SILVER CREEK
CAPITAL MANAGEMENT

OVERVIEW
QUANTITATIVE SOLUTIONS
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Introduction

Over the last half-century, the investment community has incorporated computers and quantitative analysis into more and more of the investment process. Before, investment decisions were made entirely by humans. Now investment decisions are either entirely human based, entirely machine based, or determined by some combination of humans and machines.

Quantitative tools can process the vast amount of information available, think with the rationality of algorithms, and search for nuanced relationships. As a result, quantitative strategies has the potential to increase diversification, reduce risk, and enhance returns.

Given the broad scope in which quantitative analysis can be used to enhance the investment making process, different investors emphasize different aspects of a quantitative-based investment solution. Quantitative investing can be as straightforward as a momentum strategy that buys stocks that performed well last month or as complex as feeding nanosecond data into a neural network system that outputs a buy or sell decision with no causal linkage.

In the following series of articles, we discuss the world of quantitative-driven investing. We outline how it differs from other types of investing and why we believe that the exposure is important.

WHAT IS QUANTITATIVE INVESTING?

What is quantitative investing? Over the last half-century, machines have crept into the investment management process, and recently their usage has grown rapidly. By now nearly every asset manager has heard how a subset of investors use machines in their investment making process. But what does that mean? Quantitative investing can be used to play two essential roles.

For the majority of investors, quantitative capabilities are a tool to help make investment decisions. They can provide a simple overlay on more standard strategies such as fundamental investing, alternative beta, global macro, and equity market neutral strategies. However, they can also span into their own strategy, such as statistical arbitrage or low latency trading.

There is a spectrum of quantitative investing and where an asset manager falls on that spectrum depends on the utilization of machines in the investment making process. That is, an investor is more heavily quant-based the more rule-based their decisions are and the less the investment selections are made on a case-by-case decision based on a human's subjective opinion.

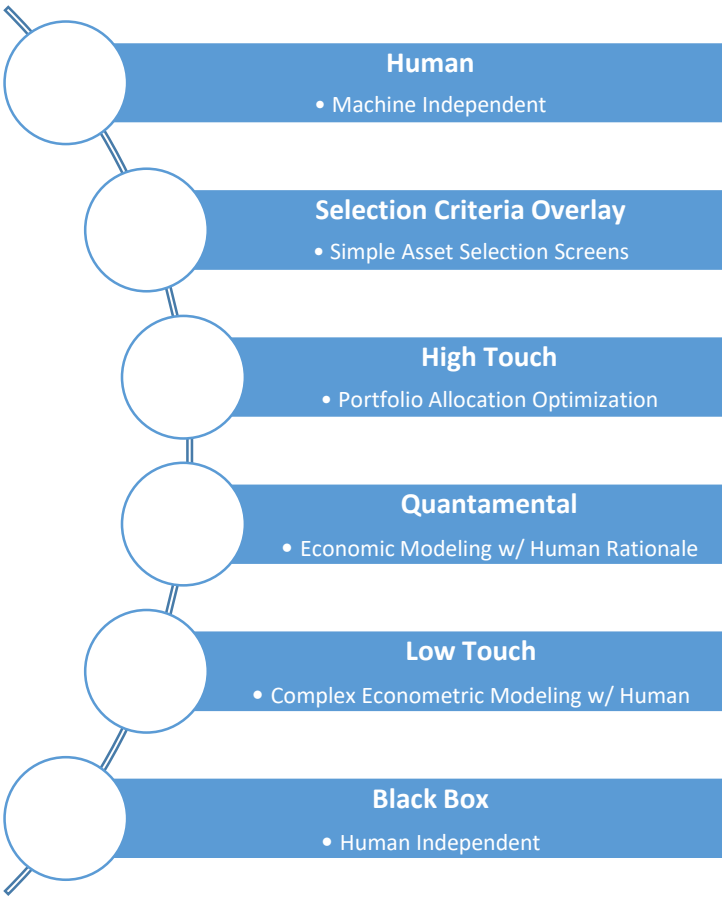
On the no-quant end of the spectrum is a human investor that depends on their own analysis, calculations, and pattern recognition. One can think of it as an investor sitting at their desk reading a company's 10-K report and, based on that information, deciding whether the stock is over- or under-valued. It could also be an investor watching a stock ticker and when they see a particular pattern they choose to buy the stock.

On the all-quantitative end of the spectrum is the machine investor that runs independent of the human. The machine is responsible for all aspects of the investment, from the decision on whether to buy or sell an asset, how to implement the purchase, how long to hold it, how much of the asset to hold, and how and when to sell it. This is referred to as a "blackbox" investment model. It can run independent of human involvement.

