Gotta CAPM' All
An empirical study on the validity of the CAPM against four unique assets

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Abstract

This study investigates expected returns against actual and annualized (or CSE) returns on four unique assets, GOOGL, Silver, Bitcoin, and Pokémon Cards using the classic CAPM with historical and adjusted betas across varying time periods depending on the assets history. The data used in this paper was gathered mainly from Bloomberg Professional Services but also other reliable secondary sources. The Capital Asset Pricing Model is the found to be the preferred method when calculating pricing asset returns due to its simplistic nature. The paper used two different versions of beta for the CAPM Calculation, historical beta and adjusted beta models during periods of 8.5 years, 3 years and 1 year for GOOGL and Silver. Bitcoin periods were based on historical data since it was introduced, the periods that was used were 5.5 years, 3 years and 1 year. Pokémon Cards used different periods due to lack of consistent data points, the time-periods used were 5 months, 3 months and 1 month. All four assets used the same Risk-free rate which was Treasury Notes 1-year monthly rate. In this paper, various assets, time periods, and betas are used to empirically suggest the ideal way investors can use the CAPM. This research looks at the four different types of assets to predict their returns and what implications the returns have on investment in these assets.

Keywords: historical beta, adjusted beta, expected returns, actual returns, capital asset pricing model, annualized returns, CSE (Change from Start to End) Returns

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Introduction

As the CAPM is currently one of the most used asset pricing theories, this study wanted to take a closer look at how unique assets fare when using the CAPM to predict returns in an out of sample period. There are many different models to calculate the rate of return depending on the types of capital that needs to be calculated. Graham & Harvey (2001) claimed that 75% of CFOs are constantly using the multi-factor model CAPM as a tool for operational analysis. This statement was extremely intriguing, and it was decided that the CAPM was the model to be used for this study. Other methods such as APT were considered, but the CAPM is used in the end for the ease of calculations and interpretations as well as reasonable assumptions.

This paper examining changes in risk over time and finding the difference between expected and actual return (forecasting error) of four different assets using the CAPM with two different types of beta. The four assets that are analyzed in this research are GOOGL (Alphabet Inc.'s Share), Silver, Bitcoin (XBT) and Pokémon cards. The four assets are taken from market indexes, with purpose of understanding the relationship between risk, rate of return and the nature of the four assets. These assets were specifically chosen for their unique characteristics which help understand the CAPM more effectively for different types of assets. Asset returns could be predicted with a variety of models including Arbitrage Pricing Theory (APT), Capital Asset Pricing Model (CAPM), & Gordon Method but for the reason of calculative simplicity, the CAPM will be used for this study. This study will answer the question "which beta and time period does the CAPM most effectively predict returns for various assets?"

Capital Asset Pricing Theory Model (CAPM) is one of the most frequently used models to evaluate and analyze assets with assumption, methods and ideas as Boskovska & Josifovska, (2016) stated. This model is used to determine the required rate of return of assets that is observed as pertaining a relatively high risk. The CAPM model features a beta that reflects the level of risk in comparison to the market, also called "exposure to the market". The Beta is a tool to measure the systematic risk of an asset. The slope from a linear regression between historical price changes in the asset and portfolio is the simplest method to calculate and interpret beta and is the methods being used in this empirical study.

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Literature Review

This research is using traditional methods with the purpose to see if CAPM are reliable and to modernize the research the assets that are has been analyzed are in different industries to observe any similarities/difference in the asset return results. According to Cagnetti (2002), "An enormous amount of literature has been written on the two models. It is widely believed that the APT performs very well compared to the CAPM and provides an attractive alternative." The Arbitrage Pricing Theory or APT was developed by Ross (1976) to predict relationships between the returns of a market portfolio with the returns of an asset through the consideration of macroeconomic variables. However, the CAPM has been chosen as the pricing model tested in this paper because of relative simplicity and intuitiveness.

According to French (2016), the time traveler compared five developed and six developing markets during various periods to compare different results and see if they were consistent. Their result was that the volatility changed between the different markets he also found that the CAPM is more accurate to predict long horizon investments than short positions, the long horizon studied was a three year period. French (2016) also found that it is better to use three years' assumptions in developing economies and as much as nine years in developed economies. For our study, periods no longer than 8.5 years have been used similar to French (2016). French (2017) Found that the CAPM mispriced by at most 0.99 percent on average for the out of sample year's return but "if one selects the proper input length and beta for their market type it can be reduced to as low as 0.01 percent." This statement is the justification for investigating the CAPM across the various time periods and types of beta in this study, to find out where and when the CAPM is the most effective at predicting returns for our four unique chosen assets.

Jagannathan & Mcgrattan, (1995) used historical data based on average returns because over long time periods it is seen to somewhat accurately predict actual returns with the expected return. Jagannathan & Mcgrattan, (1995), used four different assets and found a positively sloped result from the CAPM model but was found to be more accurate over longer time periods. These results are the reason this paper is considering the a relatively long timeline, 2007 was chosen as it was the year before the start of the economic recession and it would be interesting to see how CAPM also performs in these periods of economic crisis.

