillator is defined as the difference between Aroon up and Aroon down, and ranges from -100 to +100 [9]. One strategy for using the Aroon oscillator is as follows. When the Aroon oscillator is above 70 or below -70, the current up or down trend (respectively) is likely to continue. When the oscillator dips below 50 or rises above -50, this signals that the trend is likely to stop soon. When the oscillator crosses the zero line, the current trend is likely to change to the opposite trend. Investors using the Aroon oscillator will buy, sell, or keep their assets appropriately according to these trend predictions.

Example timing strategies:

Buy:

- Oscillator crosses up through zero
- Oscillator crosses up through -50 and crosses zero within 3 days

Sell:

- Oscillator crosses down through zero
- Oscillator crosses down through 50 and crosses zero within 3 days

5.2.9 Chaikin oscillator

The Chaikin Oscillator is simply the Moving Average Convergence Divergence indicator (MACD) applied to the Accumulation/Distribution Line [10]. The formula is the difference between the 3-day exponential moving average and the 10-day exponential moving average of the Accumulation/Distribution Line. Just as the MACD-Histogram is an indicator to predict moving average crossovers in MACD, the Chaikin Oscillator is an indicator to predict changes in the Accumulation/Distribution Line. In correspondence with the timing strategies we have that there are two bullish signals that can be generated from the Chaikin Oscillator: positive divergences and centerline crossovers. There are also two bearish signals that can be generated from the Chaikin Oscillator: a negative divergence and a bearish centerline crossover.

Example timing strategies:

Buy:

- Oscillator crosses up through zero

Sell:

- Price breaks through upper price channel and oscillator obtains negative slope within 5 days

6 Simulation Planning

6.1 Simulation goals

We are interested in comparing the effectiveness of various strategies for portfolio management based on technical analysis. In particular, we would like to compare these strategies' performance with a fixed, diverse set of stocks to choose from, in trading schemes with both medium- and long-term trading intervals. In addition, we would like to compare the effectiveness of combinations of multiple strategies taken together.

6.2 Simulation design

Prior to starting the simulation we choose a pool of 272 stocks from diverse sectors of the market and with diverse market capitalization. We then create a portfolio for each possible unordered pair of buy strategy and sell strategy, out of the timing strategies listed in Section 5.2. With twenty timing strategies, twenty single-strategy portfolios and 190 unordered dual-strategy portfolios are possible, for a total of 210 portfolios. Please see Appendix I for the complete list of portfolios with corresponding timing strategy pairs.

We simulate these portfolios for seven weeks. At the end of each trading day the next day's trade signals are generated for each stock in the stock pool from indicator data computed for the current day, using the close price as the last available price information. Once the trade signals are all generated for a given day, Algorithm 1 converts these signals to buy and sell requests of integer quantities of shares. These requests are carried out on the next day, using the open price of the stock as the simulated buying and selling price. This cycle repeats until a full history of the portfolios over 32 trading days is generated.

6.3 Simulation procedure

Prior to starting the simulation we generate a list of 210 portfolios and assign to each one a distinct unordered pair of buy signal type and sell signal type. We initialize each portfolio with $100,000 cash and no stock. On each trading day we execute the following algorithm:

1. Retrieve open, high, low, and close (OHLC) price data for each stock.
2. For each stock compute each technical analysis indicator using the close price.
3. For each stock in the stock pool and each trading signal type, compute the trading signal—a floating-point value from -1 to 1—using the indicator data, as prescribed by the timing strategies. Values [-1, 0) are “sell” signals, (0, 1] are “buy” signals, and 0 is a “stay”.
4. For each portfolio P, determine the final trading signal for each stock S in the stock pool. Denote the membership of S in P as $P[S]$. Let b be the buy signal value and s be the sell signal value for $P[S]$. Compute the final signal $t(P[S])$:
   - If $b > 0$ and $s \geq 0$ then let $t(P[S]) = b$.
   - If $b \leq 0$ and $s \geq 0$ then let $t(P[S]) = 0$.

- If $b \leq 0$ and $s < 0$ then let $t(P[S]) = s$.
- If $b > 0$ and $s < 0$ then let $t(P[S])$ equal the signal value which most recently crossed 0.

5. For each portfolio *P* and each stock *S*, denote the quantity of *P*[*S*], in shares, as $q(P[S])$. Sell the appropriate amount of *S* if $t(P[S]) < 0$:
   - If $q(P[S]) = 0$ then do nothing.
   - If $q(P[S]) > 0$ then sell $-t(P[S]) * q(P[S])$ shares of S by subtracting them from $q(P[S])$, converting them to their cash value, and adding that to $q(P[cash])$.
6. For each portfolio *P* let the spending cash $c(P) = r * worth(P)$, for a predetermined spending ratio *r*. Let *sum* equal the sum of each $t(P[S])$, for all $t(P[S]) > 0$.
7. When the market opens on the next trading day, let *price*(*S*) be the opening share price of *S*. For each portfolio *P* and each stock *S*, buy $t(P[S]) * c(P) / (sum * price(S))$ shares of *S* by subtracting their cash value from $q(P[cash])$ and adding them to $q(P[S])$.

Algorithm 1: The core simulation algorithm

We repeat this procedure for each day of the simulation, recording the state of each portfolio on each day. We measure the weekly and cumulative performance of each portfolio every week using rate of return, variance, maximum drawdown, Sharpe ratio, Jensen's alpha, and Treynor ratio.

6.4 Simulation logistics

To assist us in simulating 210 portfolios trading stocks from a pool of 272 companies (see Section 6.5.2), we use Qtstalker [11], a stock charting program, and KInvestSim [12], an investment simulator program.

Qtstalker, an open source technical analysis and stock charting tool, provides us with a means to retrieve daily quote data and automatically compute technical analysis indicators on each of our stocks. The price and indicator data can then exported to an XML file for use by e.g. KInvestSim. With Qtstalker one can also create “backtest rules” which can generate buy and sell signals, but it provides no method of easily automating these rules on hundreds of stocks, nor any method of combining buy and sell signals from different rules.

KInvestSim, an open source investment simulator, allows us to import the price and indicator data generated by Qtstalker, write scripts which generate buy and sell signals, and simulate multiple portfolios in parallel by applying combinations of the trade signals. The simulation results are then viewable for all portfolios along with measures of rate of return, variance, market covariance, beta, maximum drawdown, Sharpe ratio, Jensen's alpha, and Treynor ratio. Various tables of results are also exportable as comma-separated value (CSV) files, which can be imported into most spreadsheet software.

6.4.1 KInvestSim screenshots

Investment: ^GSPC

Date	+DI	-DI	AroonOsc	BBC	BBL	BBU	ChaikinOsc	Close	DIR	High	KBC	KBL	KBU	LinearReg	nearR
2008-07...	10.2215	37.6806	-71.4286	1289.68	1257.07	1322.29	-3.6768...	1284.91	-81.2897	1285.31	1299.83	1279.52	1320.14	1274.91	-82.8
2008-07...	11.4876	33.7549	-71.4286	1277.59	1260.88	1294.31	-4.1150...	1261.52	-82.4924	1292.17	1292.78	1271.73	1313.83	1264.86	-83.2
2008-07...	10.7236	34.7551	-85.7143	1273.54	1254.52	1292.56	-3.7976...	1262.9	-82.5045	1271.48	1285.89	1264.95	1306.83	1260.44	-76.6
2008-07...	9.5542	34.6787	-92.8571	1268.33	1243.94	1292.72	-3.8266...	1252.31	-82.39	1273.95	1278.14	1256.33	1299.96	1251.75	-80.3
2008-07...	8.6728	31.2255	-92.8571	1267.07	1244.65	1289.49	-1.6282...	1273.7	-81.3684	1274.17	1272.11	1249.61	1294.61	1254.04	-74.6
2008-07...	8.7793	28.0746	-85.7143	1259.02	1239.28	1278.77	-2.2173...	1244.69	-81.4003	1277.36	1267.3	1244.07	1290.53	1247.99	-78.6
2008-07...	8.2108	28.6775	-100	1257.4	1237.41	1277.39	-1.1563...	1253.39	-80.2404	1257.65	1264.18	1241.11	1287.24	1250.27	-64.6
2008-07...	7.4202	29.3581	-100	1252.72	1229.39	1276.04	-8.6182...	1239.49	-80.2835	1257.27	1259.11	1235.42	1282.81	1243.73	-76.2
2008-07...	6.7916	26.9722	-85.7143	1247.91	1217.44	1278.39	-1.9928...	1228.3	-80.2817	1253.5	1252.04	1228	1276.08	1234.74	-80.7
2008-07...	6.1264	31.4273	-92.8571	1236.16	1209.41	1262.9	-2.6177...	1214.91	-80.4572	1234.35	1246.21	1221.47	1270.96	1224.19	-84.4
2008-07...	8.6796	28.411	-92.8571	1236.29	1209.37	1263.21	-5.1144...	1245.36	-77.4657	1245.52	1244.02	1218.6	1269.43	1228.69	-74.1
2008-07...	12.9479	26.7259	-85.7143	1237.68	1206.93	1268.42	2.2922e...	1260.32	-74.3227	1262.31	1245.02	1219.93	1270.11	1235.84	47.99
2008-07...	12.5468	25.898	-57.1429	1241.91	1205.94	1277.88	4.49441...	1260.68	-69.5007	1262.23	1243.39	1219.35	1267.43	1243.45	81.43
2008-07...	13.7797	24.9367	-57.1429	1248.25	1212.95	1283.56	4.56578...	1260	-59.1567	1267.74	1245.31	1222.12	1268.49	1248.83	83.57
2008-07...	15.5203	22.775	-57.1429	1260.67	1240.64	1280.7	6.08856...	1277	3.4875	1277.42	1248.26	1224.69	1271.83	1263.95	84.36
2008-07...	19.0693	21.7041	-57.1429	1268.04	1248.88	1287.2	5.75553...	1282.19	50.3928	1291.17	1253.59	1230.63	1276.56	1274.87	81.47
2008-07...	17.236	27.0628	42.8571	1266.48	1244.08	1288.89	3.27649...	1252.54	55.6558	1283.22	1256.62	1233.03	1280.22	1275.24	50.61
2008-07...	16.6138	26.0859	42.8571	1265.9	1242.78	1289.02	2.03441...	1257.76	57.4076	1263.23	1261.98	1239.26	1284.71	1274.69	-42.2
2008-07...	15.2828	29.4097	42.8571	1260.77	1226.18	1295.37	-2.1417...	1234.37	59.2017	1260.09	1260.61	1237.67	1283.55	1262.82	-80.7
2008-07...	14.8864	26.8163	42.8571	1258.01	1227.02	1289	8.62221...	1263.2	61.3636	1263.2	1260.97	1237.61	1284.33	1257.9	-80.4
2008-07...	20.4249	25.0713	42.8571	1258.43	1226.13	1290.72	2.92446...	1284.26	70.2959	1284.33	1263.92	1240.71	1287.12	1263.71	28.41
2008-07...	19.4038	23.5881	42.8571	1261.39	1229.08	1293.71	2.05423...	1267.38	69.5163	1284.93	1264.84	1241.94	1287.74	1264.56	79.14
2008-08...	18.4149	26.0311	42.8571	1261.9	1229.75	1294.06	1.09731...	1260.31	61.8401	1270.52	1262.75	1240.35	1285.16	1262.66	75.23
2008-08...	17.6256	27.2459	42.8571	1264.83	1241.9	1287.76	-4.9820...	1249.01	8.7734	1260.49	1258.6	1236.87	1280.34	1256.73	53.70
2008-08...	23.3009	24.176	35.7143	1269.17	1241.42	1296.92	-7.1766...	1284.88	17.7105	1284.88	1262.65	1239.9	1285.39	1267.2	-7.19
2008-08...	24.3093	22.959	50	1270.15	1240.08	1300.23	3.17593...	1289.19	42.8295	1291.67	1266.57	1244.34	1288.81	1279.76	62.00
2008-08...	24.3093	22.959	50	1270.15	1240.08	1300.23	3.17593...	1289.19	42.8295	1291.67	1266.57	1244.34	1288.81	1279.76	62.00
2008-08...	23.4021	22.1522	64.2857	1277.09	1242.61	1311.58	3.80343...	1296.32	54.6393	1297.85	1274.68	1251.3	1298.06	1287.05	81.54

Figure 2: Indicator data viewer for ^GSPC

Date	Momentum	Close	Open	Trade Signal
2008-07-14	-50.08	1228.3	1241.61	▼ -1
2008-07-15	-65.09	1214.91	1226.83	▼ -1
2008-07-16	-39.55	1245.36	1214.65	▼ -1
2008-07-17	-1.2001	1260.32	1246.31	▼ -1
2008-07-18	-2.22	1260.68	1258.22	▼ -1
2008-07-21	7.6899	1260	1261.82	▲ 0.122062
2008-07-22	3.3	1277	1257.08	▼ -0.864868
2008-07-23	37.5	1282.19	1278.87	0
2008-07-24	-0.85	1252.54	1283.22	▼ -1
2008-07-25	18.27	1257.76	1253.51	▲ 0.290516
2008-07-28	6.0699	1234.37	1257.76	▼ -0.992207
2008-07-29	48.2899	1263.2	1236.38	0
2008-07-30	38.9	1284.26	1264.52	▼ -1
2008-07-31	7.0601	1267.38	1281.37	▼ -1
2008-08-01	-0.37	1260.31	1269.42	▼ -1
2008-08-04	-10.99	1249.01	1253.27	▼ -1
2008-08-05	7.88	1284.88	1254.87	▲ 0.122657
2008-08-06	7	1289.19	1283.99	▼ -0.171967
2008-08-07	7	1289.19	1283.99	0
2008-08-08	38.5599	1296.32	1266.29	0
2008-08-11	70.95	1305.32	1294.42	0
2008-08-12	1.5699	1285.83	1288.64	▼ -1
2008-08-14	25.55	1292.93	1282.11	0
2008-08-15	37.8899	1298.2	1293.85	0

