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Cointegration and Statistical Arbitrage of Precious Metals

By

Judge Van Horn

Advisor: Dr. Craig Rennie

**An Honors Thesis in partial fulfillment of the requirements for the degree Bachelor of
Science in Business Administration in Finance**

Sam M. Walton College of Business

University of Arkansas

Fayetteville, Arkansas

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Introduction

In an era of constantly evolving technology, we have seen huge changes to market mechanics and how investors operate. While things like value, growth, fundamentals, and technical analysis still have their places the recent growth has been around quantitative analysis. Bots or algorithms now make up over 50% of the markets daily volume, but most people do not actually understand what these bots are doing. Many people confuse quantitative firms, or quants, with high frequency or algorithmic trading, but these are technically only subsets of quantitative finance. While high frequency trading, or HFT, is a form of quantitative finance, quant strategies can be anything where math or technology are the guiding factors in a firm's strategy. Most of these strategies are deployed by bots but many of them are not trying to capitalize on minute pricing discrepancies or arbitrage opportunities that last a fraction of a second. One quantitative strategy is called statistical arbitrage and an extremely advanced version of stat arb trading is used by the most successful hedge fund of all time. Renaissance Technologies has managed to generate returns over 60% every year since 1988.

Statistical arbitrage is an advanced form of pairs trading that uses statistical methods to enter a long position on one stock while simultaneously shorting another. In the case of statistical arbitrage, the tests are looking to find moments where two generally linked securities move in a way that is unusual and therefore expected to return to normal. Statistical arbitrage is a market neutral strategy meaning it does not require any stance on the direction of the market or timing of the business cycle. In fact, statistical arbitrage often works best in frothy or uncertain markets. The best example of this would be using securities like Coca-Cola and Pepsi. In this example we will ignore the rest of the market and assume both companies are identical. In this example Coca-Cola has a one day return of 10% while Pepsi trades completely flat. If all else was actually equal, we can assume that either Coca-Cola has just been overvalued or Pepsi is currently undervalued so we would purchase Pepsi stock while shorting Coca-Cola. In the real world nothing is this simple or clean and so we use statistics to make up for the noise.

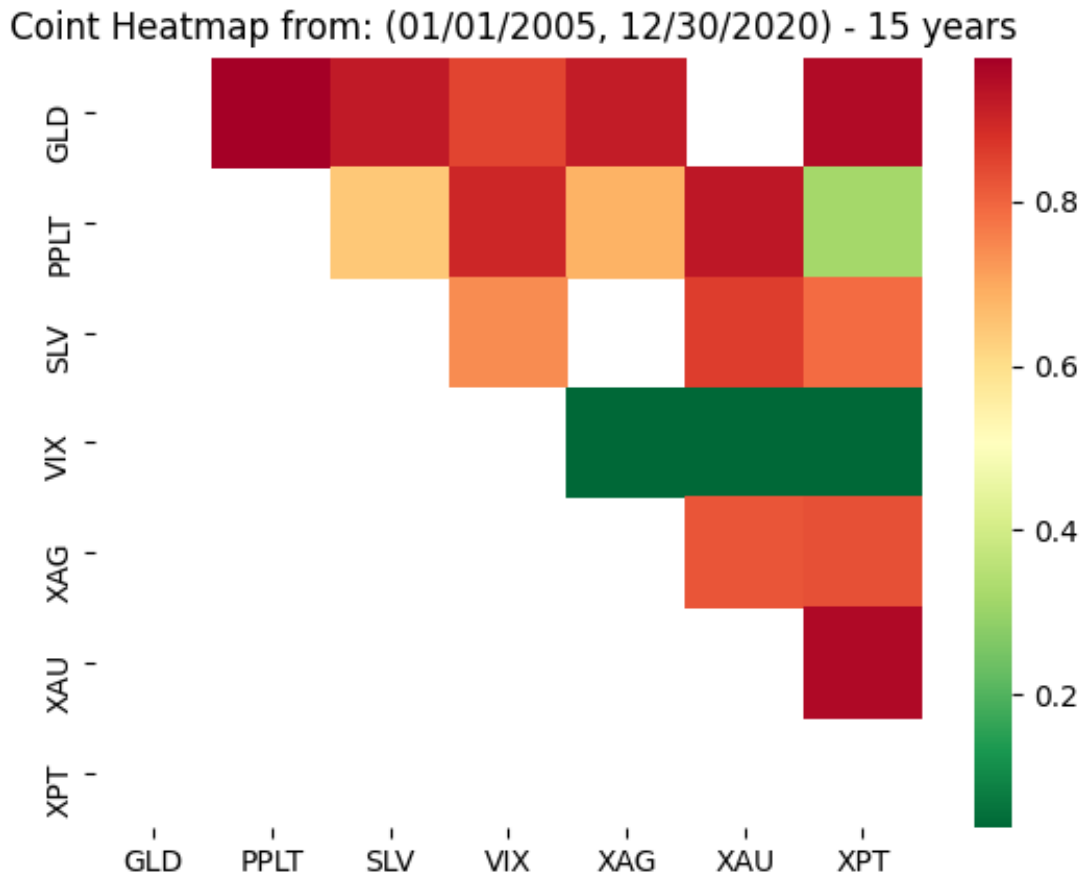
When talking about financial instruments correlation is often thrown around as a measure of the relation between two securities. An often more useful or tradeable measure is cointegration. Cointegration is the measure of two securities tendency to revert to an average price over time. In other words, cointegration ignores directionality and only cares about the distance between two securities. For a mean reversion strategy such as statistical arbitrage cointegration proves to be a far more reliable statistical measure of mean reversion, and while it is more reliable than correlation it still has its own problems. One thing to consider is that when looking over thousands of data points it is extremely easy to find at least 2 that are cointegrated at some point. Therefore, data cleaning and selection is extremely important.