French (2017) used adjusted beta when calculating CAPM because it was found to be a better future predictor and was created based on the changes betas were expected to make in the future. Marshall E. Blume (YEAR) conceptualized the adjusted beta in the CAPM formula through seeing that over long time periods "betas mean-revert back to 1.0" which is the reason why using adjusted beta might be a better way to analyze returns rather than unadjusted historical betas in the CAPM. Tofallis (2011) stated that Sharpe (1999) (the creator of a popular beta calculation method) claimed that, "Stocks with betas greater than one are more volatile than the market and are known as aggressive stocks. In contrast, stocks with betas less than one are less volatile than the market index and are known as defensive stocks". Volatility can be a

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significant variance in the result when using capital asset pricing theory. Pham (2017) did research on the CAPM using the Vietnamese stock market but their result showed that the relationship between the actual and expected return was not positive with the beta.

French (2016) used a simple method to calculate forecasting errors which was to find the difference between expected and actual results. For the purpose of this study, it was decided that the forecasting errors would be calculated the same way due to the ease of application. Simple forecasting techniques were seen in Sirigomolsingha, Apornrum & Chirakuldhanabont (2017) study but as this study is investigating the CAPM using a forecasting method previously used by an asset pricing theory study would be more appropriate.

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Data

The capital asset pricing model is a tool used to to calculate the rate and return for assets that are deemed risky. The CAPM shows the correlation between return and risk. The CAPM formula for calculating Er is:

$$E(R) = Rf + \beta\ (Rm - Rf)$$

Where:
E(R) = represents the return investors expects and requires for a certain asset.
Rf = Risk-free Rate, the CAPM assumes that the rate is constant but it is common knowledge that all investments have some degree of risk and can never be risk free. For this study, the average of the monthly rate of 1-Year Treasury Notes will be used across various time periods and assets, this is an apt representation of the Rf as returns are being predicted no more than a year ahead (out of sample).
Rm = Market Return, for this empirical study, a pre-existing or created portfolios historical pricing was used to calculate the Rm across the different time periods. This portfolio in theory accurately reflects the nature of the assets being tested, with beta confirming this.
β = Represents the Beta for the certain asset or the risk associated with that asset when compared to the market. Adjusted Beta will be calculated as follows:

$$Adjusted\ Beta = \frac{1}{3} + \frac{2}{3} \times Historical\ \beta$$

The actual return was calculated based on the average returns in the out of sample period (2016 for GOOGL, Silver and Bitcoin & February and March 2017 for Pokémon Cards). The average forecasting error was calculated as follows:

$$Average\ Forecasting\ Error = E(R) - Actual\ Return$$

The annualized and CSE returns were calculated by calculating the overall price change from the start of the out of sample data to the end and was expressed as a percentage. Annualized and CSE forecasting errors were calculated using the same formula but substituting the Actual Return value for either Annualized Returns or the CSE return.

Assumptions of the CAPM
As mentioned earlier the CAPM is often criticized and questioned for its reliability due to the assumptions of the model:

1. Taxes and Transaction Costs aren't considered
2. Investors can lend and borrow money at a risk-free rate
3. There is no perfect capital market
4. Investors are only concerned about expected returns

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Asset & Benchmark Descriptions

As an empirical investigation is being performed on these assets, it is important to understand them and their background. The table of various assets and their benchmark can be seen below in Table 1.

GOOGL (Alphabet Inc.'s Stock) is the parent company of online search giant Google and was formerly known as Google Inc. The company is the largest online advertiser with its AdWords platform and is well known for its search engine 'Google.com'. GOOGL was chosen as an asset for this study to use as one of the classic assets investors or CFOs might use which is stocks and because it would be interesting to see how well the CAPM performs with one of the most valuable companies both in the US and Globally. Google is featured on the S&P500, which is why it was apt to use the S&P500 as a benchmark for the asset.

Silver is a precious metal and has a long history with a huge impact of the industrial sector worldwide. More than half of the annual demand worldwide is from the industrial sector. Because of the high demand, economic growth can affect the prices for silver much greater than gold. Countries worldwide are using silver for industrial applications and some of the major industries today are the medical sector, photography sector, jewelry, investment and the solar energy sector. This paper chooses to test CAPM on Silver with the reason of the negative price trend in the market. Since April 2011 the price for Silver has gone from $202.53 to $66.38 in April 2017 and for that reason the risk and return could be brilliant calculation for this worldwide asset. The silver prices were obtained from the Silver S&P GSCI Silver Index and the benchmark used was Vanguard Metals Index.

Bitcoin, a cryptocurrency, was started by Satoshi Nakamoto in 2009 and was introduced globally in 2010. Nakamoto (2008) wrote that Bitcoin was introduced to the world to combat problems associated with classic transactions such as cost of mediation, unnecessary transfer of information, and to remove the need for a so called 'trusted' middle-man. Bitcoin's pricing has sky-rocketed tremendously since its introduction from less than a cent per Bitcoin in 2009 to over 1250$ per Bitcoin as of April 2017. Bitcoin is seen as an extremely high risk asset due to its unpredictable performance YoY, as risk is a variable in the CAPM it was chosen as the third asset to use to see the effect of high risk on the CAPM. As Bitcoin, is an extremely risky currency, the benchmark needed to be risky currencies. The risky currencies used to calculate the Rm and create the benchmark portfolio were Indian Rupee, Indonesian Rupiah, South African Rand and Turkish Lira as they were found to be some of the highest risk currencies in the past decade. The portfolio assumed that the currencies were equally weighted so a simple average of the historical pricing across all currencies was used as the risky currency portfolio.