Figure 3: Timing strategy tester results for Momentum strategy on ^GSPC

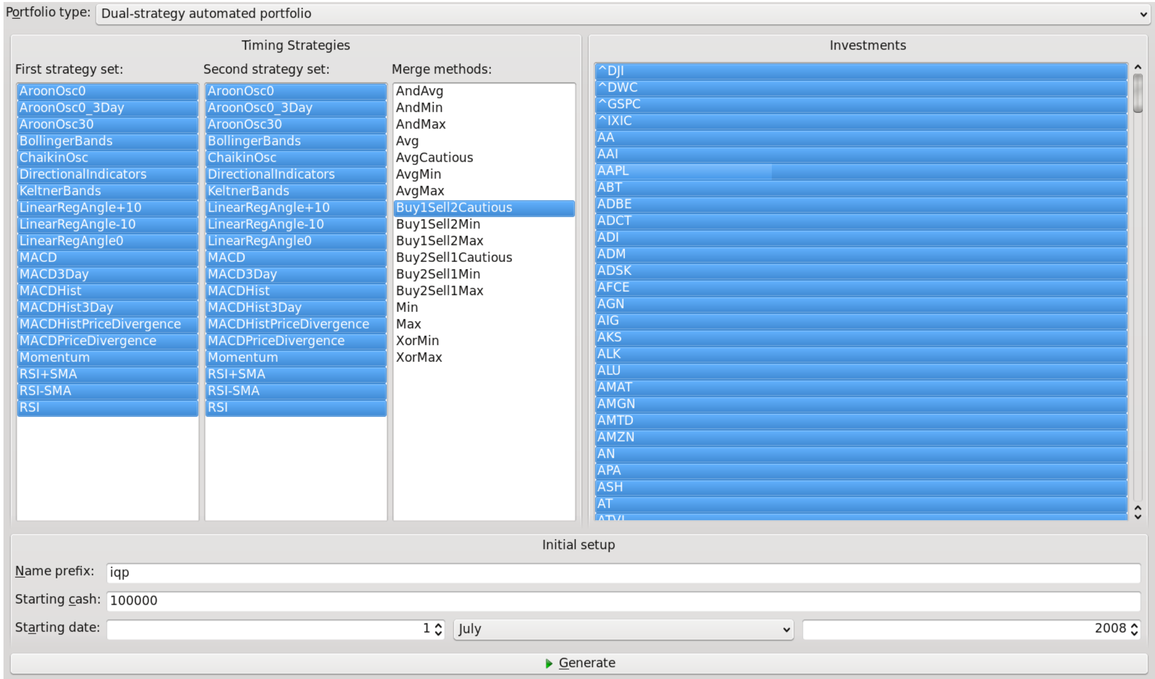

Figure 4: Generating the portfolios for our simulation

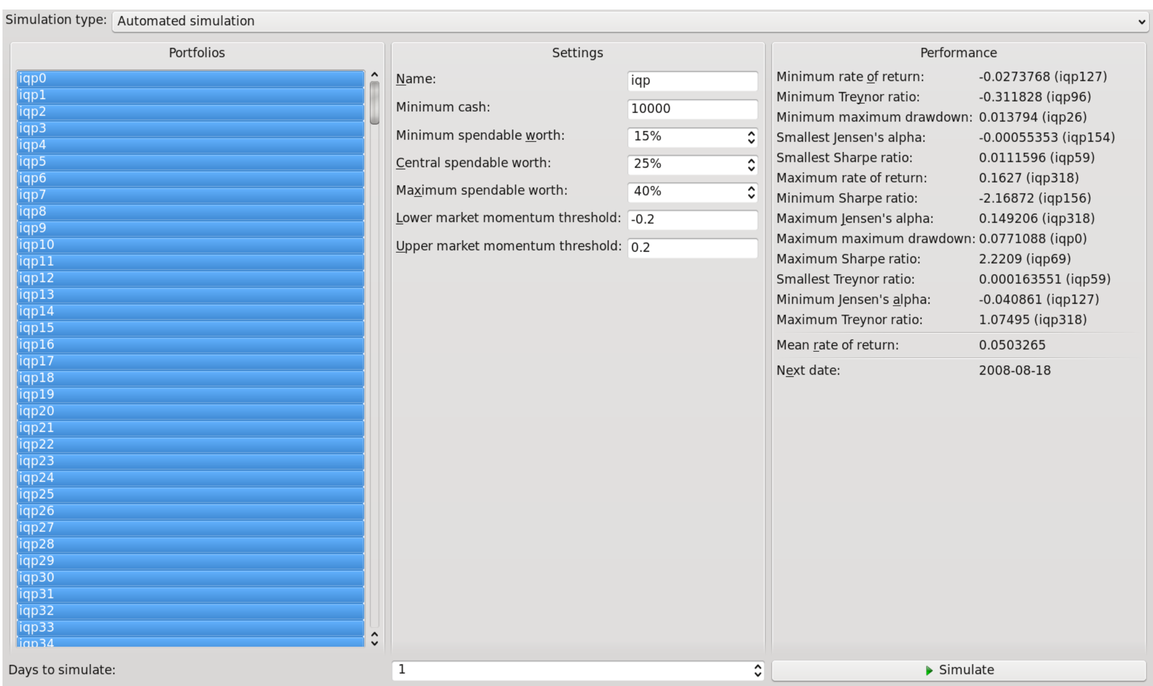

Figure 5: The simulation controller

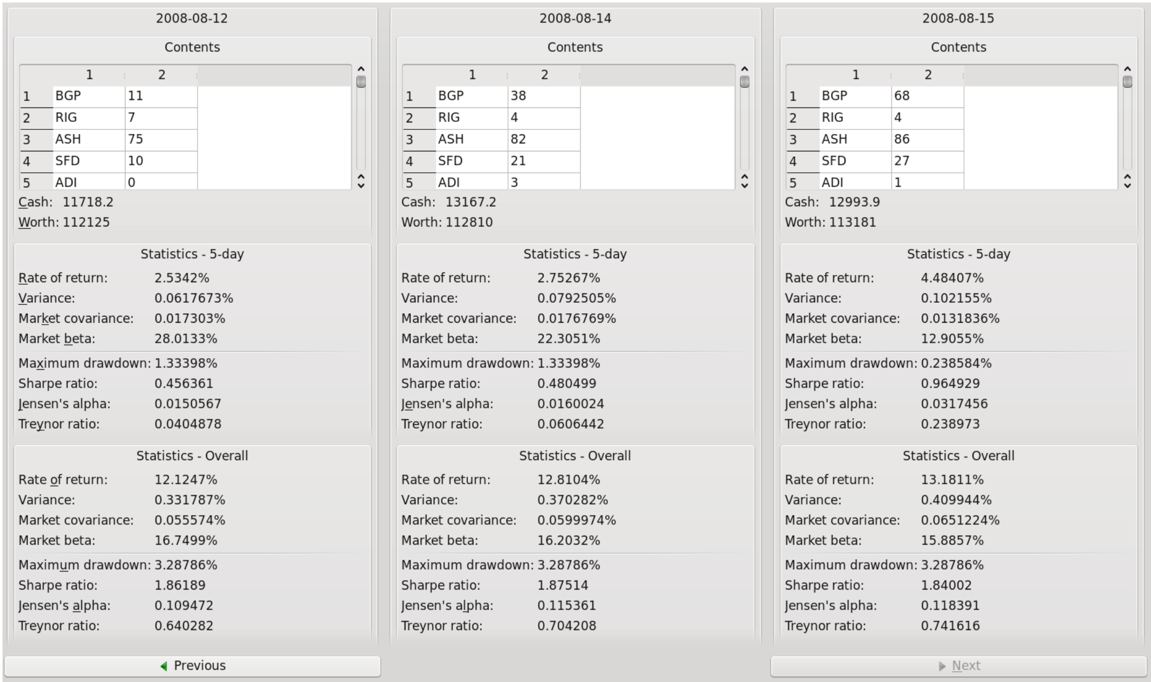

Figure 6: Viewing the last three days of portfolio 'iqp187'

6.5 Stock screening and selection

6.5.1 Market sectors

Energy

Figure 7: XLE one-year history [Source: http://finance.google.com/]

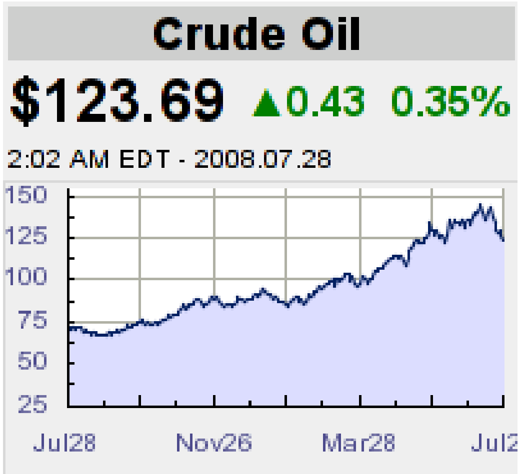

Figure 8: Crude oil prices one-year history [Source: http://www.oil-price.net/]

Includes:
- Oil
- Natural Gas
- Power Plants
- Exploration Equipment

The Energy Sector of the stock market is a group of stocks that specialize in either supplying or generating energy. This category includes companies that supply or run power stations, that deal with examining and exploring for new oil fields that operate to extract and refine oil, and other similar tasks. In recent years the demand for energy has been steadily increasing, and this increase in demand has also caused prices for power and oil to increase. This increase has affected many other sectors of the market because in today's global economy where products are shipped and refined in many different countries before they are sold to consumers, travel expenses which never used to be an issue are now major issues. This has lowered consumer confidence and put a strain on millions of middle and lower class citizens who are struggling to pay increased travel expenses. Unfortunately oil is a necessary commodity and with no fix in sight global economies will continue to be controlled by it. Stock prices in recent months have been slowly rising as demand remains high for energy. Oil prices while recently reaching new records in the $140's in the past month have begun to drop as speculation about future availability is getting better.

Consumer Discretionary

Figure 9: XLY one-year history [Source: http://finance.google.com/]

<u>Includes:</u>
- Automotive
- Clothing Manufacturing
- Home Construction
- Hotels
- Restaurants

The consumer sector of the market is comprised of industries such as entertainment, housing, automotive, sales, clothing, and restaurants that provide non-life-essential items to the public. This sector of the market is heavily dependent upon consumer happiness and economic stability. When confidence is high consumers spend more on luxury items and things they do not necessarily need. On the contrary when consumer confidence is low and there is talk of a recession, such as in today's economy, people generally tend to save what money they make and limit luxurious spending. Automobile sales drop and the airline industry loses money because people do not want to travel or vacation. In order to deal with this companies will begin to lay off nonessential personnel and will work hard to cut costs and close weak performing parts of themselves. Because of high oil prices in the past few years consumer cyclical spending has been declining steadily. Stock prices in recent months have lost on average 30%. This sector is also known as the "consumer non-cyclical" sector.

Consumer Staples

Figure 10: XLP one-year history [Source: http://finance.google.com/]

Includes:
- Alcoholic Beverage
- Cosmetics & Personal Care
- Food
- Health Care Providers
- Household Products
- Medical Supplies
- Pharmaceuticals
- Tobacco

In this category are companies that produce and sell items needed for everyday life. Commodities such as food, health care, alcohol, tobacco, medical supplies, and pharmaceuticals are all considered staples to everyday life and fall under this category.

Because living conditions have remained relatively unchanged in the past year stock prices have changed little. This is a steady sector that is relatively safe to invest into because even in times of recession and hardship people will always buy essential everyday items. This sector is also known as the "consumer cyclical" sector.

Financial

Figure 11: XLF one-year history [Source: http://finance.google.com/]

<u>Includes:</u>
- Banks
- Insurance
- Securities Brokers

One of the hardest hit sectors of the market in the past year has been the financial sector. Comprised of banks, securities brokers, and insurance companies, mortgages and loans are where most of the money in this sector is invested. Consequently, because of lack of oversight in this sector and due to bad lending practices the United States has lost considerable amounts of wealth in the past year. The housing market bubble burst and prices have been sharply declining after years of growth. These falling prices are coupled with increased mortgage rates as banks try to fight off foreclosures all over the country. Homeowners are finding that their houses are worth less than the amount of money they owe in mortgage payments and are choosing to walk away. Also, the amount of unpaid loans has skyrocketed and banks and financial institutions have faced billions of dollars in losses. Earlier in the year one of the major financial institutions, Bear Stearns, almost collapsed after it was revealed that billions of dollars had been lost by the company due to its heavy investments in subprime mortgages. More recently, the two biggest companies in this sector, Fannie Mae and Freddie Mac have also been on the verge of collapsing and measures are being taken now to try and rescue them before it happens. There is no quick fix in sight and so prices will most likely continue to fall.

Basic Materials

Figure 12: XLB one-year history [Source: http://finance.google.com/]

Includes:
- Raw materials processing
- Mining / Refining
- Chemical Producers
- Forestry

The materials sector is made up of companies that explore, discover, excavate, and process raw material deposits. This includes raw minerals, metals, wood, chemicals, and other materials which are used to produce finished goods. After the raw materials have been excavated they are refined in various factories before being shipped off to manufacturers to be used to make products and pharmaceuticals. This sector relies heavily on business cycles and consumer confidence. Consequently prices are more volatile than many other sectors and while there has been overall growth in the past year, it has not come without temporary losses. The basic materials sector also relies heavily on construction companies.

Technology

Figure 13: XLK one-year history [Source: http://finance.google.com/]

Includes:
- Communications
- Computers
- Office Equipment
- Semiconductors (computer chips)
- Software

The technology sector is a category comprised of companies that deal with development, research, or distribution of any technologically based product or a service for the product. All computer, communications, office supply, computer hardware, and computer software companies are included in this sector. Computers and entertainment systems have been getting better and faster over the years and with new products every few months, retailers have been generating billions of dollars in revenues. By continuously creating newer and better products this sector is insured of repeat customers and promises to remain strong. Competition has increased in the past year with new software and hardware companies forming, and there have been many increases in computing recently. Although prices have dropped in recent months this sector usually recovers well and stock prices should begin to increase again soon.

Utilities

Figure 14: XLU one-year history [Source: http://finance.google.com/]

Includes:
- Electrical
- Telephone
- Natural Gas Delivery
- Water

Another important sector of the market is the Utilities sector which includes water companies, electric companies, and gas companies. The cost to run these companies is enormous and they are subject to carrying very large amounts of debt. However, because they are staples in everyday life it is in their best interests to keep costs steady and prices level so as not to anger the public. Due to the amount of money needed to run these plants they often need to borrow it from lenders, and so prices rise and fall according to interest rates on these loans. Due to rising oil and gas prices, costs have significantly increased for utility companies in recent years. However, the need to keep utility costs affordable has put even more strain on these companies to operate more efficiently and restructure themselves to lower costs. In the coming years analysts predict that the need for clean water will increase dramatically, so the companies providing this commodity may become more significant as time goes on.

Health Care

Figure 15: XLV one-year history [Source: http://finance.google.com/]

Health Care has become an important issue in the last year and is becoming more important each day. Hundreds of billions of dollars are invested into this sector annually and the number keeps rising. With the presidential election in the fall this sector is poised for changes in the coming years. Whether health care will become universal or government subsidized remains to be seen, but it is clear that unless changes are made it will become unsustainable if left unchanged. Each year costs have increased while coverage levels have remained the same. As a result stock prices have started to decline in the last few months.

Transportation

Figure 16: DJT one-year history [Source: http://finance.google.com/]

<u>Includes:</u>
- Airfreight Services
- Airlines
- Railroads
- Ocean-going Shipping
- Trucking

The transportation industry is made up of companies that transport products or people to various places. This sector is made up of railroad companies, trucking companies, airline companies, and shipping companies. It affects every other sector of the market due to the fact that in today's society packages and products are expected to move around the globe. However, transportation costs have been rising steadily for the past few years. Since 2001 oil has skyrocketed in price and gasoline and jet fuel prices have quadrupled. The effects have been increased prices for many necessary commodities and have forced consumers to charge more for products.

Conglomerates

Figure 17: GE one-year history [Source: http://finance.google.com/]

Figure 18: MMM one-year history [Source: http://finance.google.com/]

A conglomerate is a corporation that owns enough stock in smaller subsidiary companies to control management and the decisions made by them. Most conglomerates try to diversify and own companies in different sectors of the market to minimize risk. However, some have become successful by staying in only one. Although the smaller businesses are each run individually they are still controlled by the senior companies' management team. While many conglomerates still exist today, they reached their peak in the 1960's and 1970's and since then have begun to break up.

Industrial

Figure 19: XLI one-year history [Source: http://finance.google.com/]

<u>Includes:</u>
Heavy Machinery
Electrical Equipment
Engineering
Construction
Aerospace & Defense

The industrial sector relies on large contracts that are often government funded. It is comprised of heavy machinery, electrical equipment, engineering, construction, and aerospace & defense companies. This sector of the market relies on big government and large corporations that have billions of dollars in contracts. Engineers create a variety of products and perform many services that generate revenue for companies. With the ongoing conflicts the United States is engaged in the defense and aerospace industry has been booming in the past few years. The government continues to fund hundreds of billions of dollars in defense contracts for new missiles and aircrafts each year and will continue to do so. However, because many of these companies rely on billion dollar contracts any change in the economy could trigger a decline in demand for capital goods which will cause stock prices to fall. This sector is also known as the capital goods sector.