Grouping Securities and Establishing Cointegration

Since it is possible to get false positives while checking cointegration over large sets of data it is generally best to start with securities that have a logical or economical reason to be cointegrated. The prime example as stated is Coke and Pepsi, but this could be any industry, sub-industry, or group of companies that would have a logical reason to revert to a common average price. Precious metals represent a group of commodities that will likely move in similar ways. Not only do they represent a great opportunity for statistical arbitrage they also serve the dual

purpose of being a traditional store of value. By including VIX price data in our tests of cointegration it is possible to gain insight on the flow of money during times of increased market volatility and fear.

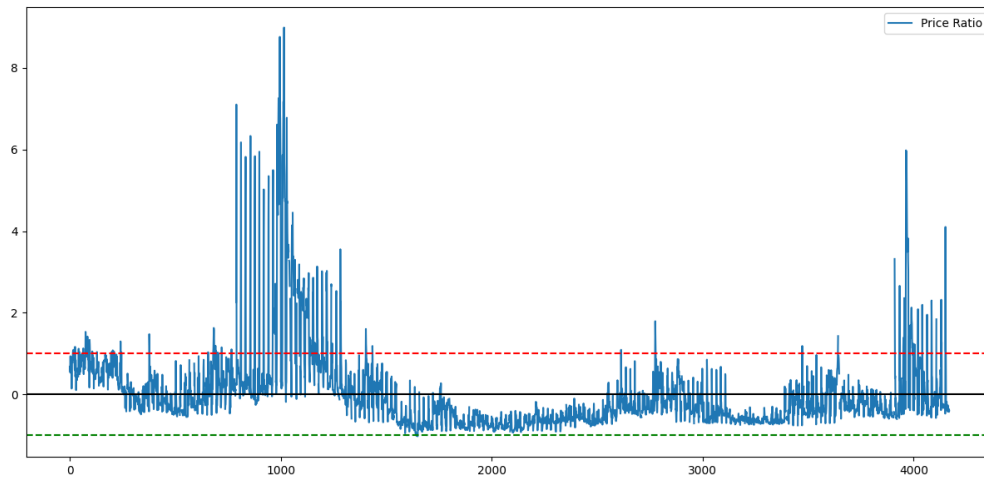
When testing data for cointegration we are going to be running $n(n-1)/2$ comparisons, where n represents the number of tests. This means with a confidence interval of 95% it is extremely important to use clean data that has a lower chance of returning a false significant p-value, it is also important to minimize the number of pairs to only the most likely candidates. In order to minimize the chance of a false positive 15 years of daily adjusted close data has been web scraped and cleaned into a python data frame for the securities GLD, PPLT, SLV, XAG, XAU, XPT, and VIX. Each pair is tested for cointegration based on a confidence interval of 95% and returned to a separate data frame. It is then possible to represent these p-values as a heatmap to better understand how the possible pairs actually relate based on our test.