Pokémon started back in 1995 as a gameboy game. Over time they have created animated television, toys, books and trading card games. Players in the card game pretends to be a Pokémon trainer for the Pokémon's and battle other gamers through attacking them, damage and knock out. Trading Pokemon cards were very popular in the beginning of 2000s. In July 2016 Pokémon GO was released and Pokémon had a new era, and Pokémon once again became extremely popular. With the Pokémon GO in the market people started to collect Pokémon cards again and the cards that were sold back in 2000 got suddenly a precious high demand and the prices on Ebay for these cards skyrocketed. Cards are today sold for over $500. This paper used Pokémon cards to predict the return on investment in the future to see if it is worth an investment or not. The Pokémon cards that are used in this paper are a portfolio

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created from five randomly different cards from the top 100 Pokémon's cards available online. The Pokémon's used were Kyogre, Mewtwo, Golem, Audino and Raichu. In 2014 pokemonprices.com launched which made it possible to see the historical pricing for Pokémon cards and made it possible to use Pokémon as an asset in this research.

To graphically observe the historical changes in prices for all the assets please refer to **Graph 5-8**, the graph helps understand the nature of the asset to a greater extent and provides valuable insight to its history and how risky the asset is.

Methodology

This paper will be using data gathered from Bloomberg Professional Services as well as various secondary sources to analyze the expected return of each of the mentioned assets. The secondary data gathered includes the historical pricing (HP) of the asset, portfolios of similar assets or indexes and the Monthly 1-Year Treasury Rates, this data will be used to check if the CAPM is a capable model to predict the expected returns of assets in the year 2016 for GOOGL, Silver, & Bitcoin and the most recent months' data in 2017 for Pokémon Cards.

For GOOGL & Silver, this study is going to analyze the CAPM across 8.5 years (2007-2015), 3 years (2012-2015) and 1 year (2015) and use the expected return results to compare with the out of sample year (2016). The data for 2017 was not used as 2016 was the last complete year of data. For Bitcoin, all time periods are similar with the exception of the 8.5 years as it is replaced with 5.5 years (2010-2015) due to the history of the asset as explained above. Pokémon Cards tests used 5 months, 3 months, and 1 month due to the amount and form of data available (daily). It is worth noting that the data collected of the Historical Pricing of Pokémon Cards is inconsistent so the months are not necessarily consecutive and whole. The out of sample period is 1 month or 31 days of data between February and March 2017.

The portfolio of assets will consist of assets that are similar in nature to the assets being tested. The portfolio can either be in the form of a group of assets combined into a portfolio or can be a pre-existing index such as the S&P500. The average of the portfolio of similar assets in different time periods will be used as the return on market portfolio (Rm) in the CAPM formula and as benchmarks for the various assets. The historical pricing of the asset & the market portfolio will be used to calculate Beta (**β**) across the various time periods. This will be done by simply calculating the slope of the historical price percent changes with the portfolio percent changes and applying the value of this slope in the CAPM formula. The slope of the historical pricing of the asset and the portfolio will be used as the Historical Beta to use in the CAPM and to calculate the Adjusted Beta for the second type of the CAPM. The Historical Beta will need to be calculated three times using the data from the three different chosen time periods for the specific asset. The table below shows the asset and the market portfolio used in the CAPM and to calculate Beta.

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Table 1: Table of Various Assets and Benchmarks

Asset	Benchmark (Used for Rm)
GOOGL Stock	S&P500 Historical
Silver (SPGSSIP)	Vanguard Metal Index
Bitcoin (XBT:USD)	Risky Currencies Portfolio
Pokémon Card Portfolio	Wilshire 5000

The treasury 1 year note rates in the US will be used consistently across all assets as the Risk-Free Rate (Rf) in the CAPM Formula. 1 Year Treasury Notes are being used as several years of data are being used to predict returns one year forward. For Bitcoin, GOOGL, and Silver the standard monthly rates are going to be used, but Rf for calculating the return on the Pokémon Card portfolio is going to be using monthly rates divided by 31 to reflect the rates on a daily basis within a given month. The 1 Year Treasury Notes Monthly Rate was obtained from the US Treasury's website.

After inputting the Historical Beta, Rm, and Rf in the CAPM across the different periods and repeating the process for the Adjusted Beta, the output will be values of the expected returns and expressed as a percentage. These percentages will then be subtracted from the actual and annualized (or CSE) returns to see the forecasting error which will also be denoted in percentage. For each asset, the results (forecasting errors) will be cross examined across the different betas and time periods to see which beta and time period work best with the various assets. Significant under or overestimations shows that the CAPM may not take into consideration other variables affecting pricing such as macroeconomic factors. Slight over or underestimations helped identify which period and betas use yielded the best results. These results can be seen as assumptions for the CAPM to work just as well with assets of similar nature to the assets that were found to work with the CAPM.

All results were rounded to 4 dp to allow for greater insight and accuracy, for the purpose of the analysis in this study they were rounded to 2 dp.

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Results

To observe the accuracy of the results from the CAPM, an Actual Monthly Return (AMr) and an Annualized Return (Ar) (or Actual Daily Return (ADr) and Change from Start to End (CSE) for Pokémon Cards) were calculated. The expected returns from the historical beta model and the adjusted beta model were calculated on various timelines and then compared to the two different values of actual return to find out the over or underestimation from the CAPM to the actual returns during the different time periods. All expected returns are monthly and in percentage form except for Pokémon cards which are daily returns in percentage form. 'Historical & Adjusted Beta Models' are referring to the classic CAPM just using the two different types of Beta. The values of the forecasting error are rounded down to 2 dp from 4 dp as shown in the data which can be seen in **Tables 2-4 in the Appendix**, so the significance of results may slightly be hindered due to the rounding of these values. Also, the positive values suggest overestimation and negative values indicate underestimation, for this study the lowest forecasting error in each asset and between the assets is going to be identified.