6.5.2 Stock pool

By selecting stocks from the top, middle, and bottom (in terms of market capitalization) of each market sector, we created the following stock pool for our simulation:

Basic Materials

AA	Alcoa Inc. (NYSE)
AKS	AK Steel Holding Company (NYSE)
ASH	Ashland Inc. (NYSE)
CMC	Commercial Metals Company (NYSE)
DD	E.I. Du Pont de Nemours & Company (NYSE)
DOW	The Dow Chemical Company (NYSE)
FCX	Freeport-McMoRan Copper & Gold Inc. (NYSE)
HUN	Huntsman Corporation (NYSE)
IP	International Paper Company (NYSE)
LTR	Latitude Resources plc
MT	ArcelorMittal (NYSE) (ADR)
PPG	PPG Industries, Inc. (NYSE)
PTV	Pactiv Corporation (NYSE)
SIAL	Sigma-Aldrich Corporation (NASDAQ)
SLR	Solitario Exploration & Royalty Corp.
SSCC	Smurfit-Stone Container Corporation (NASDAQ)
USU	USEC Inc. (NYSE)
VTSS	Vitesse Semiconductor
X	United States Steel Corporation (NYSE)

Industrial

BA	The Boeing Company (NYSE)
CAT	Caterpillar Inc. (NYSE)
GR	Goodrich Corporation (NYSE)
HIT	Hitachi Ltd. (NYSE) (ADR)
IR	Ingersoll-Rand Company Limited (NYSE)
LMT	Lockheed Martin Corporation (NYSE)

Conglomerates

GE	General Electric Company (NYSE)
MMM	3M Company (NYSE)

Consumer Discretionary

BWA	BorgWarner Inc. (NYSE)
DAI	Daimler AG (NYSE)
F	Ford Motor Company (NYSE)

GM	General Motors Corporation (NYSE)
HMC	Honda Motor Co. Ltd. (NYSE) (ADR)
LEA	Lear Corporation (NYSE)
LIZ	Liz Claiborne Inc. (NYSE)
MVL	Marvel Entertainment Inc. (NYSE)
NKE	NIKE Inc. (NYSE)
NSANY	Nissan Motor Co. Ltd. (NASDAQ) (ADR)
TM	Toyota Motor Corporation (NYSE) (ADR)
TRW	TRW Automotive Holdings Corp. (NYSE)
VC	Visteon Corporation (NYSE)
WHR	Whirlpool Corporation (NYSE)

Consumer Staples

ADM	Archer Daniels Midland Company (NYSE)
BTI	British American Tobacco (AMEX) (ADR)
BUD	Anheuser-Busch Companies Inc. (NYSE)
CAG	ConAgra Foods Inc. (NYSE)
CCE	Coca-Cola Enterprises Inc. (NYSE)
CL	Colgate-Palmolive Company
CLX	The Clorox Company
CPB	Campbell Soup Company
DF	Dean Foods Company (NYSE)
FLO	Flowers Foods Inc. (NYSE)
GIS	General Mills Inc. (NYSE)
HNZ	H.J. Heinz Company (NYSE)
HSY	The Hershey Company (NYSE)
ITY	Imperical Tobacco Group PLC (NYSE) (ADR)
K	Kellogg Company (NYSE)
KFT	Kraft Foods Inc. (NYSE)
KO	The Coca-Cola Company (NYSE)
MO	Altria Group Inc. (NYSE)
PEP	PepsiCo, Inc. (NYSE)
PG	The Procter & Gamble Company (NYSE)
PM	Philip Morris International Inc. (NYSE)
SFD	Smithfield Foods, Inc. (NYSE)
SLE	Sara Lee Corp. (NYSE)
TSN	Tyson Foods, Inc. (NYSE)
TUP	Tupperware Brands Corporation (NYSE)
UL	Unilever plc (NYSE) (ADR)

Energy

APA	Apache Corporation (NYSE)
COP	ConocoPhillips (NYSE)
CVX	Chevron Corporation (NYSE)
DVN	Devon Energy Company (NYSE)
HAL	Halliburton Company (NYSE)

MUR	Murphy Oil Corporation (NYSE)
NE	Noble Corporation (NYSE)
OXY	Occidental Petroleum Corporation (NYSE)
RIG	Transocean Inc. (NYSE)
SLB	Schlumberger Limited (NYSE)
SUN	Sunoco, Inc. (NYSE)
TSO	Tesoro Corporation (NYSE)
XOM	Exxon Mobil Corporation (NYSE)

Financial

AIG	American International Group Inc. (NYSE)
AMTD	TD Ameritrade Holding Corp. (NASDAQ)
BAC	Bank of America Corporation (NYSE)
C	Citigroup Inc. (NYSE)
CMA	Comerica Incorporated (NYSE)
DJ	Dow Jones & Co. Inc.
GLD	SPDR Gold Trust (NYSE) (ETF)
GS	Goldman Sachs Group Inc. (NYSE)
JPM	JP Morgan Chase Co. (NYSE)
LEH	Lehman Brothers Holdings Inc. (NYSE)
MER	Merrill Lynch & Co. Inc. (NYSE)
MS	Morgan Stanley (NYSE)
SBC	Brompton Split Banc Corp.
SCHW	The Charles Schwab Corporation (NASDAQ)
UNH	UnitedHealth Group Inc. (NYSE)
WB	Wachovia Corporation (NYSE)
WFC	Wells Fargo & Company (NYSE)

Health Care

ABT	Abbot Laboratories (NYSE)
AGN	Allergan Inc. (NYSE)
AMGN	Amgen Inc. (NASDAQ)
BAX	Baxter International Inc. (NYSE)
GENZ	Genzyme Corporation (NADSAQ)
GILD	Gilead Sciences Inc. (NASDAQ)
GLH	Global Health Ltd.
GSK	GlaxoSmithKline plc (NYSE) (ADR)
HGSI	Human Genome Sciences (NASDAQ)
IMCL	ImClone Systems Incorporated (NASDAQ)
JNJ	Johnson & Johnson (NYSE)
MLNM	Millennium Pharmaceuticals I (NASDAQ)
MRK	Merck & Co. Inc. (NYSE)
MYGN	Myriad Genetics Inc. (NASDAQ)
NVS	Novartis AG (NYSE) (ADR)
PDLI	PDL BioPharma Inc. (NASDAQ)
PFE	Pfizer Inc. (NYSE)

RDY	Dr. Reddy's Laboratories Limited (NYSE) (ADR)
SEPR	Sepracor Inc. (NASDAQ)

Services

AFCE	AFC Enterprises (NASDAQ)
AMZN	Amazon.com Inc. (NASDAQ)
AN	Autonation Inc. (NYSE)
AZO	Autozone Inc. (NYSE)
BBY	Best Buy Co. Inc. (NYSE)
BGP	Borders Group Inc. (NYSE)
BJ	BJ's Wholesale Club Inc. (NYSE)
BKC	Burger King Holdings Inc. (NYSE)
CBRL	CBRL Group Inc. (NASDAQ)
CBS	CBS Corporation (NYSE)
CC	Circuit City Stores Inc (NYSE)
CCU	Clear Channel Communications Inc. (NYSE)
CHTR	Charter Communications Inc. (NASDAQ)
COST	Costco Wholesale Corporation (NASDAQ)
CRA	Celera Group, Applera Corp. (NYSE)
CVS	CVS Caremark Corporation (NYSE)
DIS	The Walt Disney Company (NYSE)
DISH	DISH Network Corp. (NASDAQ)
DRI	Darden Restaurants Inc. (NYSE)
DTV	The DIRECTV Group Inc. (NASDAQ)
EBAY	eBay Inc. (NASDAQ)
EMMS	Emmis Communications Corporation (NASDAQ)
EXPE	Expedia Inc. (NASDAQ)
FTE	France Telecom SA (NYSE) (ADR)
GPS	The Gap Inc. (NYSE)
HD	The Home Depot Inc. (NYSE)
IPG	Interpublic Group of Companies Inc. (NYSE)
JBX	Jack in the Box Inc. (NYSE)
JCP	J.C. Penney Company Inc. (NYSE)
KKD	Krispy Kreme Doughnuts (NYSE)
KR	The Kroger Co. (NYSE)
LDG	Longs Drug Stores Corp. (NYSE)
LOW	Lowe's Companies Inc. (NYSE)
M	Macy's Inc. (NYSE)
MCD	McDonald's Corporation (NYSE)
MGM	MGM Mirage (NYSE)
MNST	Monster Worldwide Inc. (NASDAQ)
NFLX	Netflix Inc. (NASDAQ)
NTT	Neotel International Inc.
NWS	NEWS Corp. (NYSE)
ODP	Office Depot Inc. (NYSE)

OMC	Omnicom Group Inc. (NYSE)
PETM	Petsmart Inc. (NASDAQ)
Q	Qwest Communications International Inc. (NYSE)
RAD	Rite Aid Corporation (NYSE)
ROIA	Radio One Inc. (NASDAQ)
RSH	RadioShack Corporation (NYSE)
S	Sprint Nextel Corporation (NYSE)
SBUX	Starbucks Corporation (NASDAQ)
SIRI	Sirius Satellite Radio Inc. (NASDAQ)
SPLS	Staples Inc. (NASDAQ)
SWY	Safeway Inc. (NYSE)
T	AT&T Inc. (NYSE)
TEF	Telefonica S.A. (NYSE) (ADR)
TGT	Target Corporation (NYSE)
TRB	Tribal Group plc
TWX	Time Warner Inc. (NYSE)
USM	United States Cellular Corporation (AMEX)
VIA	Viacom, Inc. (NYSE)
VOD	Vodafone Group Plc (NYSE) (ADR)
VZ	Verizon Communications Inc. (NYSE)
WAG	Walgreen Company (NYSE)
WEN	Wendy's International (NYSE)
WFMI	Whole Foods Market, Inc. (NASDAQ)
WMG	Warner Music Group Corp. (NYSE)
WMK	Weis Markets, Inc. (NYSE)
WMT	Wal-Mart Stores, Inc. (NYSE)
XMSR	XM Satellite Radio Holdings Inc. (NASDAQ)
YHOO	Yahoo! Inc. (NASDAQ)
YUM	Yum! Brands, Inc. (NYSE)

Technology

AAPL	Apple Inc. (NASDAQ)
ADBE	Adobe Systems Inc. (NASDAQ)
ADCT	ADC Telecommunications (NASDAQ)
ADI	Analog Devices Inc. (NYSE)
ADSK	Autodesk Inc. (NASDAQ)
ALU	Alcatel-Lucent (NYSE)
AMAT	Applied Materials Inc. (NASDAQ)
ATVI	Activision Inc. (NASDAQ)
BRCM	Broadcom Corporation (NASDAQ)
CA	CA Inc. (NASDAQ)
CAJ	Canon Inc. (NYSE) (ADR)
CHKP	Check Point Software Technologies Ltd. (NASDAQ)
CMCA	ComCam Inc.
CNXT	Conexant Systems Inc. (NASDAQ)

COMS	3Com Corporation (NASDAQ)
CPWR	Compuware Corporation (NASDAQ)
CRUS	Cirrus Logic Inc. (NASDAQ)
CSC	Computer Sciences Corporation (NYSE)
CSCO	Cisco Systems Inc. (NASDAQ)
DELL	Dell Inc. (NASDAQ)
DT	Deutsche Telekom AG (NYSE) (ADR)
EDS	Electronic Data Systems Corporation (NYSE)
ELNK	EarthLink Inc. (NASDAQ)
EMC	EMC Corporation (NYSE)
ENR	Energizer Holdings Inc. (NYSE)
ERIC	Telefonaktiebolaget LM Ericsson (NASDAQ) (ADR)
ERTS	Electronic Arts Inc. (NASDAQ)
FLEX	Flextronics International Ltd. (NASDAQ)
GLW	Corning Incorporated (NYSE)
GOOG	Google Inc. (NASDAQ)
HPQ	Hewlett-Packard Company (NYSE)
IBM	International Business Machines Corp. (NYSE)
INTC	Intel Corporation (NASDAQ)
JAVA	Sun Microsystems Inc. (NASDAQ)
JNPR	Juniper Networks Inc. (NASDAQ)
LLTC	Linear Technology Corporation (NASDAQ)
LSI	LSI Corporation (NYSE)
MOT	Motorola Inc. (NYSE)
MSFT	Microsoft Corporation (NASDAQ)
MU	Micron Technology Inc. (NYSE)
NOK	Nokia Corporation (NYSE) (ADR)
NOVL	Novell Inc. (NASDAQ)
NT	Nortel Networks Corporation (NYSE) (USA)
NVDA	NVIDIA Corporation (NASDAQ)
ORCL	Oracle Corporation (NASDAQ)
PCLN	Priceline.com Incorporated (NASDAQ)
PLXS	Plexus Corp. (NASDAQ)
QCOM	QUALCOMM, Inc. (NASDAQ)
RHAT	Red Hat, Inc. (NYSE)
RIMM	Research In Motion Limited (USA) (NASDAQ)
RMBS	Rambus Inc. (NASDAQ)
SAP	SAP AG (NYSE) (ADR)
SNDK	SanDisk Corporation (NASDAQ)
SSTI	Silicon Storage Technology, Inc. (NASDAQ)
STX	Seagate Technology (NYSE)
SYMC	Symantec Corporation (NASDAQ)
TER	Teradyne, Inc. (NYSE)
THQI	THQ Inc. (NASDAQ)

TTWO	Take-Two Interactive Software, Inc. (NASDAQ)
TXN	Texas Instruments Incorporated (NYSE)
UIS	Unisys Corporation (NYSE)
UNTD	United Online, Inc. (NASDAQ)
VRSN	Verisign, Inc. (NASDAQ)
WDC	Western Digital Corp. (NYSE)
XRX	Xerox Corporation (NYSE)
Transportation	
AAI	AirTran Holdings (NYSE)
ALK	Alaska Air Group Inc.
DAL	Delta Air Lines Inc. (NYSE)
JBLU	JetBlue Airways Corporation (NASDAQ)
LCC	US Airways Group Inc. (NYSE)
LUV	Southwest Airlines Co. (NYSE)
NWA	Northwest Airlines Corporation (NYSE)
UNP	Union Pacific Corporation (NYSE)
Utilities	
D	Dominion Resources Inc. (NYSE)
DUK	Duke Energy Corporation (NYSE)
EP	El Paso Corporation (NYSE)
EXC	Exelon Corporation (NYSE)

Figure 20: Stock pool for the simulation

6.6 Timing Strategies

The investment simulator used in this simulation, KInvestSim, features a multilanguage scripting interface to implement timing strategies. Each script must implement two functions: *requiredIndicators*() and *tradeSignal*(). KInvestSim uses the output of *requiredIndicators*(), an array of indicator names, to provide the script with the indicator data it requires. Then KInvestSim calls *tradeSignal*(), which can be any computation that returns a floating-point value in [-1, 1].

Initially we planned on using the example timing strategies listed in sections 5.2.1-5.2.9, as they are well-known strategies requiring at most a few calculations, provided that the necessary indicator data is already available. However, after testing them we found them to be either too liberal, too conservative, or simply ineffective, at anticipating trends and acting on those anticipations. Consequently we made a number of modifications to the original scripts which appeared to improve their performance. Our full list of scripts is given in Appendix III.

7 Simulation Results

After running the simulation for 32 trading days we have gathered a wealth of statistical data on the portfolios' progress and performance. The full record of trades for all portfolios can be found in the file "portfolio-trades.csv" [13]. The portfolios averaged almost 87 trades per day per portfolio. Thus it is infeasible to provide here a fully detailed walkthrough of even a single day of one portfolio. Instead, Section 7.1 reviews the weekly progress of six portfolios arbitrarily chosen from the whole set. Section 7.2 analyzes the distributions of each of the final statistics of the 210 portfolios.

7.1 Weekly portfolio tracking

Six portfolios have been arbitrarily chosen from the set of 200 used in the simulation. This section provides weekly (every five trading days) tracking of these portfolios' five-day statistics. That is, each row of the tables below provides statistics on the portfolio's performance during the previous five days.

7.1.1 Portfolio 'iqp2'

Date	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
07/09/08	-0.045859%	0.000519%	0.001138%	2.192140	-6.345090	0.084849	-0.006596
07/16/08	-0.122780%	0.004994%	0.005561%	1.113490	-2.154730	-0.000238	-0.013676
07/23/08	3.606570%	0.023077%	0.018914%	0.819609	1.452530	0.009301	0.026922
07/30/08	-1.990970%	0.031577%	0.020545%	0.650619	-1.908260	-0.025851	-0.052119
08/06/08	1.215990%	0.015679%	0.005107%	0.325749	-0.146957	0.001470	-0.005649
08/15/08	4.138880%	0.070988%	0.014288%	0.201272	1.027970	0.028800	0.136079

Table 1: Weekly five-day statistics for 'iqp2'

This portfolio used the AroonOsc0 strategy and the MACD strategy for its buy and sell signals. Over the seven trading weeks its variance steadily went up, and with it so did the rate of return. The portfolio beta decreased steadily, allowing the portfolio to reach an overall return of 5.0309% by the end of the simulation. On the other hand, its alpha, Sharpe ratio, and Treynor ratio fluctuated too much to allow a strong positive rate of return to develop. The full record of trades for this portfolio is found in the file "portfolio-trades.csv" [13] at lines 4849-7618.

7.1.2 Portfolio 'iqp15'

Date	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
07/09/08	-1.071120%	0.001686%	0.002860%	1.696740	-6.018810	0.052154	-0.014564
07/16/08	0.480273%	0.008675%	0.006348%	0.731788	-0.987489	0.000654	-0.012568
07/23/08	6.343690%	0.056054%	0.022385%	0.399349	2.088090	0.043218	0.123794
07/30/08	-1.930930%	0.077019%	0.031039%	0.403004	-1.200240	-0.028318	-0.082653
08/06/08	-0.723413%	0.010818%	0.004543%	0.419940	-2.041530	-0.016967	-0.050565
08/15/08	2.166230%	0.022744%	0.012250%	0.538607	0.508073	0.011439	0.014226

Table 2: Weekly five-day statistics for 'iqp15'

This portfolio used the DirectionalIndicators strategy and the Momentum strategy for its buy and sell signals. It had no strong trends in any of its weekly statistics. Consequently its overall return rate was a modest 3.5312%. The full record of trades for this portfolio is found in the file "portfolio-trades.csv" [13] at lines 34248-36273.