It is our view that the use of simple screens, such as selecting stocks with a particular P/E ratio, dividend payout, and 12-month return pattern, are not considered quantitative investing. While technically dependent on machines, these tools have the quantitative aspect only being used at the margin. We exclude this type of screening from what we believe defines quantitative investing.

However, we view the more complex and machine reliant action of portfolio optimization as part of the quantitative investing universe. Our reasoning is that such an optimization is dependent on machines to be utilized, and that a meaningful degree of the human subjectivity, at least with respect to the portfolio weights, is eliminated. We consider this type of quantitative investing to be "high-touch." It is still heavily human dependent.

In between the portfolio optimization and blackbox operation is where most quantitative investors reside. The in-between states is where the basis of an investment decision is an econometric model used that is beyond the scope of a human's internal calculation ability. Sometimes that econometric model will have a clear intuitive narrative along with it, such as the use of weather prediction software to determine future oil prices. Other times the inputs will simply produce a recommended investment, without a clear economic rational, as in more sophisticated pairs-trading algorithms.



The econometric model based investment process can often be used as a tool, for instance, where an asset manager follows a systematic macro strategy, but their investment decisions depend on complex econometric modeling of how various shocks will flow through the economy.

Near the far end of the machine based spectrum, the quantitative investing tool becomes its own quantitative strategy. We delineate the transition to a quant strategy based on whether a machine is needed for the investment strategy to exist. Most naturally this fits in with sophisticated statistical arbitrage strategies and strategies that rely on low latency. In addition to only being feasible by a machine, these strategies will often be carried out with the human investor only passively supervising the algorithm's buying and selling activity.

EVOLUTION OF QUANT INVESTING

While quantitative investing has recently received much attention, the idea of using machines in the investment process has been around for decades. What has evolved is the degree to which machines have infiltrated the investment process. What follows is a road map that outlines the evolution of quantitative investing and how it is used in the investment universe.

MODERN PORTFOLIO THEORY. In 1952 the father of quantitative investing, Harry Markowitz, published an article describing modern portfolio theory, also known as mean variance analysis.[1] In the article he lays out the idea that to optimize the allocation of assets within a portfolio, an investor must take into consideration the co-movement (covariance) of the assets. Once a portfolio grows beyond a handful of assets, the calculation becomes very time consuming and requires the use of a computer.

SIMPLE STATISTICAL ARBITRAGE. Between the 1950s and early 1980s machines did not encroach much further into the investment process. However, starting in the early 1980s Morgan Stanley employed computers to do more than simply optimize the allocation of assets within a portfolio, it used the machines to pick which assets should be included in the portfolio. Computers were used to monitor price data and to detect statistical patterns in the data that resulted in investable anomalies. Two examples of this are pairs trading and momentum.

> *Pairs trading.* Pairs trading is among the first investment strategies that today we now refer to as statistical arbitrage. The basic concept is simple. First, determine two (or more) assets that have a high probability of moving together. When Stock A goes up by 1%, Stock B usually goes up by 1%. The investment hypothesis is that the two stocks should move in sync. Next, monitor these pairs for anomalies in their co-movement. For instance, Stock A goes up by 1% but Stock B goes down by 2%. The prediction is that either the price of Stock A will fall, or the price of Stock B will rise. The final step is then to sell short Stock A and buy Stock B, anticipating they will converge in the near future.
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> *Momentum trading.* Another simple statistical arbitrage strategy that the introduction of computers allowed to be systematically followed was momentum. The momentum investment hypothesis is as simple as it sounds: a stock will generally continue moving in the same direction it has recently been moving. To carry out this strategy an investor would buy assets that recently increased in price and sell short assets that recently decreased in price, anticipating that the price continued to move in the same direction as in the recent past.

COMPLEX STATISTICAL ARBITRAGE. Since the 1990s, the use of machines in the investment process has exploded. Whereas the simple statistical arbitrage activities were feasible for humans to implement, albeit time consuming and tedious, more recent developments in statistical arbitrage are beyond the scope of human implementation. The following five items are tools used to carry out complex statistical arbitrage.

[1] Markowitz, Harry. 1952. *Portfolio Selection*. Journal of Finance. 7(1): 77-91.

Big Data. Even the pairs trading and momentum strategy discussed in the simple statistical arbitrage concept use more data than is easy for a human to analyze. Since then, the amount of data that some quantitative investors use has exploded. Perhaps the largest financial data comes from information produced by the stock market itself, the order, cancel, and trade activities occurring on the varying stock exchanges. Just in the United States the stock exchanges regularly produce dozens of gigabytes of information each day. Such vast amounts of data allow for small statistical relationships to be detected and exploited that would be overlooked with less granular data.