We immediately see that VIX and all of the precious metal spot prices have extremely strong cointegration over the past 15 years. This means that it is theoretically possible to gain insight on the amount of fear in the market based on the spot prices of precious metals. It is now important to run follow-up tests in order to understand exactly what kind of interaction our pairs have.

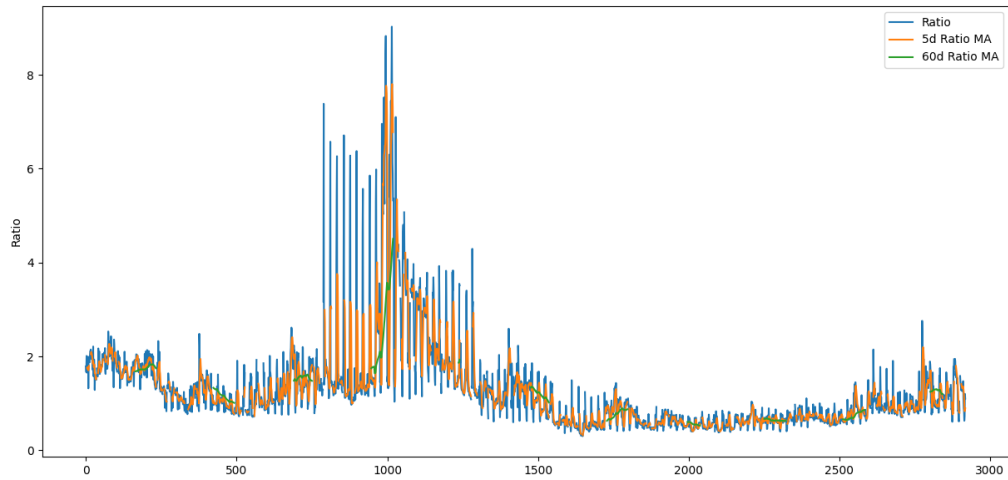
Price Ratio and Mean Reversion

To keep everything concise all future tests will be run over the silver spot price, XAG, and VIX. The first goal is to understand how well our two securities do revert to the mean. We can visualize this by plotting the ratio between the two prices. In this case the x axis is our data points where approximately 252 data points represents one year, this is done to make it easier to split our data in to in sample and out of sample data in the future.