7.1.3 Portfolio 'iqp21'

Date	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
07/09/08	-2.427390%	0.008677%	0.006773%	0.780540	-4.108900	-0.002914	-0.049035
07/16/08	-2.966250%	0.157228%	0.014136%	0.089909	-1.101140	-0.042452	-0.485628
07/23/08	3.496190%	0.084101%	0.042969%	0.510922	0.722821	0.013005	0.041028
07/30/08	0.956319%	0.029507%	0.020158%	0.683161	-0.258288	0.004024	-0.006495
08/06/08	-1.898860%	0.011705%	-0.000574%	-0.049052	-3.049130	-0.033487	0.672523
08/15/08	1.546610%	0.018290%	0.009746%	0.532861	0.108404	0.005202	0.002751

Table 3: Weekly five-day statistics for 'iqp21'

This portfolio used the KeltnerBands strategy and the LinearRegAngle+10 strategy for its buy and sell signals. It started out taking on heavier losses than most of the other portfolios during the first two weeks. None of its statistics had any particularly strong trends except the beta coefficient, which stayed close to 0.5. It only partially recovered its losses by the end, producing an overall -2.7377%. The full record of trades for this portfolio is found in the file "portfolio-trades.csv" [13] at lines 49417-49845.

7.1.4 Portfolio 'iqp81'

Date	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
07/09/08	-0.909676%	0.001450%	0.003129%	2.158270	-6.066180	0.074677	-0.010702
07/16/08	0.359506%	0.028655%	0.011605%	0.404999	-0.614668	-0.004953	-0.025691
07/23/08	3.185510%	0.029831%	0.017449%	0.584947	1.033790	0.008745	0.030524
07/30/08	-0.780900%	0.019311%	0.015135%	0.783787	-1.569410	-0.012101	-0.027825
08/06/08	1.577630%	0.010921%	0.003987%	0.365118	0.169976	0.005486	0.004865
08/15/08	3.481800%	0.061137%	0.017616%	0.288144	0.841950	0.022838	0.072249

Table 4: Weekly five-day statistics for 'iqp81'

This portfolio used the MACD strategy and the MACDHist strategy for its buy and sell signals. Like practically all of the portfolios, it took some losses during the first week as it bought up stocks but did not yet have many good opportunities to sell them. After that, except for the market's slump in the week up to 7/30/08, the portfolio maintained a small but steady positive rate of return. All of its statistics were at their least favorable extremes on the first week. Its returns were highest when it had the highest values of market covariance, indicating that to some extent it effectively latched on to the market's uptrends. Its beta coefficient, Sharpe ratio, and Treynor ratio were also highest during the weeks with highest return. This portfolio finished with an overall return of 5.3238%. The full record of trades for this portfolio is found in the file "portfolio-trades.csv" [13] at lines 235066-235649.

7.1.5 Portfolio 'iqp133'

Date	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
07/09/08	-0.721188%	0.001741%	0.003239%	1.859900	-5.083360	0.063045	-0.011405
07/16/08	0.624737%	0.066239%	0.020741%	0.313124	-0.301227	-0.003537	-0.024759
07/23/08	9.027010%	0.279233%	0.053181%	0.190454	1.443350	0.073304	0.400465
07/30/08	-1.376110%	0.146385%	0.042813%	0.292468	-0.725584	-0.024139	-0.094920
08/06/08	4.064770%	0.070153%	0.007507%	0.107013	1.006090	0.027735	0.249015
08/15/08	5.866490%	0.206695%	0.023845%	0.115365	0.982429	0.045474	0.387160

Table 5: Weekly five-day statistics for 'iqp133'

This portfolio used the MACDPriceDivergence strategy and the RSI-SMA strategy for its buy and sell signals. It achieved a high rate of return relatively quickly, was only modestly impacted by the slump of the week up to 7/30/08, and finished with an outstanding 16.270% return. Its variance, beta coefficient, Sharpe ratio, Jensen's alpha, and Treynor ratio all reached locally optimal extremes whenever the return reached its local maxima. This was the top portfolio in our simulation, by rate of return. The full record of trades for this portfolio is found in the file "portfolio-trades.csv" [13] at lines 346902-348237.

7.2 Overall portfolio statistics

Figures 52 through 58 provide a summary of the results of our simulation. The full table of final portfolio statistics can be found in Appendix II. The rates of return are calculated by taking the ratio of the portfolios' change in worth over the seven weeks and their starting worth. The starting worth of all portfolios is $100,000, and the final worth of each portfolio is the sum of its cash and the market worth of its stocks at the end of the simulation.

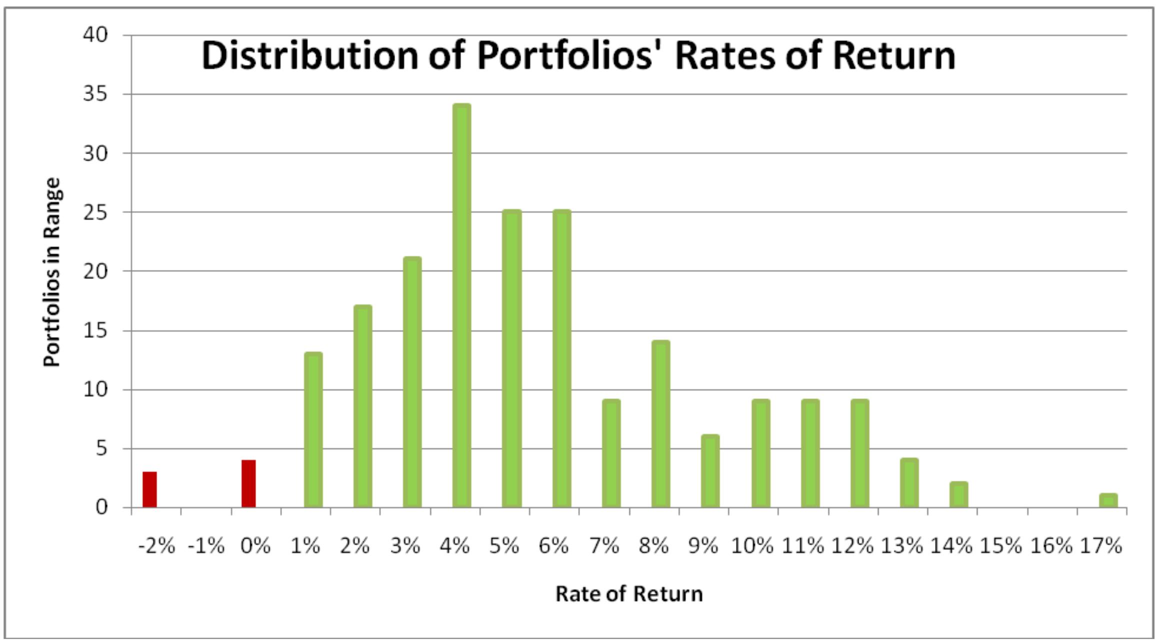

Figure 21: Distribution of portfolios' rates of return (x-axis labels are associated with the tick to the right)

Out of 210 portfolios, 202 had a positive rate of return—96%. The portfolios' variances were bounded above by 0.6%. Their mean rate of return was 5.033%. The minimum rate of return was -2.738% (portfolio 'iqp21'), and the maximum was 16.270%

(portfolio 'iqp133’). Seven portfolios had rates of return exceeding 12%. Eight portfolios had negative rates of return. A total of 25 portfolios had rates of return exceeding 10%. The distribution of rates of return was approximately normal. The seven best and eight worst portfolios are shown in Figure 53.

The S&P 500 index’s price increased from $1284.91 to $1298.20 over the seven weeks of the simulation. Its rate of return was therefore 1.03%, so on average the portfolios of the simulation outperformed the S&P 500 by 488.6%.

Portfolios with negative ROR	**Portfolios with ROR >= 12%**
iqp0 (AroonOsc0, AroonOsc0)	iqp10 (DirectionalIndicators, MACD3Day)
iqp21 (KeltnerBands, LinearRegAngle+10)	iqp30 (KeltnerBands, MACDPriceDivergence)
iqp31 (KeltnerBands, Momentum)	iqp84 (MACD, MACDPriceDivergence)
iqp46 (LinearRegAngle+10, Momentum)	iqp95 (MACD3Day, MACDPriceDivergence)
iqp91 (MACD3Day, MACD3Day)	iqp130 (MACDPriceDivergence, MACDPriceDivergence)
iqp137 (AroonOsc0_3Day, MACDHist)	iqp133 (MACDPriceDivergence, RSI-SMA)
iqp193 (ChaikinOsc, ChaikinOsc)	iqp187 (BollingerBands, MACDPriceDivergence)
iqp206 (ChaikinOsc, Momentum)	

Figure 22: Best and worst portfolios, by rate of return (ROR).

The timing strategies of the portfolios in Figure 53 provide both a comparative analysis and a suggestion for future development. From the comparative perspective, MACDPriceDivergence was probably the most effective timing strategy used in our simulation. It is present in every one of the seven best portfolios, which all had rates of return in excess of 12%. Timing strategies used alone were rarely good performers—four of the twelve worst portfolios used single timing strategies, and MACDPriceDivergence is the only single-timing strategy portfolio present in the top six. From the development perspective, the Momentum timing strategy is in need of major improvements, especially in its buying component. AroonOsc0 and ChaikinOsc should also be improved, if possible, or should be split into better-performing modified strategies.

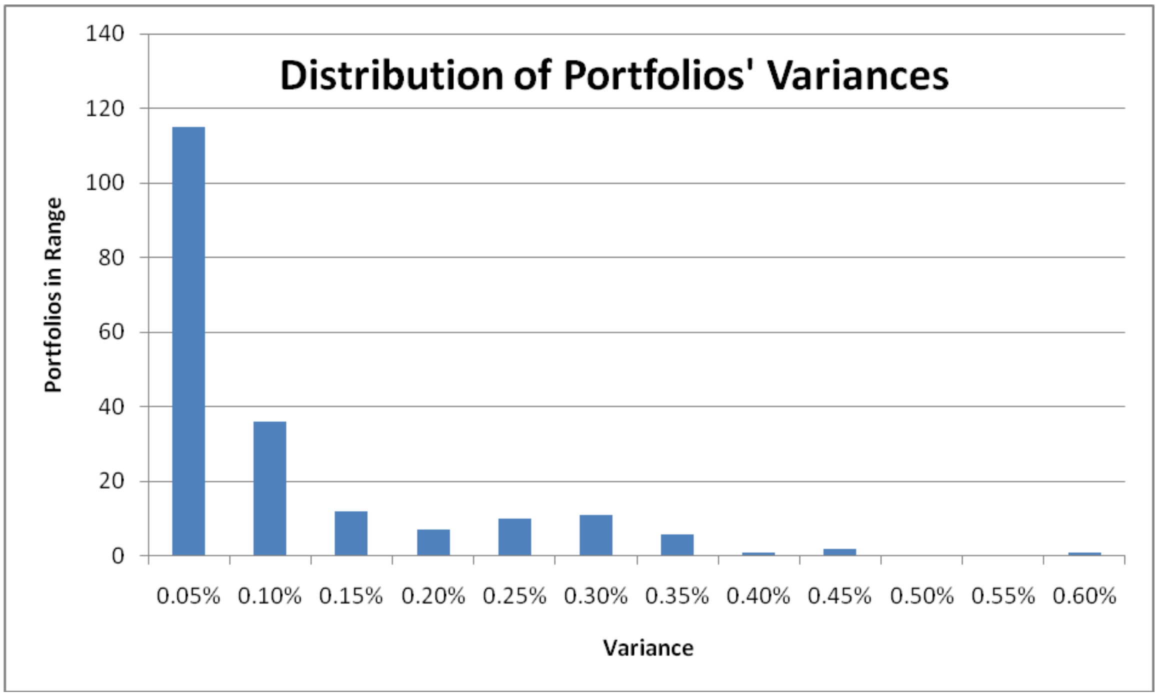

Figure 23: Distribution of portfolios' variances (x-axis labels are associated with the tick to the right)

The distribution of the portfolios' variances in rate of return was approximately an exponential decay. This is the most favorable distribution because it indicates that in general the portfolios performed consistently, for better or worse, so their expected future performance is close to their performance in this simulation.

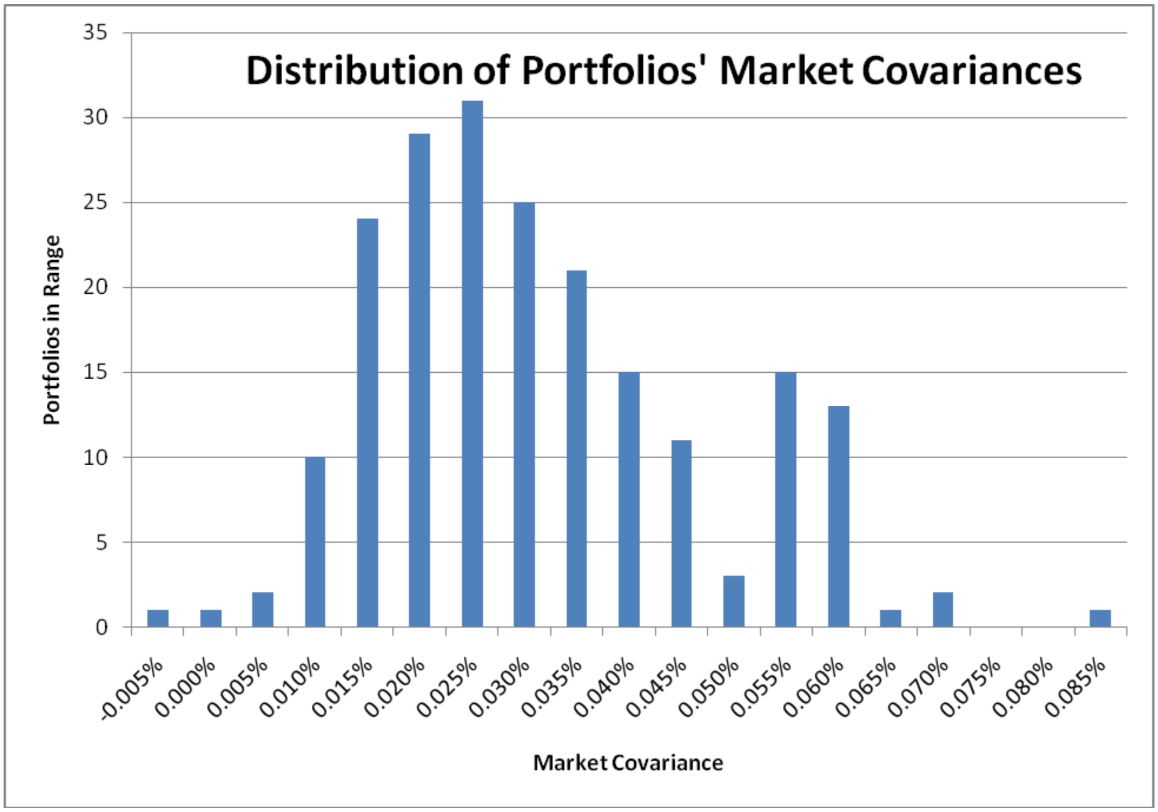

Figure 24: Distribution of portfolios' market covariances (x-axis labels are associated with the tick to the right)

Market covariance is a measure of the extent to which a portfolio changed together with the market. Figure 55 shows the distribution of the portfolios' market covariances. The distribution was approximately normal. Almost all were positive, but the covariances were all low, indicating that all of our portfolios were weakly correlated with the market. The portfolios with negative market covariance were some of portfolios with negative rates of return. This is to be expected because the market gained value during the seven-week period, and these portfolios moved opposite to the market. The portfolios with highest market covariance were the ones with the highest rates of return.