Artificial Intelligence. A result of big data is the need to understand it. Humans evolved to detect patterns and make causal inferences. Yet, machines can now detect some patterns better than humans, and they can iterate and learn from their past pattern detection successes and failures. Such a process is referred to as artificial intelligence. Artificial intelligence is a process that allows a machine to learn from its past experiences and to adopt moving forward. The application to investment is straightforward. Using big data and artificial intelligence, a machine can learn from its past behavior and improve its ability to uncover investment opportunities.

High Frequency Trading. High frequency trading is the new day trader. Just like the day trader of the 1990s were humans bought and sold throughout the day based off of simple patterns, high frequency traders also buy and sell throughout the day based off of data patterns. The difference is time scale. The human day trader could respond to a buy or sell signal in about half a second, and would hold securities for seconds, minutes, or hours. The machine high frequency trader can respond in microseconds (1/1,000,000th of a second) and is capable of holding a position for mere microseconds as well.

Textual & Sentiment Analysis. Numerical analysis is easy for computers. A harder source of data to analyze is text. Many of the events that affect a security's value come from textual news. For instance, the threat of competitors, the death of a CEO, or the impact of a new regulation. While humans can read the news and react, there is far too much content affecting the market for a human to process. Textual analysis by machines can now read and have rudimental understanding of the textual information. The understanding is currently basic and is in terms of the sentiment (i.e.whether the text is positive or negative for the value of the security).

News Analytics. News analytics is the combination of high frequency trading and textual analysis. News providers now have services that relay the news in a machine readable format. That is, instead of sending an investor the daily newspaper, news syndicates provide an almost instantaneous news feed to subscribers. The quant investor has an algorithm read an article upon its release, analyzing the text, and categorizing the article based on which securities it affects and whether it is good or bad news. This takes milliseconds (1/1000th of a second) to perform and to be transferred through the data feed. Combining speed with quantity means even textual news can be traded on by machines before a human has the chance to open an email containing the news story.

WHY QUANT NOW?

The rise of passive investors and the advances in technology explain why a quantitative based investment strategy is more valuable today than in the past.

PASSIVE INVESTORS. One of the more recent shifts in investing trends has been the rise of passive investing. The motive behind passive investing is the polar opposite of the quantitative hedge fund investment.

Purchasing a passive product like an ETF that tracks the S&P 500 index is the optimal investment if markets are efficient.

A market is efficient when prices fully reflect all available information. There are three types of market efficiency that refer to different degrees of information being imbedded into prices. Weak form market efficiency says that all past price information is

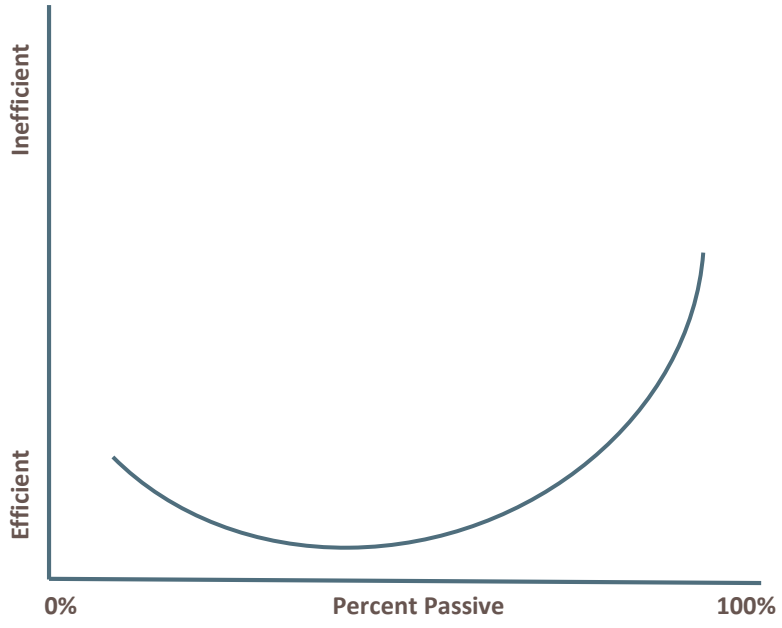
incorporated into the current price. Semi-strong form market efficiency says that all public information – past prices, annual reports, news articles, etc. – is incorporated into the current price. Finally, the strong form market efficiency says that all public information and private information – such as personal CEO meetings, early M&A discussions, etc. - is incorporated into the current price. When not specified, the semi-strong form of market efficiency is typically assumed.