GOOGL (Alphabet Inc.'s Share)

When doing a comparison between the Historical and Adjusted Betas in the same time periods, it can be seen the Adjusted Beta displays a lower risk except for the Beta in the 3-year time frame. Both the historical and adjusted beta do however show similar levels of risk in all 3 periods. If observing the Beta by itself, GOOGL isn't extremely risky, it is only slightly riskier than the market (S&P500) in the 8.5 and 1 year period. The reasons for this slight risk could be attributed to the economic recession which occurred in the 8.5 years period and the corporate restructuring of Google Inc. which occurred in 2015 and during the 1 year period. Please refer to Table 2 & 3, to see the comparison of forecasting errors over different time periods and while using the different betas for GOOGL.

The historical beta model showed a tendency to overestimate the returns expected in a specific time with the exception of the 1-year period where the model underestimated the return by 0.23%. As Alphabet Inc, is a technology based company and as technology is very dynamic in nature, the return on the investment in a tech company would be more accurate to predict using longer time range. This is evident, as the 8.5 year estimation using the historical beta has the lowest overestimation and lowest error at 0.08% which shows the CAPMs effectiveness when using a historical beta.

The adjusted beta model had the lowest overestimation and best forecasting result at the one-year period. This shows a difference to the historical betas forecast error as the adjusted beta was found to work better in the shortest period. Historical Beta overall performed much better in most time periods and across the time periods had a lower average forecasting error. When comparing the expected monthly return to the actual monthly returns, the Adjusted Beta Model at the 1-year period is found to be the most accurate with an overestimation of 0.24%,

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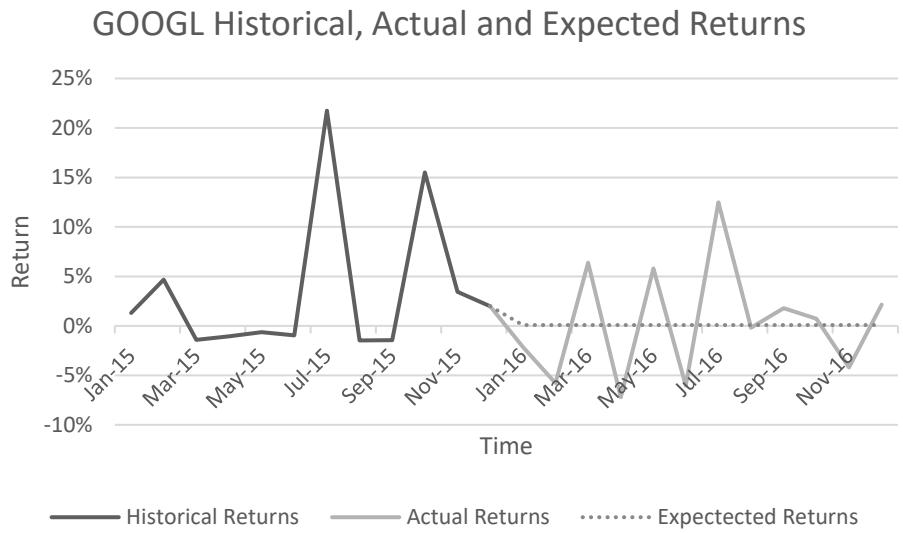
but it would be preferable to use the historical beta at 8.5 years as it was an overall better predictor even though there was a slight overestimation or positive forecasting error.

When annualizing the expected returns from both models, it is possible to see the validity of CAPM on predicting total annuals returns based on the expected monthly returns that have been annualized. The annualized return for the year 2016 was 4%. Both models had similar results when using Actual Monthly Returns, but by annualizing it both models have over or underestimated to a much greater extent with the greatest difference between the expected and annualized returns being underestimated by the adjusted beta in the 3-year period by 12.22%. The best predictor for annualized return is the historical beta model at the 8.5-year period where the model overestimated by 0.62%, which is similar to the results observed in the average forecast errors above. The historical beta model didn't perform very well in shorter periods with a significant overestimation in the 3-year period and underestimation in the 1 year period. The adjusted beta model however had the opposite results with the closest estimation at the 1 year period at 2.55%. Even though adjusted beta is calculated using historical beta, the results vary with the usage of the different betas.

Investors can use the observations made here on GOOGL, to use the CAPM to predict and measure the effectiveness of their investments in various companies of the same nature or companies present in the S&P500. It is suggested to use the Historical CAPM approach with an 8.5-year period as it has been empirically seen that it is a more accurate method of estimating returns, a graphical representation of this can be seen below in Graph 1. The CAPM tends to overestimate returns, in both the historical and adjusted beta approach with the exceptions of 1 year with the historical beta and 3 years with the adjusted beta. The reason for unfavorable results in the 3-year period could be attributed to the S&P500's poor performance in the years prior to the out of sample year (2012-2015).

Graph 1: GOOGL Historical, Actual and Expected Returns (8.5 Year Historical Beta)



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Silver

The historical and adjusted beta for Silver for all three time periods is less than 1 meaning that silver overall is an asset which is less risky than the market or other similar assets such as Gold and Platinum. The highest beta for both models occurred in the three-year period with the historical beta at 0.73 and the adjusted beta at 0.82. As suggested by the values of the betas, the three-year period was the period where silver was the most volatile but still less volatile than the market. The one year betas are interesting as they have dropped considerably, which means silver is becoming less risky and is not very volatile as compared to the market in the same period. The lowest beta is the historical beta in the 1 year period at 0.43. Silver is found to have extremely low market risk, which has been observed in previous studies in regard to a similar but higher value precious metal, Gold. Please refer to Table 2 & 3, to see the comparison of forecasting errors over different time periods and while using the different betas for Silver.