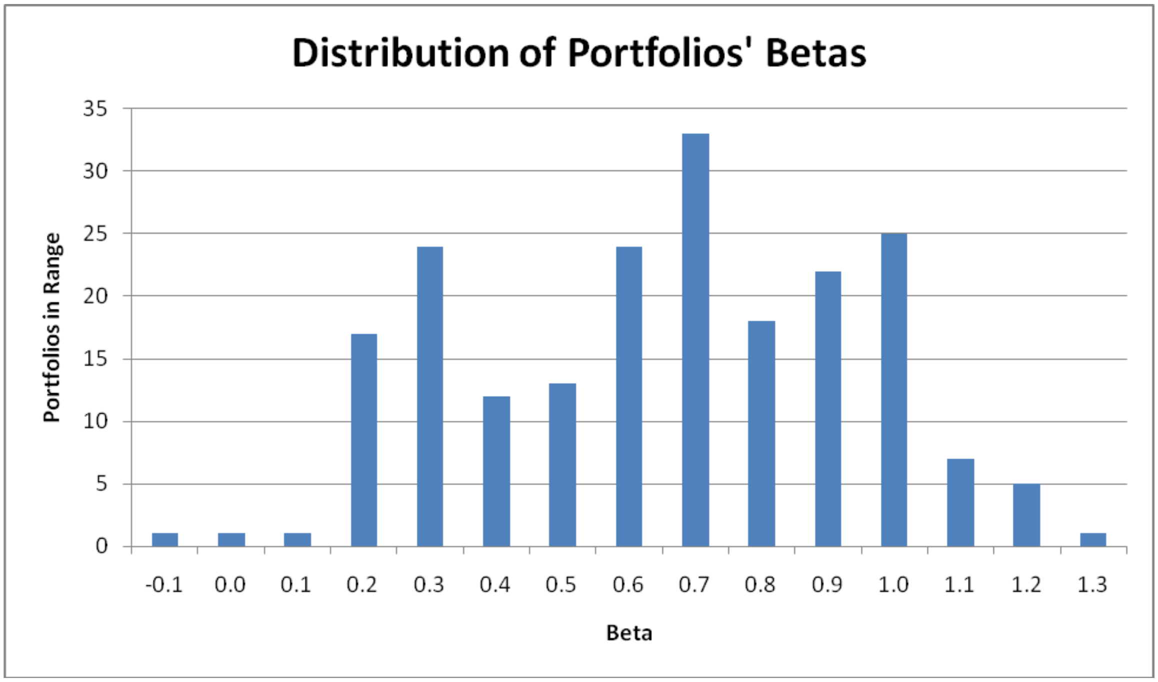

Figure 25: Distribution of portfolios' betas (x-axis labels are associated with the tick to the right)

A portfolio's beta coefficient is a measure of the correlation of its expected return with the return of the market [14]. It is the ratio of the portfolio's market covariance and its variance. The distribution of the simulation's portfolios' beta coefficients is shown in Figure 56. It is approximately a normal distribution. The portfolios with the lowest beta coefficients consisted of two classes: the portfolios with lowest rate of return and those with highest rate of return. This is intuitively reasonable: the portfolios which consistently performed worse than the market should have low beta coefficients because they are very weakly correlated with the market, but to outperform the market a portfolio cannot be too strongly correlated with it either.

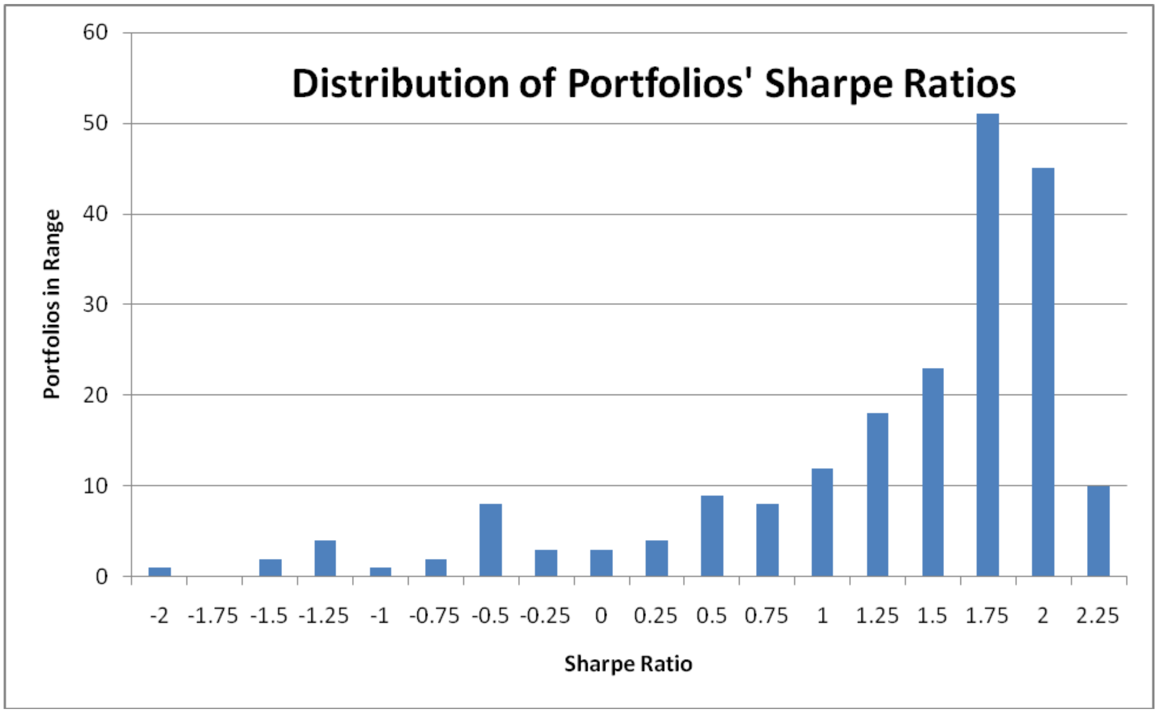

Figure 26: Distribution of portfolios' Sharpe ratios coefficients (x-axis labels are associated with the tick to the right)

A portfolio's Sharpe ratio, also known as its reward-to-variability ratio, is a measure of the excess return (risk premium) per unit of risk [15]. The distribution of the simulation's portfolios' Sharpe ratios is negatively skewed. The portfolios with the smallest Sharpe ratios are the ones with the lowest rates of return, and the twelve portfolios with rates of return over 12% all have Sharpe ratios in excess of 1.7. This is reasonable because the best portfolios need to take higher risks to gain higher returns. It is good that most of our portfolios' Sharpe ratios were greater than 1.0, because this indicates that those portfolios gained excess returns from their risk.

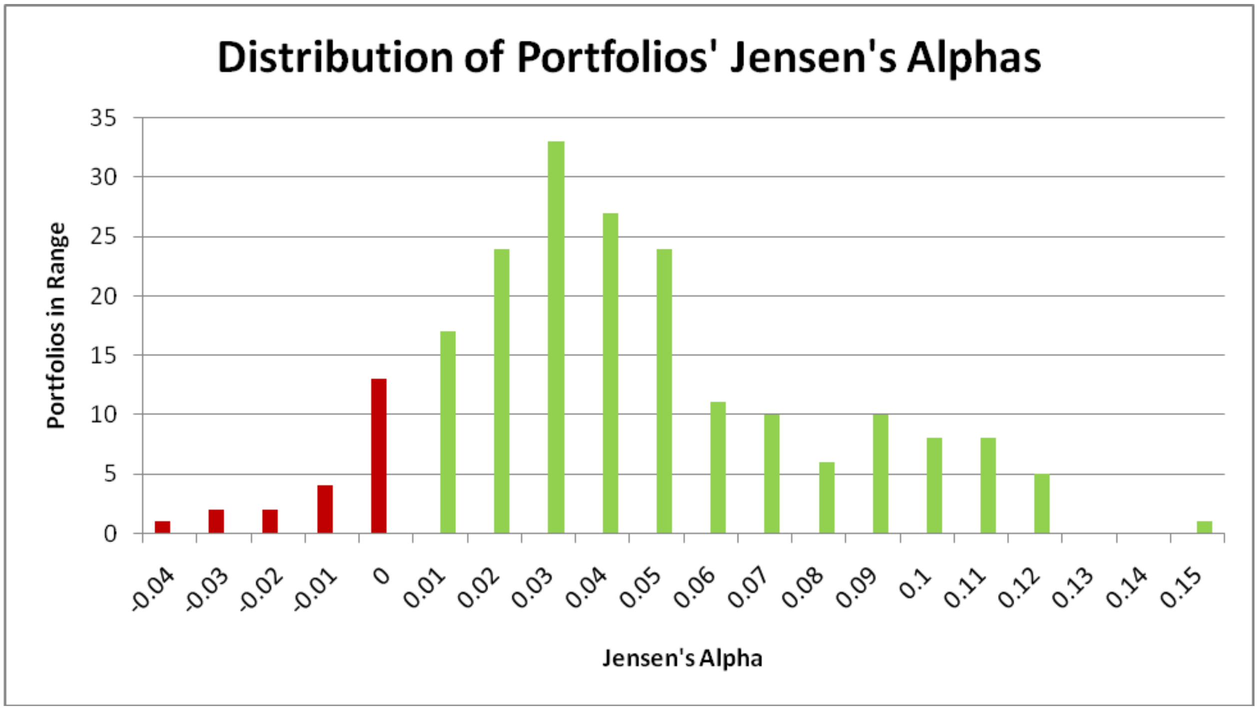

Figure 27: Distribution of portfolios' Jensen's alphas (x-axis labels are associated with the tick to the right)

Jensen's alpha is a measure of the excess return of a portfolio over its risk-adjusted expected return [16]. The simulation's portfolios' alphas were normally distributed. Out of 200 portfolios, 180 (90%) had positive alphas, that is, they performed better than expected. According to Investopedia.com, a positive value for Jensen's alpha indicates that a portfolio manager has "beaten the market" [16]. This strongly suggests that our method of simulation is effective. The six portfolios with highest return had Jensen's alphas greater than 0.108.

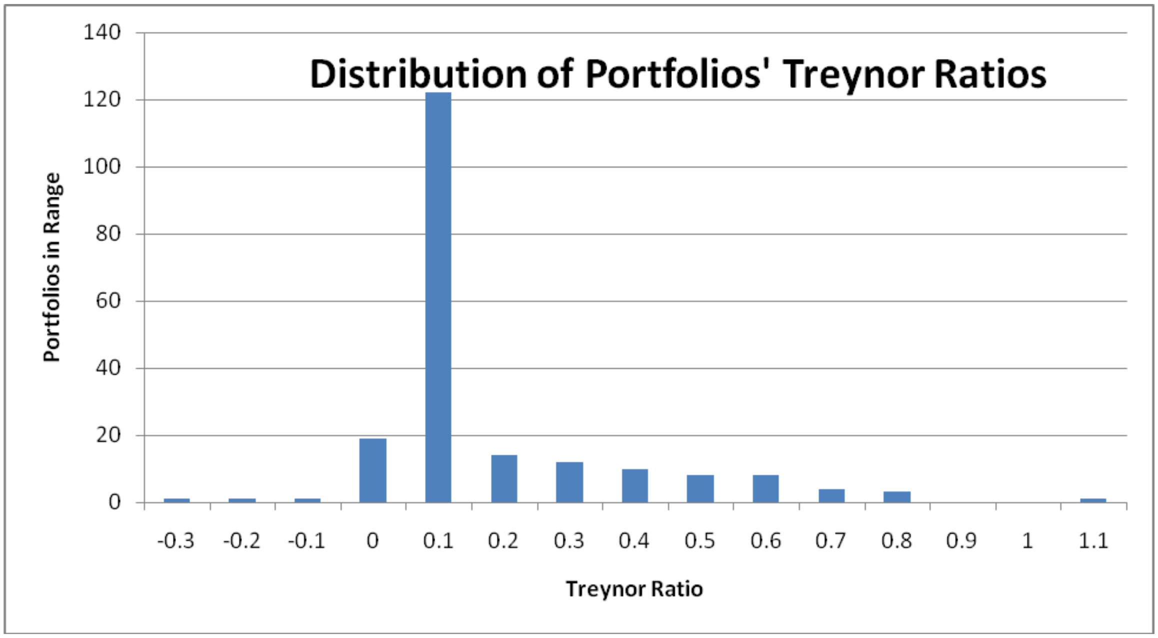

Figure 28: Distribution of portfolios' Treynor ratios (x-axis labels are associated with the tick to the right)

The Treynor ratio, also known as the reward-to-volatility ratio, is the ratio of a portfolio's excess return over a theoretical risk-free rate to the risk taken by it [17]. In our calculations we used the current return on US Treasury Bills, 1.4%, for the risk-free rate. The distribution of the simulation's portfolios' Treynor ratios is very positively skewed but is also almost entirely positive. This indicates that the portfolios had mostly good results from higher levels of risk. As expected, the portfolios with highest rates of return had the highest Treynor ratios, and those with the lowest rates of return had the lowest Treynor ratios. The six portfolios with highest return had Treynor ratios greater than 0.6.

8 Conclusion

The original goal of this project was to assess the effectiveness of various timing strategies and of automated trading in general. We addressed this goal by performing the 210-portfolio simulation described in chapter 6. The results, which are summarized in chapter 7, are very satisfactory. Although our simulation did not take into account the commissions and other trading fees present in real stock market trading, the overwhelmingly favorable statistics indicate that this type of automated trading has the potential to be an effective basis for trading in the real world.

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Appendix I – Table of Portfolios

Portfolio	Timing Strategy 1	Timing Strategy 2
iqp0	AroonOsc0	AroonOsc0
iqp1	AroonOsc0	AroonOsc0_3Day
iqp2	AroonOsc0	MACD
iqp3	DirectionalIndicators	DirectionalIndicators
iqp4	DirectionalIndicators	KeltnerBands
iqp5	DirectionalIndicators	LinearRegAngle+10
iqp6	DirectionalIndicators	LinearRegAngle-10
iqp7	DirectionalIndicators	LinearRegAngle0
iqp8	AroonOsc0	MACD3Day
iqp9	DirectionalIndicators	MACD
iqp10	DirectionalIndicators	MACD3Day
iqp11	DirectionalIndicators	MACDHist
iqp12	DirectionalIndicators	MACDHist3Day
iqp13	DirectionalIndicators	MACDHistPriceDivergence
iqp14	DirectionalIndicators	MACDPriceDivergence
iqp15	DirectionalIndicators	Momentum
iqp16	DirectionalIndicators	RSI+SMA
iqp17	DirectionalIndicators	RSI-SMA
iqp18	DirectionalIndicators	RSI
iqp19	AroonOsc0	MACDHist
iqp20	KeltnerBands	KeltnerBands
iqp21	KeltnerBands	LinearRegAngle+10
iqp22	KeltnerBands	LinearRegAngle-10
iqp23	KeltnerBands	LinearRegAngle0
iqp24	AroonOsc0	MACDHist3Day
iqp25	KeltnerBands	MACD
iqp26	KeltnerBands	MACD3Day
iqp27	KeltnerBands	MACDHist
iqp28	KeltnerBands	MACDHist3Day
iqp29	KeltnerBands	MACDHistPriceDivergence
iqp30	KeltnerBands	MACDPriceDivergence
iqp31	KeltnerBands	Momentum
iqp32	KeltnerBands	RSI+SMA
iqp33	KeltnerBands	RSI-SMA
iqp34	KeltnerBands	RSI
iqp35	AroonOsc0	MACDHistPriceDivergence
iqp36	LinearRegAngle+10	LinearRegAngle+10
iqp37	LinearRegAngle+10	LinearRegAngle-10