The logic behind the passive investment is that markets are efficient and so there is no point in trying to select specific stocks or exposures strategically; alternatively the logic is that markets are efficient enough that the cost of chasing mispricings is greater than the potential reward of finding and capturing them.

Passive investing assumes that there are other participants in the market who are sufficiently incentivized to seek out and trade on mispricings. That is, passive investors are free riding on the activities of arbitragers. Now suppose that the market became 100% populated by passive investors, what would happen? Passive investors, referred to as noise traders in the parlance of finance jargon, would buy and sell based on factors unrelated to the underlying fundamentals of the asset. Given all traders would be passive, the stock price would move with the external ebbs and flows of investable assets from the noise traders and the relative value of each stock would be locked in (with respect to the allocation of investments within the index). Very quickly, such an investment ecosystem would result in massive mispricings. This logic is the basis of the Grossman-Stiglitz Paradox (On the Impossibility of Informationally Efficient Markets, American Economic Review, 1980) - arbitrageurs must be able to earn profits, otherwise they would have no incentive to seek out mispricings.

The market becoming 100% passive is unrealistic. The question though is at what percentage of passive market participation do investment opportunities increase for active managers? Surely there are massive opportunities when the market is 100% passive. When the market is 100% active it will be difficult to find arbitrage opportunities.

The change in market efficiency between 0 and 100% passive is likely non-linear. As the amount of passive investing increases it may become harder for the remaining active managers to outperform. The reason being that the first converts to passive investing will be the worst active managers. Poor active managers were likely pushing prices away from their efficient price (hence why they were poor); with them being removed there are fewer mispricings in the market. At some point the relative tradeoff between removing bad managers and increasing price-taking activity of passive investors will flip and passive investing will begin to create more mispricings than it removes.



In 2016, passive investing holds accounts for 38% of the total U.S. equity assets under management.[2] Where does this place us on the passive investing – efficiency curve? We think we are now on the early portion of the upward segment of the curve.

[2] Goldman Sachs Global Investment Research: Global Markets Institute. January 9 2017. Directors' dilemma: Responding to the rise of passive investing.

TECHNOLOGY IMPROVEMENTS. Besides the recent wave of passive investing, the technological advances have reached a point where machines now have a competitive advantage to humans in their ability to engage in procedures in the investment process. We discuss some of the core technologies used by quantitative investors in our Technologies articles. Generally though, until recently computers had limited memory, limited processing power, and rather primitive learning algorithms. In addition, unless the machine was fed well organized structured data, it would not be able to utilize the information contained in the data.

Now, however, the computer constraints have been relaxed. Memory is cheap and vast. Processing power has continued to follow Moore's law, and in addition we have unleashed the power of distributed parallel processing. Machine learning has had important breakthroughs with the advance of more technical neural network systems, such as deep learning, and improvements in natural language processing. Big data has developed efficient algorithms to handle large data sets consistent of both structured and unstructured data. Consequently, the ability for computers to test strategies, detect anomalies, and trade on them has improved to the point where teams of humans could not cover as much material as a single computer.

HOW QUANT CAN BE USED IN A PORTFOLIO

For many investors the transition of the investing process being human-driven to being more and more machine-driven has been relatively sudden. The adoption rate of the quantitative approach has spanned the spectrum from full adoption of automation and machine-driven processes to a skeptical "wait and see" approach. There is no uniformly correct amount of how much quantitative processes should be in an investor's portfolio. It depends on the goals and objectives of each investor.

Quantitative processes have the ability to provide three main benefits: Information Acquisition, Bias Reduction, and Pattern Recognition.

INFORMATION ACQUISITION. The amount of data relevant to financial markets is enormous. Humans are superior to machines at many things, but crunching large amounts of data is not one of them. For instance, in the second quarter of 2017, the U.S. Options market experienced a peak volume of 16.4 *billion* messages in one day.[3] Without machines it is impossible to absorb all this information. As a consequence, a quantitative approach means more information can be gleaned by the investor and incorporated in to their decision making process.

Even if an investor is indifferent to the millisecond-by-millisecond market movements, and is content to focus only on monthly activities in their portfolio of a few dozen stocks, the limitations of human computation still binds. One of the earliest insights in the academic finance literature was that the correlation between stocks matters. Markowitz (1952, Journal of Finance) shows that the optimal portfolio allocation requires knowing how stocks move together. This calculation takes a computer a fraction of a second to perform. A human could spend hours trying to derive the optimal allocation for even a small portfolio.

By processing data quickly and systematically both the investment selection process and the allocation of the investment can be improved.