The historical beta model tends to underestimate the returns across all periods of times. The historical beta approach for Silver worked best in the 8.5-year period with an underestimation of 2.04% and worst in the 3-year period at -3.06%. As the actual average monthly return is 1.44%, the underestimations from the CAPM model using the historical beta are extreme underestimations. These significant underestimations would not be favorable for investors to use as the expected returns calculated are all negative whereas actual returns are positive.

The adjusted beta model unlike the historical beta model tends to overestimate actual returns but had a lower forecasting error when comparing it to the previous model. These overestimations were closer estimations than the historical beta model's results which means for an asset like silver the adjusted beta approach may yield more accurate results. The adjusted beta consecutively overestimated returns, but not as drastically as the historical beta model underestimated returns. The adjusted beta model had the closest estimation in the 8.5-year period at 0.65% which is similar to the results from the historical beta where the closest estimation the different periods was found in the longest 8.5-year period. However, the adjusted beta results are more useful as both the expected and actual returns were positive and the results in each period were also better estimations that the same periods when using the historical beta.

The annualized return in 2016 for Silver was 10.13%. The results of the difference between annualized expected returns from both models and the annualized actual returns were quite similar to the average monthly forecasting results. The historical beta model significantly overestimated returns whereas the adjusted beta model significantly underestimate returns but to a lower extent when compared to the results from the historical beta. The annualized return results are not preferable and would not be recommended for investors investing in Silver.

The CAPM can be used to estimate the returns of silver but with the context that the CAPM will tend to underestimate expected returns in the case of historical beta and overestimate in the case of adjusted beta. Like Alphabet Inc.'s Stock, the 8.5-year period expected returns yielded the most accurate predictions when using the historical beta, but

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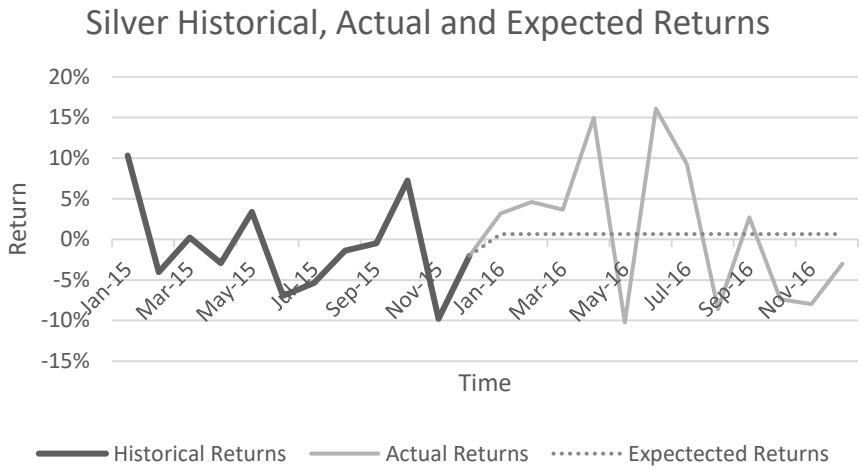
unlike Alphabet Inc.'s stock, the adjusted beta also yielded the most accurate results in the 8.5-year period instead of the 1 year period. Adjusted Beta was a much better beta to use for the CAPM when investigating returns from silver as they yielded on average better estimations and the lowest forecasting error in the empirical study of silver was 0.65% in the 8.5-year period. A graphical representation of the 8.5-year period which has the lowest error can be seen below in Graph 2 which also shows how volatile silver's returns have been. However, one way Silver's empirical study of the CAPM differs is that the adjusted beta model seems to be more effective at calculating an estimate monthly return on silver instead of the historical beta model which was found to significantly underestimate Silver's returns across all periods. Investors should use the Adjusted Beta model at the longest period possible for its efficacy, and should avoid the using the annualized method of estimating results.

Graph 2: Silver Historical, Actual and Expected Returns (8.5 Year Adjusted Beta)



Bitcoin (XBT)

Bitcoin historically has been an extremely unpredictable and volatile asset, since its beginning its value has grown exponentially to a point where investors are reluctant to invest due to the possible cause of being a bubble. Please refer to Table 2 & 3, to see the comparison of forecasting errors over different time periods and while using the different betas for Bitcoin.

Looking at the historical and adjusted beta, in the 5.5 and 1 year period they show an inverse relation to the market direction and a lower risk than the market which can be seen by the negative betas. However, this does not suggest relative low volatility as they are extreme negative betas. In the 3-year period, both the historical and the adjusted betas showed positive betas greater than 1 meaning they were slightly riskier (10-20%) than the market (Risky Currencies Portfolio). The 1 year betas are the stand out values, with the historical beta at -6.08 and the adjusted beta at -3.72. This could be due to the speculation of a bubble from bitcoin and other cryptocurrency traders.