Portfolio	Timing Strategy 1	Timing Strategy 2
iqp38	LinearRegAngle+10	LinearRegAngle0
iqp39	AroonOsc0	MACDPriceDivergence
iqp40	LinearRegAngle+10	MACD
iqp41	LinearRegAngle+10	MACD3Day
iqp42	LinearRegAngle+10	MACDHist
iqp43	LinearRegAngle+10	MACDHist3Day
iqp44	LinearRegAngle+10	MACDHistPriceDivergence
iqp45	LinearRegAngle+10	MACDPriceDivergence
iqp46	LinearRegAngle+10	Momentum
iqp47	LinearRegAngle+10	RSI+SMA
iqp48	LinearRegAngle+10	RSI-SMA
iqp49	LinearRegAngle+10	RSI
iqp50	AroonOsc0	Momentum
iqp51	LinearRegAngle-10	LinearRegAngle-10
iqp52	LinearRegAngle-10	LinearRegAngle0
iqp53	AroonOsc0	RSI+SMA
iqp54	LinearRegAngle-10	MACD
iqp55	LinearRegAngle-10	MACD3Day
iqp56	LinearRegAngle-10	MACDHist
iqp57	LinearRegAngle-10	MACDHist3Day
iqp58	LinearRegAngle-10	MACDHistPriceDivergence
iqp59	LinearRegAngle-10	MACDPriceDivergence
iqp60	LinearRegAngle-10	Momentum
iqp61	LinearRegAngle-10	RSI+SMA
iqp62	LinearRegAngle-10	RSI-SMA
iqp63	LinearRegAngle-10	RSI
iqp64	AroonOsc0	RSI-SMA
iqp65	LinearRegAngle0	LinearRegAngle0
iqp66	AroonOsc0	RSI
iqp67	LinearRegAngle0	MACD
iqp68	LinearRegAngle0	MACD3Day
iqp69	LinearRegAngle0	MACDHist
iqp70	LinearRegAngle0	MACDHist3Day
iqp71	LinearRegAngle0	MACDHistPriceDivergence
iqp72	LinearRegAngle0	MACDPriceDivergence
iqp73	LinearRegAngle0	Momentum
iqp74	LinearRegAngle0	RSI+SMA
iqp75	LinearRegAngle0	RSI-SMA
iqp76	LinearRegAngle0	RSI
iqp77	AroonOsc0	AroonOsc30
iqp78	AroonOsc0_3Day	AroonOsc0_3Day
iqp79	MACD	MACD

Portfolio	Timing Strategy 1	Timing Strategy 2
iqp80	MACD	MACD3Day
iqp81	MACD	MACDHist
iqp82	MACD	MACDHist3Day
iqp83	MACD	MACDHistPriceDivergence
iqp84	MACD	MACDPriceDivergence
iqp85	MACD	Momentum
iqp86	MACD	RSI+SMA
iqp87	MACD	RSI-SMA
iqp88	MACD	RSI
iqp89	AroonOsc0_3Day	AroonOsc30
iqp90	AroonOsc0_3Day	BollingerBands
iqp91	MACD3Day	MACD3Day
iqp92	MACD3Day	MACDHist
iqp93	MACD3Day	MACDHist3Day
iqp94	MACD3Day	MACDHistPriceDivergence
iqp95	MACD3Day	MACDPriceDivergence
iqp96	MACD3Day	Momentum
iqp97	MACD3Day	RSI+SMA
iqp98	MACD3Day	RSI-SMA
iqp99	MACD3Day	RSI
iqp100	AroonOsc0_3Day	ChaikinOsc
iqp101	AroonOsc0_3Day	DirectionalIndicators
iqp102	MACDHist	MACDHist
iqp103	MACDHist	MACDHist3Day
iqp104	MACDHist	MACDHistPriceDivergence
iqp105	MACDHist	MACDPriceDivergence
iqp106	MACDHist	Momentum
iqp107	MACDHist	RSI+SMA
iqp108	MACDHist	RSI-SMA
iqp109	MACDHist	RSI
iqp110	AroonOsc0_3Day	KeltnerBands
iqp111	AroonOsc0_3Day	LinearRegAngle+10
iqp112	MACDHist3Day	MACDHist3Day
iqp113	MACDHist3Day	MACDHistPriceDivergence
iqp114	MACDHist3Day	MACDPriceDivergence
iqp115	MACDHist3Day	Momentum
iqp116	MACDHist3Day	RSI+SMA
iqp117	MACDHist3Day	RSI-SMA
iqp118	MACDHist3Day	RSI
iqp119	AroonOsc0_3Day	LinearRegAngle-10
iqp120	AroonOsc0_3Day	LinearRegAngle0
iqp121	MACDHistPriceDivergence	MACDHistPriceDivergence

Portfolio	Timing Strategy 1	Timing Strategy 2
iqp122	MACDHistPriceDivergence	MACDPriceDivergence
iqp123	MACDHistPriceDivergence	Momentum
iqp124	MACDHistPriceDivergence	RSI+SMA
iqp125	MACDHistPriceDivergence	RSI-SMA
iqp126	MACDHistPriceDivergence	RSI
iqp127	AroonOsc0	BollingerBands
iqp128	AroonOsc0_3Day	MACD
iqp129	AroonOsc0_3Day	MACD3Day
iqp130	MACDPriceDivergence	MACDPriceDivergence
iqp131	MACDPriceDivergence	Momentum
iqp132	MACDPriceDivergence	RSI+SMA
iqp133	MACDPriceDivergence	RSI-SMA
iqp134	MACDPriceDivergence	RSI
iqp135	AroonOsc0_3Day	MACDHist
iqp136	AroonOsc0_3Day	MACDHist3Day
iqp137	Momentum	Momentum
iqp138	Momentum	RSI+SMA
iqp139	Momentum	RSI-SMA
iqp140	Momentum	RSI
iqp141	AroonOsc0_3Day	MACDHistPriceDivergence
iqp142	AroonOsc0_3Day	MACDPriceDivergence
iqp143	RSI+SMA	RSI+SMA
iqp144	RSI+SMA	RSI-SMA
iqp145	RSI+SMA	RSI
iqp146	AroonOsc0_3Day	Momentum
iqp147	AroonOsc0_3Day	RSI+SMA
iqp148	RSI-SMA	RSI-SMA
iqp149	RSI-SMA	RSI
iqp150	AroonOsc0_3Day	RSI-SMA
iqp151	AroonOsc0_3Day	RSI
iqp152	RSI	RSI
iqp153	AroonOsc0	ChaikinOsc
iqp154	AroonOsc30	AroonOsc30
iqp155	AroonOsc30	BollingerBands
iqp156	AroonOsc30	ChaikinOsc
iqp157	AroonOsc30	DirectionalIndicators
iqp158	AroonOsc30	KeltnerBands
iqp159	AroonOsc30	LinearRegAngle+10
iqp160	AroonOsc30	LinearRegAngle-10
iqp161	AroonOsc30	LinearRegAngle0
iqp162	AroonOsc0	DirectionalIndicators
iqp163	AroonOsc30	MACD

Portfolio	Timing Strategy 1	Timing Strategy 2
iqp164	AroonOsc30	MACD3Day
iqp165	AroonOsc30	MACDHist
iqp166	AroonOsc30	MACDHist3Day
iqp167	AroonOsc30	MACDHistPriceDivergence
iqp168	AroonOsc30	MACDPriceDivergence
iqp169	AroonOsc30	Momentum
iqp170	AroonOsc30	RSI+SMA
iqp171	AroonOsc30	RSI-SMA
iqp172	AroonOsc30	RSI
iqp173	AroonOsc0	KeltnerBands
iqp174	BollingerBands	BollingerBands
iqp175	BollingerBands	ChaikinOsc
iqp176	BollingerBands	DirectionalIndicators
iqp177	BollingerBands	KeltnerBands
iqp178	BollingerBands	LinearRegAngle+10
iqp179	BollingerBands	LinearRegAngle-10
iqp180	BollingerBands	LinearRegAngle0
iqp181	AroonOsc0	LinearRegAngle+10
iqp182	BollingerBands	MACD
iqp183	BollingerBands	MACD3Day
iqp184	BollingerBands	MACDHist
iqp185	BollingerBands	MACDHist3Day
iqp186	BollingerBands	MACDHistPriceDivergence
iqp187	BollingerBands	MACDPriceDivergence
iqp188	BollingerBands	Momentum
iqp189	BollingerBands	RSI+SMA
iqp190	BollingerBands	RSI-SMA
iqp191	BollingerBands	RSI
iqp192	AroonOsc0	LinearRegAngle-10
iqp193	ChaikinOsc	ChaikinOsc
iqp194	ChaikinOsc	DirectionalIndicators
iqp195	ChaikinOsc	KeltnerBands
iqp196	ChaikinOsc	LinearRegAngle+10
iqp197	ChaikinOsc	LinearRegAngle-10
iqp198	ChaikinOsc	LinearRegAngle0
iqp199	AroonOsc0	LinearRegAngle0
iqp200	ChaikinOsc	MACD
iqp201	ChaikinOsc	MACD3Day
iqp202	ChaikinOsc	MACDHist
iqp203	ChaikinOsc	MACDHist3Day
iqp204	ChaikinOsc	MACDHistPriceDivergence
iqp205	ChaikinOsc	MACDPriceDivergence

Portfolio	Timing Strategy 1	Timing Strategy 2
iqp206	ChaikinOsc	Momentum
iqp207	ChaikinOsc	RSI+SMA
iqp208	ChaikinOsc	RSI-SMA
iqp209	ChaikinOsc	RSI

Appendix I: Table of portfolios with their constituent timing strategies

Appendix II – Table of Final Portfolio Statistics

Portfolio	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
"iqp0"	-0.438269%	0.020367%	0.002216%	0.108786	-1.288080	-0.017985	-0.168980
"iqp1"	3.308410%	0.022821%	0.020348%	0.891602	1.263280	0.022345	0.021404
"iqp2"	5.030860%	0.039956%	0.025632%	0.641504	1.816420	0.038655	0.056599
"iqp3"	0.694967%	0.014195%	0.013893%	0.978760	-0.591762	-0.003471	-0.007203
"iqp4"	8.570370%	0.194803%	0.048909%	0.251066	1.624590	0.072622	0.285597
"iqp5"	3.044010%	0.016180%	0.015904%	0.982909	1.292440	0.020035	0.016726
"iqp6"	4.192290%	0.028623%	0.023433%	0.818667	1.650440	0.030917	0.034108
"iqp7"	4.736180%	0.036212%	0.025563%	0.705921	1.753160	0.035943	0.047260
"iqp8"	4.122330%	0.026180%	0.022663%	0.865650	1.682490	0.030389	0.031448
"iqp9"	4.630380%	0.035580%	0.027082%	0.761162	1.712590	0.035087	0.042440
"iqp10"	5.087210%	0.042502%	0.027807%	0.654247	1.788520	0.039265	0.056358
"iqp11"	5.454720%	0.061769%	0.033648%	0.544734	1.631450	0.042539	0.074435
"iqp12"	5.359080%	0.058303%	0.032338%	0.554653	1.639630	0.041619	0.071379
"iqp13"	7.726550%	0.150805%	0.041991%	0.278447	1.629140	0.064284	0.227209
"iqp14"	12.178500%	0.331930%	0.057568%	0.173433	1.870840	0.108420	0.621480
"iqp15"	3.531160%	0.043550%	0.023215%	0.533064	1.021230	0.023261	0.039980
"iqp16"	5.916080%	0.061369%	0.034920%	0.569019	1.823000	0.047242	0.079366
"iqp17"	4.572090%	0.052794%	0.032289%	0.611601	1.380560	0.033958	0.051865
"iqp18"	3.749170%	0.025694%	0.023604%	0.918675	1.465540	0.026851	0.025571
"iqp19"	3.318020%	0.029698%	0.023199%	0.781165	1.112980	0.022037	0.024553
"iqp20"	9.968160%	0.252548%	0.053965%	0.213683	1.704970	0.086463	0.400975
"iqp21"	-2.737680%	0.105088%	0.014824%	0.141062	-1.276380	-0.040861	-0.293324
"iqp22"	8.226410%	0.100716%	0.040376%	0.400890	2.151020	0.069730	0.170281
"iqp23"	7.243110%	0.089253%	0.040526%	0.454055	1.955840	0.060092	0.128687
"iqp24"	3.436750%	0.031525%	0.023265%	0.738009	1.147130	0.023066	0.027598
"iqp25"	8.802190%	0.205338%	0.050342%	0.245166	1.633520	0.074918	0.301925
"iqp26"	9.323740%	0.229119%	0.052945%	0.231079	1.655390	0.080082	0.342902
"iqp27"	8.598990%	0.203038%	0.050117%	0.246836	1.597650	0.072893	0.291650
"iqp28"	9.001840%	0.228937%	0.051722%	0.225922	1.588770	0.076845	0.336481
"iqp29"	10.176900%	0.277690%	0.054356%	0.195744	1.665570	0.088485	0.448387
"iqp30"	12.780500%	0.447737%	0.067726%	0.151264	1.700780	0.114358	0.752360
"iqp31"	-0.243019%	0.015545%	0.013106%	0.843076	-1.317780	-0.013347	-0.019488
"iqp32"	5.176740%	0.080353%	0.037303%	0.464243	1.332350	0.039465	0.081353
"iqp33"	8.637370%	0.209489%	0.050010%	0.238724	1.581250	0.073247	0.303169
"iqp34"	3.044700%	0.043445%	0.029192%	0.671935	0.789072	0.018904	0.024477
"iqp35"	7.111130%	0.133747%	0.037304%	0.278917	1.561630	0.058131	0.204761
"iqp36"	0.326608%	0.006011%	0.006968%	1.159280	-1.384520	-0.006495	-0.009259
"iqp37"	0.721630%	0.008219%	0.008614%	1.048020	-0.748277	-0.002951	-0.006473
"iqp38"	0.797395%	0.007488%	0.009409%	1.256580	-0.696395	-0.001431	-0.004796

Portfolio	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
"iqp39"	10.917900%	0.254160%	0.050860%	0.200109	1.887940	0.095911	0.475638
"iqp40"	2.217340%	0.015194%	0.012948%	0.852169	0.663081	0.011290	0.009591
"iqp41"	3.117310%	0.017448%	0.016801%	0.962949	1.300110	0.020695	0.017834
"iqp42"	0.698663%	0.015077%	0.007985%	0.529600	-0.571167	-0.005077	-0.013243
"iqp43"	1.234870%	0.013501%	0.010236%	0.758202	-0.142118	0.001121	-0.002178
"iqp44"	1.084020%	0.014032%	0.010000%	0.712695	-0.266753	-0.000554	-0.004434
"iqp45"	3.051880%	0.019632%	0.018057%	0.919755	1.178940	0.019882	0.017960
"iqp46"	-2.513180%	0.032558%	-0.005557%	-0.170673	-2.168720	-0.039756	0.229279
"iqp47"	2.148150%	0.014325%	0.012933%	0.902822	0.625088	0.010783	0.008287
"iqp48"	1.770900%	0.009916%	0.011633%	1.173080	0.372456	0.007999	0.003162
"iqp49"	2.030280%	0.011792%	0.013631%	1.155940	0.580409	0.010530	0.005453
"iqp50"	1.934120%	0.021276%	0.015936%	0.749039	0.366185	0.008080	0.007131
"iqp51"	2.322630%	0.014016%	0.015410%	1.099420	0.779311	0.013247	0.008392
"iqp52"	2.162710%	0.014426%	0.015284%	1.059460	0.635016	0.011502	0.007199
"iqp53"	1.880140%	0.023961%	0.016654%	0.695037	0.310181	0.007343	0.006908
"iqp54"	2.888530%	0.018475%	0.018292%	0.990063	1.095130	0.018506	0.015035
"iqp55"	3.867590%	0.024594%	0.021944%	0.892239	1.573480	0.027939	0.027656
"iqp56"	2.730640%	0.017357%	0.018253%	1.051650	1.010010	0.017152	0.012653
"iqp57"	3.901770%	0.028426%	0.022833%	0.803251	1.483850	0.027955	0.031146
"iqp58"	3.736000%	0.025353%	0.022154%	0.873815	1.467110	0.026556	0.026733
"iqp59"	5.629780%	0.054405%	0.029696%	0.545838	1.813430	0.044294	0.077492
"iqp60"	0.871433%	0.009704%	0.007664%	0.789811	-0.536562	-0.002397	-0.006692
"iqp61"	3.879180%	0.023430%	0.021178%	0.903852	1.619650	0.028097	0.027429
"iqp62"	1.945390%	0.016370%	0.015694%	0.958709	0.426273	0.008960	0.005689
"iqp63"	2.056660%	0.012935%	0.014819%	1.145720	0.577381	0.010756	0.005731
"iqp64"	3.930290%	0.053078%	0.026897%	0.506737	1.098280	0.027156	0.049933
"iqp65"	3.071900%	0.022521%	0.019711%	0.875213	1.114090	0.019920	0.019103
"iqp66"	0.649119%	0.016223%	0.010121%	0.623850	-0.589536	-0.005227	-0.012036
"iqp67"	3.405590%	0.022811%	0.020039%	0.878478	1.327910	0.023268	0.022830
"iqp68"	4.209110%	0.029049%	0.022972%	0.790790	1.648180	0.030983	0.035523
"iqp69"	3.460880%	0.021565%	0.020264%	0.939629	1.403380	0.024045	0.021933
"iqp70"	3.805580%	0.024565%	0.021684%	0.882714	1.534830	0.027284	0.027252
"iqp71"	4.038380%	0.029125%	0.023069%	0.792044	1.545970	0.029280	0.033311
"iqp72"	5.591340%	0.050964%	0.029113%	0.571246	1.856600	0.044002	0.073372
"iqp73"	1.287790%	0.009988%	0.009871%	0.988321	-0.112281	0.002492	-0.001135
"iqp74"	3.668520%	0.021485%	0.019689%	0.916406	1.547650	0.026036	0.024755
"iqp75"	2.580200%	0.020154%	0.018389%	0.912437	0.831338	0.015139	0.012935
"iqp76"	2.600880%	0.017374%	0.017442%	1.003920	0.911068	0.015680	0.011962
"iqp77"	2.909610%	0.022888%	0.016470%	0.719576	0.997829	0.017728	0.020979
"iqp78"	5.187030%	0.042347%	0.029390%	0.694026	1.840300	0.040408	0.054566
"iqp79"	3.541150%	0.018649%	0.016639%	0.892255	1.567910	0.024674	0.023997