BIAS REDUCTION. Humans evolved to survive and consequently, the human brain is quite efficient and rational. However, psychology and behavioral economics has shown it is not perfectly rational. We are subject to biases and these biases can affect our investment decisions.[4]

The rationality of an algorithm depends on what the programmer codes in to the software. The difference however is that the potential for bias being introduced in to an algorithm need only be evaluated once and the algorithm will thereafter execute in a

[3] Options Price Reporting Authority. 2017. Key Operating Metrics of U.S. Options Securities Information Processor.

[4] For a brief summary of well-known biases, please see the appendix below.

rational manner. With a human performing the analysis each decision needs to be evaluated for the laundry list of potential biases that can distort investment choices.

Hardwiring rationality into decision making can improve the investment selection process.

PATTERN RECOGNITION. Humans are natural pattern-recognition machines. However, we can miss patterns due to memory and attention limitations (we also tend to see patterns were none exist – see Gambler's Fallacy in the appendix). Machines have virtually no restriction on their ability to search for and detect patterns. There are numerous examples of lead-lag relationships between financial assets being documented, both with and without economically intuitive explanations, which can produce superior returns.

By surveying the investment landscape for relationships both the investment selection and allocation of investments can be improved.

APPENDIX[5]

While entire textbooks have been written on the topic of behavior biases in finance and economics here we highlight a few of the most prominent cognitive biases and a brief description of how they work.

THE ALLAIS PARADOX. Named after its discoverer, Maurice Allais, the Allais Paradox reveals an inconsistency in how people make choices relative to what expected utility theory suggests they should make. Expected utility theory says that in a gamble two identical outcomes should be treated as irrelevant (as they are both equally likely with the same payoffs regardless of what side of the gamble is realized.) The paradox is that this is not the case. People's choice of preferred gamble is highly dependent on the possible outcome in the other part of the gamble.

PROSPECT THEORY. Prospect Theory, also known as Loss Aversion, is a broad framework for understanding how people make decisions. When making decisions involving risk, the theory suggests an asymmetry in valuing gains and losses. While gains are viewed favorable and losses negatively, gains and losses of the same magnitude are perceived differently. A loss of $20 is viewed as more painful than a gain of $20 is pleasurable.

THE GAMBLER'S FALLACY. Independent events mean that when repeating an event, the likelihood of this event's outcome is unrelated to the outcomes experienced in the past. Rolling a die, flipping a coin, or spinning a roulette wheel are examples of independent events. The Gambler's Fallacy is the inaccurate belief that if something has happened frequently in the past, it will happen less frequently in the future. For instance, suppose I flip a coin four times and each time it lands on tails, if I am susceptible to the Gambler's Fallacy then I will believe the likelihood the next coin flip will land heads is greater than 50%. Of course the true probability of the next coin flip landing heads is still 50%.

OVERCONFIDENCE. Overconfidence is among the easiest anomalies to describe. People systematically overestimate their abilities. In the investment setting this includes their ability to predict future returns and their ability to beat the market.

FRAMING EFFECT. The Framing Effect is when a person's decision changes based on how a problem is portrayed. The classic tradeoff is as follows: Suppose 600 people are affected by a life-threating disease. In a positive framing there is a choice to save 200 lives with certainty or a choice that 33% chance of saving all 600 lives and 66% chance of saving no one. In a negative framing there is a choice of having 400 people die with certainty or a 33% chance no one dying and a 66% chance all 600 people die. In the

[5] Ackert, Lucy, and Richard Deaves. 2009. *Behavioral finance: Psychology, decision-making, and markets*. Cengage Learning.

positive framework the majority of people choose the certain choice (save 200 lives), in the negative framework the majority of people choose the uncertain choice (33% chance no one dies). However, the two settings are identical other than their framing.

DISPOSITION EFFECT. An implication of Prospect Theory is the Disposition Effect. The Disposition Effect is the tendency for investors to sell the assets that have appreciated and keep the assets that have lost value. If markets are efficient and future returns cannot be predicted then whether the asset price went up or down in the past should be irrelevant. However, the price path of financial markets do matter for future performance. First, there are tax benefits to losses. Second, momentum exists, so past returns are positively correlated with future return. Both of these, however, give additional cause to not sell winners, the opposite of what is observed.

ANCHORING. Anchoring captures the tendency for people to base new information on a benchmark from the past, even if that benchmark is irrelevant. An example of anchoring is the use of an asset's purchase price in the past to determine the value of the asset today. The purchase price is irrelevant, the asset's true value should represent the current information about the present value of the future cash flows the asset will generate.