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The historical beta model tends to highly underestimate bitcoin returns in all periods. The historical beta model was significantly ineffective at estimating the actual monthly returns as the models expected returns were considerably lower. The 3-year period shows the lowest underestimation of only 6.17% from the actual monthly returns from Bitcoin which was the only period with a positive beta. In this period bitcoin was around 27% riskier than the risky currency portfolio or the market portfolio. Bitcoin is extremely volatile in general and it was expected that the CAPM would be ineffective at predicting returns as the extreme volatility leads to an unrealistic trend. As Bitcoin is known to be a volatile asset, investors can carry the assumption of underestimation by classic pricing models such as CAPM which rely on historical performance. The highest underestimation was seen in the 1 year period at a tremendous 13.90%, this result could be attributed to highest negative beta seen across all periods.

The adjusted beta model shows quite different results with the most accurate estimation at the 1 year period. The reason the adjusted beta model showed the most promising results overall is probably due to volatile nature of bitcoin, the smaller the period, the less volatile bitcoin appears to be which allows the CAPM to predict better results. The adjusted beta in the case of predicting returns for Bitcoin is superior to the historical beta model, but like the historical beta model the adjusted beta model tends to significantly underestimate the returns on an investment on Bitcoin. Although both models tend to underestimate returns, the adjusted beta model with an overall average was seen to underestimate less than the historical beta model.

Annualized returns for bitcoin are quite interesting, with a whopping 153.74% actual annualized return. The historical and adjusted betas models yielded extreme underestimations of the annualized returns on Bitcoin. The historical beta model notedly had the highest underestimation of the annualized returns by 136.35%. Although both models yielded results with inaccurate estimations, the adjusted beta once again had the lowest underestimation of 101.43% at the 1 year period. This underestimation is significant enough to be disregarded as useful, but is nonetheless the closest to the actual annualized returns.

Bitcoin is extremely volatile and has been showing unprecedented growth in the end of 2016/start of 2017. The CAPM as seen from the results above, cannot be used to predict the forward returns of Bitcoin as well as presumably other cryptocurrencies as they tend to grow and recede in tandem with Bitcoin and its performance. The significant underestimations could be used to identify a potential bubble in the cryptocurrency market in the near future. It is not recommended for cryptocurrency investors to use the CAPM to predict returns on Bitcoin due to the extremely volatile nature of this asset. Also, many business in the US have been found to accept Bitcoin as a form of payment, this form of payment however comes with a huge risk and these types of businesses, although the CAPM may not be useful to them calculating betas frequently would be a good idea to see if the asset becomes too risky. Graph 3 is a graphical representation on the comparison of historical returns to the actual and expected returns in the

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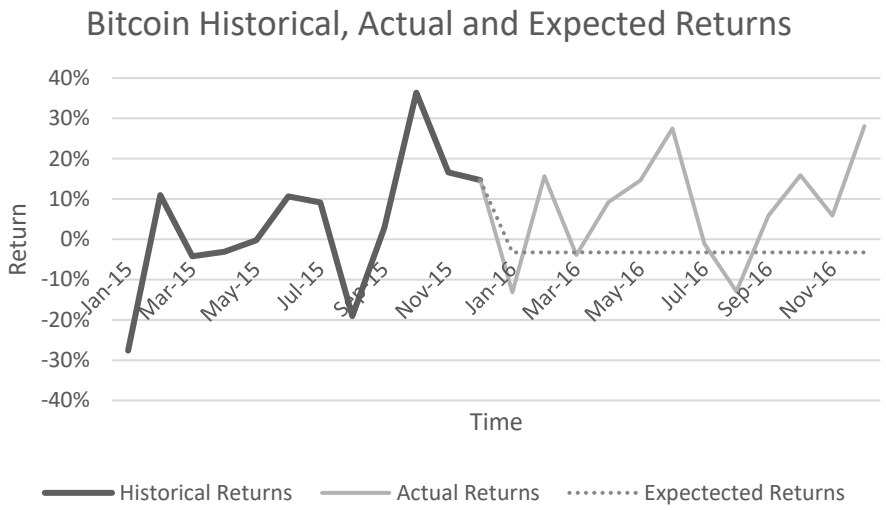
out of sample period and shows the underestimations across 2016 (gap between expected and actual returns).

Graph 3: Bitcoin Historical, Actual and Expected Returns (1 Year Adjusted Beta)



Pokémon Cards

Comparing the historical and the adjusted beta for Pokémon shows that in two of the periods for the historical, the beta is negative which means that the return of this investment will be lower than the Rf. The 1-month period of the historical beta is highly underestimated .0369 which means it is a very low risk in this investment. However, the adjusted beta is riskier than the historical and yielded better results, which also shows the low risk characteristic of this investment. Overall, Pokémon is an extremely low risk investment but also shows low return, however it is important to emphasize that the calculations are calculated by an ADr (Actual daily return) and a CSE (Change start to end) period. Please refer to Table 4 & 5, to see the comparison of forecasting errors over different time periods and the different betas.

Both the historical and the adjusted beta models showed a quite strong underestimation in the expected return during all three periods. All periods showed a negative beta and this tells that it is an investment that seems to go down when the market goes up. The reason behind the result for Pokémon Cards is most likely because of the short period of data used. Also, Pokémon cards historical pricing started in 2016 and many of the days that are available don't show any changes. However, in the 1-month period both the historical and the adjusted beta are seen to follow the market.