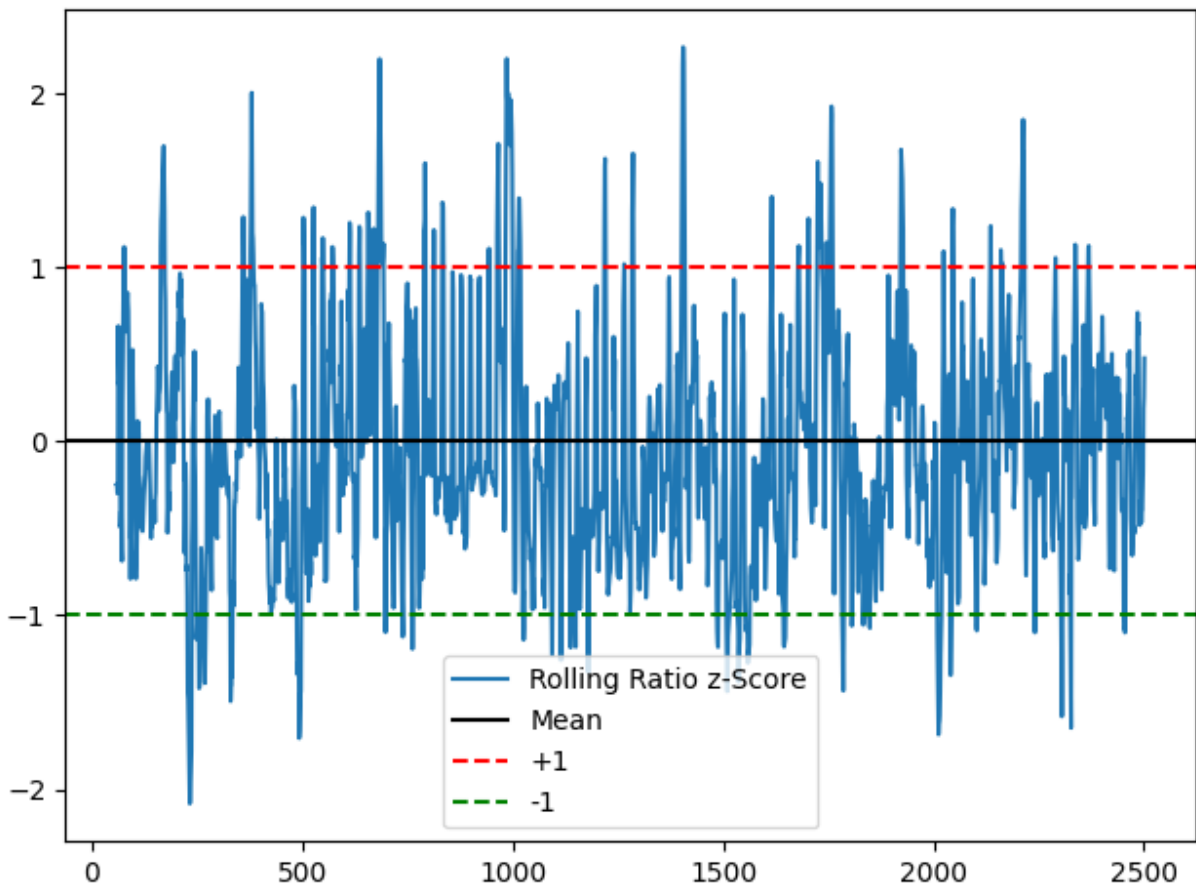


On its own the price ratio does not mean very much except to show that our pair does in fact hover around a mean. Attaching a z-score allows us to actually gain meaning from the data. At the simplest level, a valid trading strategy would be to short the ratio when it goes above 1 and long the ratio when it drops below -1. In this case just from the graph there were few instances over the past 15 years where this strategy would long the ratio but quite a few where it would short the ratio. For this z-score strategy to work it operates on the key assumption that the underlying data is normally distributed. While this generally is not completely true for financial data the graph shows that the principal itself works for this case.

A second and more worrying problem with this analysis is that recent market trends can impact our strategy. A trending market can lead to a price ratio that does not represent current market conditions. To combat this, we can attach a rolling moving average and base our z-score on these averages, this focuses our analyses and makes our data more representative of current market conditions. A 1 week moving average will be used to compute z-score and a 3-month moving average will be used for mean and standard deviation.



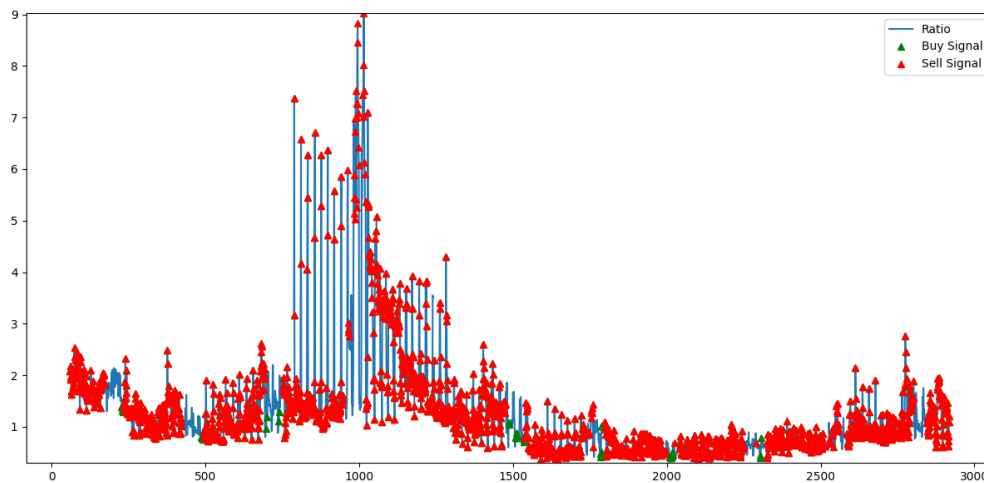
With the moving averages attached it is possible to compute a new z-score that better represents our strategy based on current market conditions.