Portfolio	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
"iqp80"	0.656929%	0.011724%	0.007755%	0.661454	-0.686259	-0.005012	-0.011234
"iqp81"	5.323820%	0.052611%	0.031591%	0.600457	1.710690	0.041434	0.065347
"iqp82"	5.785220%	0.058914%	0.032834%	0.557328	1.806690	0.045890	0.078683
"iqp83"	8.159710%	0.150325%	0.043600%	0.290038	1.743460	0.068658	0.233063
"iqp84"	12.440000%	0.323672%	0.058896%	0.181964	1.940510	0.111065	0.606713
"iqp85"	5.629540%	0.072536%	0.032321%	0.445589	1.570420	0.043925	0.094920
"iqp86"	5.302140%	0.043860%	0.030082%	0.685852	1.863230	0.041530	0.056895
"iqp87"	5.286840%	0.067603%	0.034620%	0.512104	1.494900	0.040741	0.075899
"iqp88"	3.779430%	0.025074%	0.023713%	0.945735	1.502660	0.027253	0.025160
"iqp89"	4.700440%	0.039589%	0.026375%	0.666233	1.658770	0.035441	0.049539
"iqp90"	9.534810%	0.156228%	0.041530%	0.265832	2.058110	0.082320	0.306013
"iqp91"	-0.321223%	0.017245%	0.004799%	0.278282	-1.310710	-0.016195	-0.061852
"iqp92"	4.904520%	0.043758%	0.029852%	0.682195	1.675320	0.037540	0.051371
"iqp93"	5.541100%	0.052785%	0.031860%	0.603576	1.802440	0.043618	0.068610
"iqp94"	7.964090%	0.140065%	0.042640%	0.304428	1.753920	0.066754	0.215620
"iqp95"	12.526100%	0.319444%	0.058809%	0.184097	1.968550	0.111934	0.604362
"iqp96"	4.181400%	0.036903%	0.024689%	0.669030	1.447880	0.030261	0.041574
"iqp97"	5.277790%	0.042975%	0.029693%	0.690942	1.870580	0.041305	0.056123
"iqp98"	6.026250%	0.077019%	0.037860%	0.491567	1.666980	0.048060	0.094112
"iqp99"	4.592540%	0.033930%	0.027269%	0.803676	1.733180	0.034864	0.039724
"iqp100"	3.427080%	0.024076%	0.014731%	0.611884	1.306420	0.022509	0.033129
"iqp101"	6.249860%	0.068511%	0.035199%	0.513767	1.852890	0.050377	0.094398
"iqp102"	4.558780%	0.046747%	0.028352%	0.606489	1.460980	0.033806	0.052083
"iqp103"	5.302970%	0.053862%	0.031174%	0.578788	1.681730	0.041146	0.067434
"iqp104"	7.232080%	0.123715%	0.040729%	0.329216	1.658100	0.059525	0.177150
"iqp105"	11.852400%	0.282505%	0.058198%	0.206006	1.966540	0.105277	0.507383
"iqp106"	4.152120%	0.053250%	0.025240%	0.473991	1.192630	0.029255	0.058063
"iqp107"	4.266510%	0.037641%	0.025863%	0.687085	1.477490	0.031178	0.041720
"iqp108"	6.555240%	0.094696%	0.038778%	0.409505	1.675270	0.053050	0.125890
"iqp109"	4.018890%	0.026101%	0.023321%	0.893517	1.621040	0.029456	0.029310
"iqp110"	6.479590%	0.104220%	0.034253%	0.328662	1.573450	0.051998	0.154554
"iqp111"	2.944170%	0.016133%	0.014457%	0.896139	1.215750	0.018719	0.017231
"iqp112"	5.099490%	0.049221%	0.030008%	0.609653	1.667500	0.039224	0.060682
"iqp113"	7.360690%	0.124173%	0.040343%	0.324890	1.691540	0.060795	0.183468
"iqp114"	11.747200%	0.277450%	0.056503%	0.203651	1.964400	0.104217	0.508085
"iqp115"	1.917460%	0.025627%	0.017848%	0.696467	0.323248	0.007722	0.007430
"iqp116"	3.325810%	0.026123%	0.022925%	0.877556	1.191510	0.022467	0.021945
"iqp117"	5.704370%	0.082556%	0.037193%	0.450517	1.498080	0.044691	0.095543
"iqp118"	2.567420%	0.020130%	0.019732%	0.980194	0.822815	0.015259	0.011910
"iqp119"	3.184260%	0.017588%	0.016954%	0.963900	1.345380	0.021368	0.018511
"iqp120"	4.399960%	0.029020%	0.022551%	0.777070	1.761020	0.032841	0.038606

Portfolio	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
"iqp121"	7.416090%	0.137013%	0.040593%	0.296268	1.625300	0.061244	0.203062
"iqp122"	10.066700%	0.228130%	0.050347%	0.220692	1.814520	0.087474	0.392705
"iqp123"	4.996320%	0.056256%	0.028756%	0.511162	1.516260	0.037833	0.070356
"iqp124"	4.516250%	0.032209%	0.025360%	0.787358	1.736390	0.034042	0.039579
"iqp125"	6.246470%	0.107113%	0.037627%	0.351284	1.480820	0.049749	0.137964
"iqp126"	2.703590%	0.019622%	0.017944%	0.914503	0.930624	0.016380	0.014255
"iqp127"	10.764500%	0.242694%	0.052284%	0.215434	1.900890	0.094433	0.434683
"iqp128"	6.035120%	0.061001%	0.032280%	0.529178	1.876700	0.048286	0.087591
"iqp129"	5.680870%	0.049647%	0.030604%	0.616431	1.921260	0.045063	0.069446
"iqp130"	13.180900%	0.362596%	0.061789%	0.170408	1.956440	0.118432	0.691335
"iqp131"	6.760180%	0.094205%	0.036373%	0.386102	1.746400	0.055014	0.138828
"iqp132"	9.047060%	0.136321%	0.044019%	0.322909	2.071160	0.077652	0.236818
"iqp133"	16.270000%	0.591771%	0.081861%	0.138332	1.933010	0.149206	1.074950
"iqp134"	9.752790%	0.152019%	0.047833%	0.314655	2.142320	0.084679	0.265459
"iqp135"	4.167810%	0.033236%	0.027009%	0.812622	1.518210	0.030650	0.034060
"iqp136"	3.327980%	0.025243%	0.023648%	0.936816	1.213480	0.022706	0.020580
"iqp137"	-0.570777%	0.015116%	0.009570%	0.633120	-1.602970	-0.017393	-0.031128
"iqp138"	3.862850%	0.045538%	0.024387%	0.535516	1.154110	0.026587	0.045990
"iqp139"	0.042474%	0.015926%	0.010457%	0.656622	-1.075720	-0.011174	-0.020674
"iqp140"	0.476349%	0.011568%	0.010737%	0.928153	-0.858787	-0.005842	-0.009951
"iqp141"	5.127100%	0.040542%	0.025999%	0.641273	1.851040	0.039616	0.058120
"iqp142"	7.782810%	0.099337%	0.037283%	0.375316	2.025150	0.065201	0.170065
"iqp143"	3.180000%	0.025551%	0.015367%	0.601428	1.113560	0.019999	0.029596
"iqp144"	3.238540%	0.021939%	0.021565%	0.982932	1.241260	0.021980	0.018705
"iqp145"	2.447330%	0.016932%	0.015984%	0.944055	0.804887	0.013926	0.011094
"iqp146"	0.693477%	0.025556%	0.011932%	0.466908	-0.441956	-0.005358	-0.015132
"iqp147"	6.154390%	0.060693%	0.031153%	0.513286	1.929870	0.049421	0.092626
"iqp148"	2.348490%	0.034081%	0.023658%	0.694156	0.513776	0.012023	0.013664
"iqp149"	1.113770%	0.013184%	0.014401%	1.092290	-0.249280	0.001132	-0.002620
"iqp150"	3.810830%	0.033168%	0.023318%	0.703020	1.323750	0.026679	0.034292
"iqp151"	3.408560%	0.028448%	0.019823%	0.696824	1.190860	0.022634	0.028825
"iqp152"	0.345574%	0.013989%	0.009019%	0.644711	-0.891502	-0.008187	-0.016355
"iqp153"	2.154140%	0.016603%	0.013317%	0.802112	0.585285	0.010475	0.009402
"iqp154"	5.148740%	0.050184%	0.025943%	0.516945	1.673400	0.039378	0.072517
"iqp155"	11.267800%	0.256635%	0.054381%	0.211900	1.947880	0.099453	0.465679
"iqp156"	2.703830%	0.021057%	0.016950%	0.804980	0.898521	0.015982	0.016197
"iqp157"	7.243640%	0.097867%	0.038421%	0.392585	1.867950	0.059872	0.148850
"iqp158"	10.425800%	0.321136%	0.057365%	0.178631	1.592720	0.090911	0.505274
"iqp159"	0.444542%	0.017318%	0.007153%	0.413020	-0.726051	-0.008044	-0.023134
"iqp160"	3.539760%	0.023298%	0.021368%	0.917174	1.401870	0.024752	0.023330
"iqp161"	2.910800%	0.019221%	0.018992%	0.988082	1.089720	0.018721	0.015290

Portfolio	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
"iqp162"	5.581280%	0.052905%	0.030790%	0.581985	1.817860	0.043941	0.071845
"iqp163"	7.132390%	0.077975%	0.035109%	0.450264	2.052850	0.058971	0.127312
"iqp164"	5.591100%	0.046671%	0.028381%	0.608107	1.940020	0.044135	0.068921
"iqp165"	5.207280%	0.057071%	0.030637%	0.536824	1.593700	0.040036	0.070922
"iqp166"	3.993350%	0.039293%	0.025092%	0.638583	1.308300	0.028269	0.040611
"iqp167"	7.831720%	0.148941%	0.039487%	0.265120	1.666550	0.065287	0.242596
"iqp168"	11.643400%	0.275992%	0.053678%	0.194492	1.949830	0.103146	0.526676
"iqp169"	1.613760%	0.024870%	0.015473%	0.622172	0.135551	0.004413	0.003436
"iqp170"	4.232310%	0.032420%	0.025497%	0.786453	1.573020	0.031199	0.036014
"iqp171"	4.606390%	0.071899%	0.031142%	0.433136	1.195780	0.033648	0.074027
"iqp172"	1.414240%	0.016279%	0.014172%	0.870581	0.011160	0.003326	0.000164
"iqp173"	10.352300%	0.316872%	0.057098%	0.180194	1.590350	0.090182	0.496815
"iqp174"	11.627500%	0.296792%	0.055602%	0.187343	1.877350	0.102960	0.545924
"iqp175"	6.391910%	0.056623%	0.029762%	0.525614	2.097820	0.051841	0.094973
"iqp176"	9.906770%	0.212543%	0.050267%	0.236501	1.845190	0.085933	0.359693
"iqp177"	10.719300%	0.290626%	0.055091%	0.189561	1.728680	0.093886	0.491624
"iqp178"	4.440710%	0.045603%	0.027429%	0.601474	1.423900	0.032607	0.050554
"iqp179"	4.733670%	0.030712%	0.022868%	0.744582	1.902260	0.036060	0.044772
"iqp180"	7.150790%	0.067050%	0.034296%	0.511492	2.220900	0.059378	0.112432
"iqp181"	0.947407%	0.016390%	0.008658%	0.528272	-0.353527	-0.002594	-0.008567
"iqp182"	11.682000%	0.293695%	0.057884%	0.197088	1.897280	0.103541	0.521699
"iqp183"	11.625000%	0.290434%	0.057643%	0.198472	1.897310	0.102976	0.515184
"iqp184"	11.049600%	0.265790%	0.055623%	0.209272	1.871720	0.097262	0.461104
"iqp185"	10.326200%	0.233593%	0.053272%	0.228054	1.846870	0.090096	0.391407
"iqp186"	11.574800%	0.316478%	0.057537%	0.181805	1.808650	0.102413	0.559657
"iqp187"	13.181100%	0.409944%	0.065122%	0.158857	1.840020	0.118391	0.741616
"iqp188"	9.549800%	0.173165%	0.044470%	0.256808	1.958470	0.082437	0.317350
"iqp189"	10.018300%	0.153190%	0.046544%	0.303830	2.201950	0.087294	0.283656
"iqp190"	9.677380%	0.217829%	0.050556%	0.232090	1.773510	0.083623	0.356645
"iqp191"	7.108810%	0.078324%	0.035695%	0.455734	2.039860	0.058755	0.125266
"iqp192"	2.616920%	0.014826%	0.016828%	1.135040	0.999429	0.016320	0.010721
"iqp193"	-2.190210%	0.062976%	-0.003111%	-0.049395	-1.430650	-0.036083	0.726841
"iqp194"	1.529880%	0.015630%	0.013743%	0.879293	0.103893	0.004514	0.001477
"iqp195"	4.901660%	0.054321%	0.035169%	0.647422	1.502410	0.037384	0.054086
"iqp196"	1.433770%	0.011692%	0.012237%	1.046640	0.031230	0.004165	0.000323
"iqp197"	3.087060%	0.020635%	0.018936%	0.917681	1.174440	0.020227	0.018384
"iqp198"	4.531860%	0.037736%	0.023908%	0.633556	1.612230	0.033636	0.049433
"iqp199"	2.032160%	0.015572%	0.014653%	0.941001	0.506589	0.009763	0.006718
"iqp200"	2.657090%	0.022325%	0.019912%	0.891895	0.841329	0.015833	0.014095
"iqp201"	1.840940%	0.022170%	0.016213%	0.731330	0.296145	0.007084	0.006029
"iqp202"	1.869260%	0.017177%	0.012849%	0.748022	0.358048	0.007428	0.006273

Portfolio	Rate of return	Variance	Market covariance	Beta	Sharpe ratio	Jensen's alpha	Treynor ratio
"iqp203"	1.967540%	0.021284%	0.018229%	0.856468	0.389012	0.008807	0.006626
"iqp204"	3.895330%	0.031161%	0.020947%	0.672216	1.413590	0.027412	0.037121
"iqp205"	7.458940%	0.109439%	0.035873%	0.327794	1.831520	0.061788	0.184840
"iqp206"	-0.675063%	0.018754%	0.001248%	0.066545	-1.515250	-0.020507	-0.311828
"iqp207"	1.840670%	0.025358%	0.013842%	0.545850	0.276732	0.006403	0.008073
"iqp208"	3.002870%	0.035637%	0.024139%	0.677366	0.849076	0.018506	0.023663
"iqp209"	5.619510%	0.061748%	0.033295%	0.539214	1.698060	0.044167	0.078253

Appendix II: Table of overall portfolio statistics on the last simulation day

Appendix III – Timing Strategy Scripts

AroonOsc0.es

```
function tradeSignal()
{
    ao0 = AroonOsc.value( Date0 );
    ao1 = AroonOsc.value( Date1 );
    ao2 = AroonOsc.value( Date2 );
    ao3 = AroonOsc.value( Date3 );
    upper = 0;
    lower = 0;
    if( ao0 < upper && ao1 >= upper )
        return -1;
    if( ao0 == ao1 )
        return -1/3;
    if( ao0 < ao1 && ao0 > upper && ao0 < upper + 50 )
        return -1/3 + 2/3 * ((ao0 - upper) / 50 - 1);
    if( ao0 > lower && ao1 <= lower )
    {
        r = (ao0 - lower) / 50;
        if( r > 1 )
            r = 1;
        return r;
    }
    if( ao0 > ao1 && ao1 > lower && ao2 <= lower )
    {
        r = (ao0 - lower) / 50;
        if( r > 1 )
            r = 1;
        return 1/3 * r;
    }
    if( ao0 > ao1 && ao1 > lower && ao2 > lower && ao3 <= lower )
    {
        r = (ao0 - lower) / 50;
        if( r > 1 )
            r = 1;
        return 1/6 * r;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "AroonOsc", "Close" );
}
```