The lowest underestimation is the historical beta over the 1-month period. However, none of the three periods showed promising results, Pokémon cards is a small market and sometimes shifts in prices don't occur for weeks for one card and other days the prices may jump 100%. All three periods are underestimated by approximately 2.24-2.27 percent in both

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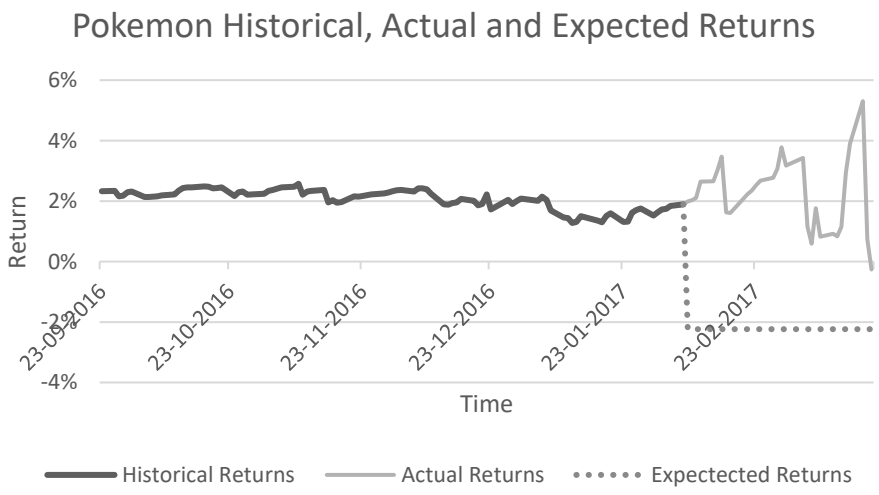
models when comparing the expected daily return to the actual daily returns. However, the historical model during the 3-month period did the closest prediction to the actual returns.

The actual daily returns across the period from February and March 2017 was 5.00%. Both models had a very similar result in the monthly change during February and March. Both the historical and the adjusted models were underestimated by approximately 4.358-5.046 percent. The best predictor for the CSE expected returns is the estimated daily return on the 1-month period that underestimated with 4.358 percent. The adjusted model seems to underestimate slightly more than the historical beta model.

Through empirical study, it is not recommended for investors to use CAPM on Pokémon cards to predict and measure future return. None of the models had a significant result and the negative expected returns when using the historical beta makes this evident. CAPM as mentioned earlier works better on long time periods. The historical pricing of Pokémon Cards is limited and this paper has only utilized data in the periods which are available and somewhat consistent. It might be worth to consider it in a few years again when the market for trading Pokémon cards has changed its dynamic. To see the graphical representation of the period with the lowest error in returns please refer to Graph 4 below which shows how significantly the CAPM underestimated the return on Pokémon Cards.

Graph 4: Pokémon Cards Historical, Actual and Expected Returns (1 Month Historical Beta)



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Comparison Across Assets

On average, the forecasting error was the lowest in the 8.5-year period for both adjusted and historical beta when looking at GOOGL, Silver & Bitcoin. However, the overall average lowest error can be seen in Table 2 in the Adjusted Beta Model for the 8.5-year period at 0.63% overestimation. The historical beta at 8.5 years showed an average underestimation and forecasting error of 0.98% like the 1 year adjusted beta which underestimated by 0.78%. However, this study is trying to look at the lowest error overall, which the adjusted beta over the 8.5 years clearly has. It is important to note and recall that Bitcoin is not included in the average error as the data for the 8.5-year period is not available due to the late introduction of the asset into the global market in 2010. Bitcoin's errors also skewed the results downwards quite a bit with all the forecasting errors significantly underestimating its returns and therefore pushing the average of the three assets downwards. For Bitcoin as stated previously, the CAPM isn't recommended to use to predict returns due to the severe underestimations.

Interestingly, when looking at the average errors of the annualized returns (Table 3), the historical beta seems to perform better than the adjusted beta with the lowest error in the 8.5-year period underestimating average returns by 8.37%. Again, the Bitcoin results adversely affected results especially with the extreme underestimations or error seen on the annualized returns.

Pokémon Cards unfortunately can't be directly compared to the other assets as the time periods drastically vary. However, like the other average forecasting errors, the adjusted beta model is found to perform better and with less error in the longest period of 5 months, similar to what French (2016) had concluded in his study.

Limitations

First, the inconsistent data for Pokémon cards historical prices might have affected the overall results. The data that is collected is not only inconsistent it is also only shown as a percent change to 2 dp, which would mean that there might have been minor price changes in the periods where no changes were seen. The data that is used for the Pokémon cards also only covers six months of data and as previous research papers have claimed earlier CAPM works better on longer time periods so the CAPM possibly couldn't use this inconsistent and data which was available for barely a year. Significant changes in the market have occurred after collecting the data and analyzing results, the inclusion of this data could have changed the result significantly. Also, as indicated by the extremely negative betas in Bitcoin, the market portfolio or benchmark chose may not have been the best choice at it only shows relation to the risky currency market in the 3 year period. A more appropriate benchmark portfolio could be made using other cryptocurrencies such as Ethereum as they are found to follow the trends in Bitcoins pricing.

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Conclusion

The classic CAPM yielded favorable results for 2 of the assets, GOOGL and Silver. For GOOGL, the best results or lowest error is seen in the 8.5 years' period with the CAPM using Historical Beta at a minute 0.08%. Through this results of this empirical study it can be assumed that other stocks in the S&P500 could be used with the CAPM to predict future returns. Investors or individuals looking to invest in any S&P500 stocks should keep in mind that the CAPM tends to slightly overestimate expected returns. For Silver, the error was slightly more significant but nonetheless close at the 8.5-year period using the Adjusted Beta at 0.65%. Both these results suggest that the benchmarks used were appropriate and that the CAPM works better in longer periods of time as also found by French (2016) in his guide to CAPM. The results of the forecasting errors for the assets that could be successfully predicted with the CAPM tended to overestimate results, so it could be worth looking into more assets across this 8.5-year period to check for reoccurrences. The overestimation may be a result of the economic recession that took place in the 8.5 year period as both these assets jumped in price after the economic crisis. The Betas of GOOGL showed similar or slightly more risk than the Market where as the Betas of Silver showed that the asset was consistently less risky in the market.