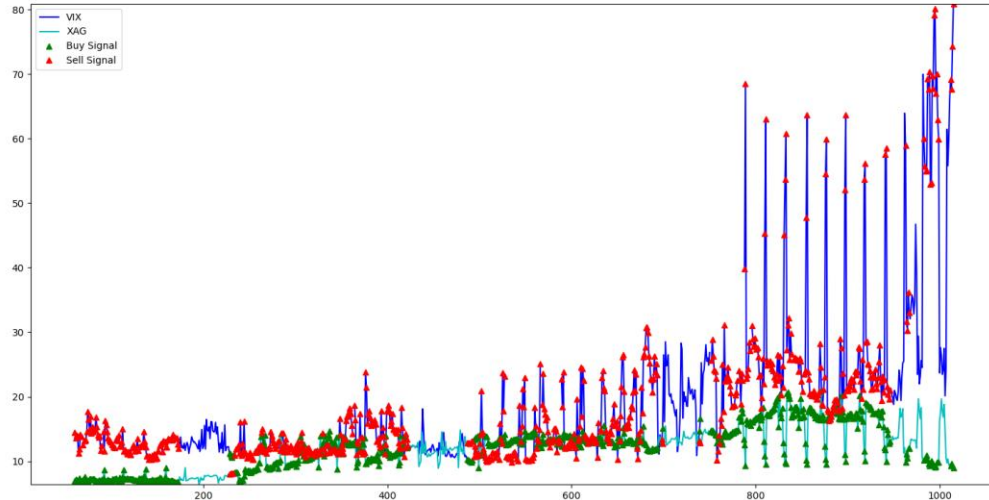
It is possible to use this new rolling z-score to better plan our entries and exits on any given trade.

Statistical Arbitrage Trading

With a now much more relevant and useful test we can begin to understand exactly how a statistical arbitrage trade would happen between the VIX and XAG. By setting a very basic set of rules it is possible to plot each point where a buy or sell would have happened over the past 15 years. First the data is split in to in sample and out of sample data. Then we can plot our buy and sell signals based on if our moving averages push above 1 or below -1 on our rolling z-score. Plotted on the price ratio it would look like this:



While this is extremely useful to understanding our trades, it does not actually make much sense regarding what the trade would look like. To fix this the buy and sell signals can be plotted on each individual security instead.



With this it is possible to draw some conclusions on how precious metals and the VIX interact in turbulent markets. Over the past 15 years the strategy favored shorting the VIX during unusually volatile markets while taking a long position in silver. We can see significant number of buy signals begin to appear on silver prior to a spike in the VIX. While this might not be purely predictive it does appear to show that movement in precious metals does have an underlying relationship with movement in the VIX. This also proves to be a robust strategy through back testing with both in sample and out of sample tests coming back very profitable. There are 2 big concerns with back testing which are overfitting and slippage. Slippage is when your orders impact the price that you are able to enter a trade at. For most retail traders this is not a problem unless the securities are fairly illiquid. Overfitting is a huge problem though as a strategy can appear hugely profitable but when tested on live data completely blow up. This was remedied through splitting data in to testing and training data. Training data made up 70% of the data points while the remaining 30 were used for an out of sample test. While there are many pieces that could make this strategy more robust including further optimization of the z-score what is really interesting to me is its ability to understand how money moves during times of uncertainty. We see silver prices are often nearing their trough when a significant number of buy signals start to appear showing that it should be reverting to the mean. This is then balanced out by short positions in the VIX with the eventuality of their gap collapsing and that profit being captured.

Conclusion

Precious metals have always been considered one of the safer and less volatile investments which makes them a key player in times of market turbulence and fear. This also makes them a prime candidate for statistical arbitrage trading as statistical arbitrage tends to perform better in turbulent markets. This is likely because emotions and volatility cause inefficiencies in asset prices. What this analysis has shown is that because people consider precious metals safe harbors of value, they will flock to them in times of fear. This perfectly coincides with the VIX market fear index allowing for statistical arbitrage opportunities. This

same analysis would be extremely interested if done including cryptocurrencies as it could possibly show whether cryptocurrencies are a store of value or if people move money out of the crypto markets when they get afraid also. Regardless of the market or profitability statistical arbitrage can be an extremely valuable tool to better understand the relationship between two assets and their macro environment as well.

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