Algorithm 2: AroonOsc0.es

AroonOsc0_3Day.es

```
function tradeSignal()
{
    ao0 = AroonOsc.value( Date0 );
    ao1 = AroonOsc.value( Date1 );
    ao2 = AroonOsc.value( Date2 );
    ao3 = AroonOsc.value( Date3 );
    if( ao0 > -50 && ao1 <= -50 )
        return 1/6;
    if( ao0 > -50 && ao1 > -50 && ao2 <= -50 )
        return 1;
    if( ao0 > -50 && ao1 > -50 && ao2 > -50 && ao3 <= -50 )
        return 1/3;
    if( ao0 < 0 )
        return -1;
    if( ao0 == ao1 )
        return -1/6;
    if( ao0 < 50 && ao1 >= 50 )
        return -1/3;
    if( ao0 < ao1 && ao1 < 50 && ao2 >= 50 )
        return -2/3;
    if( ao0 < ao1 && ao1 < 50 && ao2 < 50 )
        return -1;
    return 0;
}

function requiredIndicators()
{
    return Array( "AroonOsc", "Close" );
}
```

Algorithm 3: AroonOsc0_3Day.es

AroonOsc30.es

```
function tradeSignal()
{
    ao0 = AroonOsc.value( Date0 );
    ao1 = AroonOsc.value( Date1 );
    ao2 = AroonOsc.value( Date2 );
    ao3 = AroonOsc.value( Date3 );
    upper = 30;
    lower = -30;
    if( ao0 < upper && ao1 >= upper )
        return -1;
    if( ao0 == ao1 )
        return -1/3;
    if( ao0 < ao1 && ao0 > upper && ao0 < upper + 50 )
        return -1/3 + 2/3 * ((ao0 - upper) / 50 - 1);
    if( ao0 > lower && ao1 <= lower )
    {
        r = (ao0 - lower) / 50;
        if( r > 1 )
            r = 1;
        return r;
    }
    if( ao0 > ao1 && ao1 > lower && ao2 <= lower )
    {
        r = (ao0 - lower) / 50;
        if( r > 1 )
            r = 1;
        return 1/3 * r;
    }
    if( ao0 > ao1 && ao1 > lower && ao2 > lower && ao3 <= lower )
    {
        r = (ao0 - lower) / 50;
        if( r > 1 )
            r = 1;
        return 1/6 * r;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "AroonOsc", "Close" );
}
```

Algorithm 4: AroonOsc30.es

BollingerBands.es

```
function tradeSignal()
{
    bbl0 = BBL.value( Date0 );
    bbc0 = BBC.value( Date0 );
    bbu0 = BBU.value( Date0 );
    h0 = High.value( Date0 );
    l0 = Low.value( Date0 );
    c0 = Close.value( Date0 );
    if( l0 < bbl0 )
        return 1;
    if( c0 > bbc0 )
    {
        r = -(c0 - bbc0) / (bbu0 - bbc0);
        if( h0 > bbu0 )
            r = 2 * r;
        if( r < -1 )
            r = -1;
        return r;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "BBL", "BBC", "BBU", "Open", "High", "Low", "Close" );
}
```

Algorithm 5: BollingerBands.es

ChaikinOsc.es

```
function tradeSignal()
{
    co0 = ChaikinOsc.value( Date0 );
    co1 = ChaikinOsc.value( Date1 );
    pcu0 = PCU.value( Date0 );
    pcu1 = PCU.value( Date1 );
    pcu2 = PCU.value( Date2 );
    pcu3 = PCU.value( Date3 );
    pcu4 = PCU.value( Date4 );
    pcu5 = PCU.value( Date5 );
    h0 = High.value( Date0 );
    h1 = High.value( Date1 );
    h2 = High.value( Date2 );
    h3 = High.value( Date3 );
    h4 = High.value( Date4 );
    h5 = High.value( Date5 );
    if( co0 < 0 )
        return -1;
    if( co0 > 0 && co1 <= 0 )
        return 1;
    if( co0 < co1 )
    {
        if( h0 > pcu0 || h1 > pcu1 || h2 > pcu2 || h3 > pcu3 || h4 >
pcu4 || h5 > pcu5 )
            return -1;
        r = 3/2 * (co0 - co1) / co1;
        if( r < -1 )
            r = -1;
        return r;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "ChaikinOsc", "PCU", "High", "Close" );
}
```

Algorithm 6: ChaikinOsc.es

DirectionalIndicators.es

```
function tradeSignal()
{
    pdi0 = PlusDI.value( Date0 );
    pdi1 = PlusDI.value( Date1 );
    mdi0 = MinusDI.value( Date0 );
    mdi1 = MinusDI.value( Date1 );
    if( pdi1 < mdi1 && pdi0 > mdi0 )
        return -1;
    if( mdi1 < pdi1 && mdi0 > pdi0 )
        return 1;
    return 0;
}

function requiredIndicators()
{
    return Array( "+DI", "-DI", "Close" );
}
```

Algorithm 7: DirectionalIndicators.es

KeltnerBands.es

```
function tradeSignal()
{
    kbl0 = KBL.value( Date0 );
    kbc0 = KBC.value( Date0 );
    kbu0 = KBU.value( Date0 );
    o0 = Open.value( Date0 );
    h0 = High.value( Date0 );
    l0 = Low.value( Date0 );
    c0 = Close.value( Date0 );
    if( l0 < kbl0 )
        return 1;
    if( c0 > kbc0 )
    {
        r = -(c0 - kbc0) / (2/3 * (kbu0 - kbc0));
        if( h0 > kbu0 )
            r = 2 * r;
        if( r < -1 )
            r = -1;
        return r;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "KBL", "KBC", "KBU", "Open", "High", "Low", "Close" );
}
```

Algorithm 8: KeltnerBands.es

LinearRegAngle0.es

```
function tradeSignal()
{
    line = 0;
    lra0 = LinearRegAngle.value( Date0 );
    lra1 = LinearRegAngle.value( Date1 );
    if( lra0 < line )
        return -1;
    if( lra0 < lra1 )
        return -1;
    if( lra1 < line && lra0 >= line )
    {
        dn = (lra0 - line) / 20;
        if( dn > 1 )
            return 1;
        return dn;
    }
    if( lra0 >= lra1 )
    {
        dn = (lra0 - lra1) / (lra1 - line);
        if( dn < 1/3 )
        {
            if( dn < 1/6 )
                return dn * 6 - 1;
            return 0;
        }
        adn = (lra0 - line) / 20;
        if( adn > 1 )
        {
            if( dn > 2/3 )
                return 1;
            adn = 1;
        }
        dn = dn * adn * 3 - 1;
        if( dn > 1 )
            dn = 1;
        return dn;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "LinearRegAngle", "Close" ) ;
}
```

Algorithm 9: LinearRegAngle0.es

LinearRegAngle-10.es

```
function tradeSignal()
{
    line = -10;
    lra0 = LinearRegAngle.value( Date0 );
    lra1 = LinearRegAngle.value( Date1 );
    if( lra0 < line )
        return -1;
    if( lra0 < lra1 )
        return -1;
    if( lra1 < line && lra0 >= line )
    {
        dn = (lra0 - line) / 20;
        if( dn > 1 )
            return 1;
        return dn;
    }
    if( lra0 >= lra1 )
    {
        dn = (lra0 - lra1) / (lra1 - line);
        if( dn < 1/3 )
        {
            if( dn < 1/6 )
                return dn * 6 - 1;
            return 0;
        }
        adn = (lra0 - line) / 20;
        if( adn > 1 )
        {
            if( dn > 2/3 )
                return 1;
            adn = 1;
        }
        dn = dn * adn * 3 - 1;
        if( dn > 1 )
            dn = 1;
        return dn;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "Close", "LinearRegAngle" ) ;
}
```

Algorithm 10: LinearRegAngle-10.es

LinearRegAngle+10.es

```
function tradeSignal()
{
    line = 10;
    lra0 = LinearRegAngle.value( Date0 );
    lra1 = LinearRegAngle.value( Date1 );
    if( lra0 < line )
        return -1;
    if( lra0 < lra1 )
        return -1;
    if( lra1 < line && lra0 >= line )
    {
        dn = (lra0 - line) / 20;
        if( dn > 1 )
            return 1;
        return dn;
    }
    if( lra0 >= lra1 )
    {
        dn = (lra0 - lra1) / (lra1 - line);
        if( dn < 1/3 )
        {
            if( dn < 1/6 )
                return dn * 6 - 1;
            return 0;
        }
        adn = (lra0 - line) / 20;
        if( adn > 1 )
        {
            if( dn > 2/3 )
                return 1;
            adn = 1;
        }
        dn = dn * adn * 3 - 1;
        if( dn > 1 )
            dn = 1;
        return dn;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "Close", "LinearRegAngle" ) ;
}
```

Algorithm 11: LinearRegAngle+10.es

MACD3Day.es

```
function tradeSignal()
{
    macd0 = MACD.value( Date0 );
    macd1 = MACD.value( Date1 );
    macd2 = MACD.value( Date2 );
    macd3 = MACD.value( Date3 );
    if( macd0 < 0 && macd1 > 0 )
        return -1/3;
    if( macd0 < 0 && macd1 < 0 && macd2 > 0 )
        return -2/3;
    if( macd0 < 0 && macd1 < 0 && macd2 < 0 && macd3 > 0 )
        return -1;
    if( macd0 > 0 && macd1 < 0 )
        return 1/3;
    if( macd0 > 0 && macd1 > 0 && macd2 < 0 )
        return 2/3;
    if( macd0 > 0 && macd1 > 0 && macd2 > 0 && macd3 < 0 )
        return 1;
    return 0;
}

function requiredIndicators()
{
    return Array( "MACD", "Close" );
}
```

Algorithm 12: MACD3Day.es

MACD.es

```
function tradeSignal()
{
    macd0 = MACD.value( Date0 );
    macd1 = MACD.value( Date1 );
    if( macd0 < 0 && macd1 > 0 )
        return -1;
    if( macd0 > 0 && macd1 < 0 )
        return 1;
    return 0;
}

function requiredIndicators()
{
    return Array( "MACD", "Close" );
}
```

Algorithm 13: MACD.es

MACDHist3Day.es

```
function tradeSignal()
{
    macdh0 = MACDHist.value( Date0 );
    macdh1 = MACDHist.value( Date1 );
    macdh2 = MACDHist.value( Date2 );
    macdh3 = MACDHist.value( Date3 );
    if( macdh0 < 0 && macdh1 > 0 )
        return -1/3;
    if( macdh0 < 0 && macdh1 < 0 && macdh2 > 0 )
        return -2/3;
    if( macdh0 < 0 && macdh1 < 0 && macdh2 < 0 && macdh3 > 0 )
        return -1;
    if( macdh0 > 0 && macdh1 < 0 )
        return 1/3;
    if( macdh0 > 0 && macdh1 > 0 && macdh2 < 0 )
        return 2/3;
    if( macdh0 > 0 && macdh1 > 0 && macdh2 > 0 && macdh3 < 0 )
        return 1;
    return 0;
}

function requiredIndicators()
{
    return Array( "MACDHist", "Close" );
}
```

Algorithm 14: MACDHist3Day.es

MACDHist.es

```
function tradeSignal()
{
    macdh0 = MACDHist.value( Date0 );
    macdh1 = MACDHist.value( Date1 );
    macdh2 = MACDHist.value( Date2 );
    macdh3 = MACDHist.value( Date3 );
    if( macdh0 < 0 && macdh1 > 0 )
        return -1/3;
    if( macdh0 < 0 && macdh1 < 0 && macdh2 > 0 )
        return -2/3;
    if( macdh0 < 0 && macdh1 < 0 && macdh2 < 0 && macdh3 > 0 )
        return -1;
    if( macdh0 > 0 && macdh1 < 0 )
        return 1/3;
    if( macdh0 > 0 && macdh1 > 0 && macdh2 < 0 )
        return 2/3;
    if( macdh0 > 0 && macdh1 > 0 && macdh2 > 0 && macdh3 < 0 )
        return 1;
    return 0;
}

function requiredIndicators()
{
    return Array( "MACDHist", "Close" );
}
```

Algorithm 15: MACDHist.es

MACDHistPriceDivergence.es

```
function tradeSignal()
{
    macdh0 = MACDHist.value( Date0 );
    macdh1 = MACDHist.value( Date1 );
    c0 = Close.value( Date0 );
    c1 = Close.value( Date1 );
    if( macdh0 < macdh1 && c0 > c1 )
        return -1;
    if( macdh0 > macdh1 && c0 < c1 )
        return 1;
    return 0;
}

function requiredIndicators()
{
    return Array( "MACDHist", "Close" );
}
```

Algorithm 16: MACDHistPriceDivergence.es

MACDPriceDivergence.es

```
function tradeSignal()
{
    macd0 = MACD.value( Date0 );
    macd1 = MACD.value( Date1 );
    c0 = Close.value( Date0 );
    c1 = Close.value( Date1 );
    if( macd0 < macd1 && c0 > c1 )
        return -1;
    if( macd0 > macd1 && c0 < c1 )
        return 1;
    return 0;
}

function requiredIndicators()
{
    return Array( "MACD", "Close" );
}
```

Algorithm 17: MACDPriceDivergence.es

Momentum.es

```
function tradeSignal()
{
    mom0n = Momentum.value( Date0 ) / Close.value( Date0 );
    mom1n = Momentum.value( Date1 ) / Close.value( Date1 );
    mom2n = Momentum.value( Date2 ) / Close.value( Date2 );
    if( mom0n < 0 )
        return -1;
    if( mom0n < mom1n && mom1n > 0 && mom2n > 0 )
        return -1;
    if( mom0n < mom1n )
    {
        dn = (mom0n - mom1n) / mom1n;
        if( dn <= -2/3 )
            return -1;
        return dn * 3 / 2;
    }
    if( mom0n > 0 && mom1n < 0 )
    {
        if( mom0n > 0.05 )
            return 1;
        return mom0n * 20;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "Momentum", "Close", "Open" );
}
```

Algorithm 18: Momentum.es

RSI.es

```
function tradeSignal()
{
    rsi0 = RSI.value( Date0 );
    rsi1 = RSI.value( Date1 );
    if( rsi0 < rsi1 )
    {
        if( rsi0 < 50 )
            return -1;
        if( rsi0 < 70 )
            return (rsi0 - 70) / 20;
    }
    if( rsi0 > rsi1 )
    {
        if( rsi1 < 40 && rsi0 > 30 && rsi0 < 50 )
            return (50 - rsi0) / 20;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "RSI", "Close" );
}
```

Algorithm 19: RSI.es

RSI+SMA.es

```
function tradeSignal()
{
    rsi0 = RSI.value( Date0 );
    rsi1 = RSI.value( Date1 );
    sma0 = BBC.value( Date0 );
    sma1 = BBC.value( Date1 );
    if( rsi0 < rsi1 && sma0 < sma1 )
    {
        if( rsi0 < 50 )
            return -1;
        if( rsi0 < 70 )
            return (rsi0 - 70) / 20;
    }
    if( rsi0 > rsi1 && sma0 > sma1 )
    {
        if( rsi1 < 40 && rsi0 > 30 && rsi0 < 50 )
            return (50 - rsi0) / 20;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "RSI", "BBC", "Close" );
}
```

Algorithm 20: RSI+SMA.es

RSI-SMA.es

```
function tradeSignal()
{
    rsi0 = RSI.value( Date0 );
    rsi1 = RSI.value( Date1 );
    sma0 = BBC.value( Date0 );
    sma1 = BBC.value( Date1 );
    if( rsi0 < rsi1 && sma0 > sma1 )
    {
        if( rsi0 < 50 )
            return -1;
        if( rsi0 < 70 )
            return (rsi0 - 70) / 20;
    }
    if( rsi0 > rsi1 && sma0 < sma1 )
    {
        if( rsi1 < 40 && rsi0 > 30 && rsi0 < 50 )
            return (50 - rsi0) / 20;
    }
    return 0;
}

function requiredIndicators()
{
    return Array( "RSI", "BBC", "Close" );
}
```