This study found that the single factor CAPM might not be an effective method to price or predict the return on assets with characteristics like Bitcoin and Pokémon Cards as seen with the significant forecasting error on Pokémon Cards and especially Bitcoin. The CAPM which Sharpe (1964) created implies that Beta is the only measure of risk required to measure an asset or portfolios expected return, Fama and French (1996) found that multi-variate or multi-factor models such as ICAPM and APT yield better results based on their research done on an NYSE Stock Portfolio. For similar studies in the future, it would be advised to avoid the classic CAPM and use ICAPM, APT or other pricing models to see how accurately those models could predict results for Bitcoin and Pokémon Cards. APT was after all created so that macroeconomic factors contributing to the risk of an asset could be considered in an asset pricing model. The APT would then act as a substitute for the CAPM and would then help identify which asset pricing model would be more effective at predicting returns. Taking the limitations and the results of this study into consideration could help create a more thorough study of the effectiveness of different asset pricing models into consideration.

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Appendix

Table 2: Average Forecasting Errors of GOOGL, Silver, & Bitcoin (E(R) – AMr)

	Historical β				Adjusted β			
Years	**1**	**3**	**5.5**	**8.5**	**1**	**3**	**5.5**	**8.5**
GOOGL	-0.2342%	0.7229%		0.0832%	0.2440%	-0.9870%		0.6050%
Silver	-2.3576%	-3.0562%		-2.0404%	0.6837%	0.7876%		0.6478%
Bitcoin	-13.8976%	-6.1712%	-8.6791%		-3.2612%	-8.5948%	-6.8037%	
Average	-5.4964%	-2.8349%	-8.6791%	-0.9786%	-0.7778%	-2.9314%	-6.8037%	0.6264%

Years: 1 is 2015, 3 are 2012-2015, 5.5 are 2010-2015, 8.5 are 2007-2015

Table 3: Annualized Forecasting Errors of GOOGL, Silver, & Bitcoin (E(R)*12 – Annualized Returns)

	Historical β				Adjusted β			
Years	**1**	**3**	**5.5**	**8.5**	**1**	**3**	**5.5**	**8.5**
GOOGL	-3.1861%	8.2985%		0.6223%	2.5526%	-12.2204%		6.8845%
Silver	-21.1654%	-29.5489%		-17.3585%	15.3297%	16.5771%		14.8993%
Bitcoin	-229.0636%	-136.3472%	-166.4421%		-101.4270%	-165.4310%	-143.9379%	
Average	-84.4717%	-52.5325%	-166.4421%	-8.3681%	-27.8482%	-53.6914%	-143.9379%	10.8919%

Years: 1 is 2015, 3 are 2012-2015, 5.5 are 2010-2015, 8.5 are 2007-2015

Table 4: Average Forecasting Errors of Pokémon Cards (E(R) – ADr)

	Historical β			Adjusted β		
Months	**1**	**3**	**5**	**1**	**3**	**5**
Pokémon Cards	-2.2364%	-2.2425%	-2.2446%	-2.2759%	-2.2632%	-2.2586%

Table 5: Change from Start to End (CSE) Forecasting Errors of Pokemon Cards (E(R) – CSE Return)

	Historical β			Adjusted β		
Months	**1**	**3**	**5**	**1**	**3**	**5**
Pokémon Cards	-4.358%	-4.548%	-4.614%	-5.584%	-5.190%	-5.046%

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Graph 5: GOOGL Price History

Graph 6: Silver Price History

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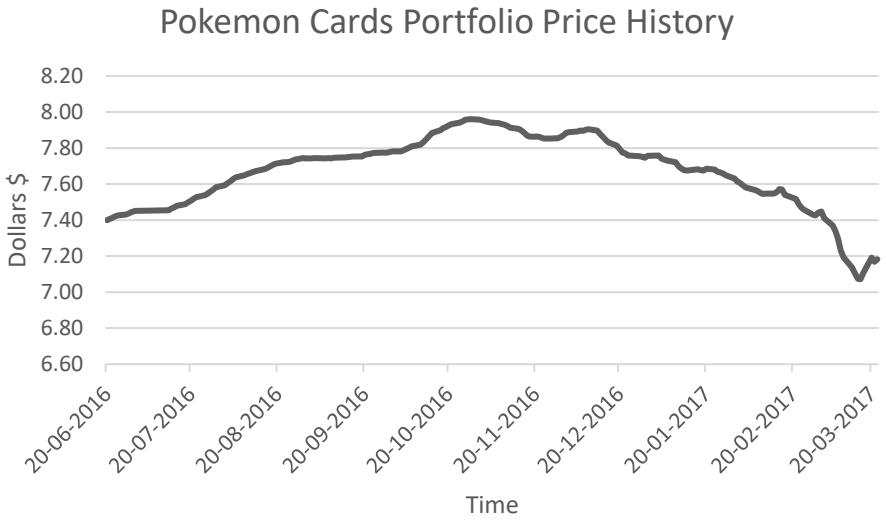
Graph 7: Bitcoin (XBT:USD) Price History

Graph 8: Pokémon Cards Price History



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